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Electron-blocking layers beneficial?

III-Vs aid the mission to Mars

Power amps: CMOS weakens grip of GaAs

Can CPV move away from robots?

60 W equivalent ducks under $10

SIMS

Scrutinising VCSELs

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ALWAYS ONE STEP AHEAD

editorial view

by Dr Richard Stevenson, Editor

Is a battle brewing?

AS I GAZE INTO MY CRYSTAL BALL, I fear for a future where chipmakers fight their peers in court while lining the pockets of lawyers.

This wouldn't be the first time that this has happened. Not that long ago, leading LED makers fought it out over what they believed to be patent infringements. And such days could return with a vengeance when firms claim that they have the upper hand regarding the intellectual property surrounding GaN-on-silicon, and they decide to put their rivals to the sword.

That's certainly still a little way off, but interest in the manufacture of GaN-on-silicon products is definitely rising. It's not just the lure of a cheap substrate that is attracting the developers of LEDs, power electronics and RF transistors to build their devices on this foundation – it is the opportunity to process epiwafers at very low costs in fully depreciated silicon lines. Although GaN-on-silicon products are rare today, shipments of these devices will surge throughout this decade, and when revenues reach significant levels, this could trigger a series of court battles.

Winning in the courts may be far from easy. There are several approaches to combatting any lattice and thermal mismatches between the nitride films and the silicon substrate, and there will be claims that some approaches are significantly different, due

to variations in film thickness or composition; and there will also be arguments that certain patents should not be valid, because they are too general and simply state what was common knowledge at the time.

Hopefully, such scenes will not take place, and instead of calling in the lawyers, we will learn from the mistakes of the past, cross-licensing technology when appropriate. For if we can do that, it will leave more cash for investing in GaN-on-silicon, so we will all share a slice of a far bigger pie.

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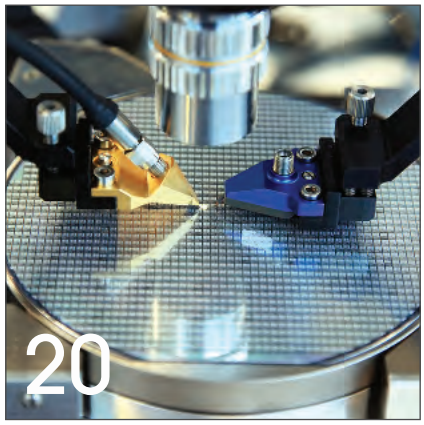
features



Magazine & Front Cover designed by Mitch Gaynor

Ammono and Unipress raise the bar in GaN manufacturing

Scientists from Ammono and the Institute of High Pressure Physics of the Polish Academy of Sciences (Unipress) have conceived a new proprietary breakthrough technology, which allows the cheap and fast production of ammonothermal GaN,

This approach is based on hybrid Ammono-HVPE GaN seeds. Ammonothermal GaN is seen as an ideal material for performance driven electronic and optoelectronic applications, which require very good crystal quality.

An example of such applications are laser diodes, where the output power and lifetime depend strongly on the GaN substrate quality. Other cases are power transistors and Schottky diodes, where the reliability is related primarily to the device crystalline structure and thus the substrate quality. Last but not least, ultra-high brightness LEDs benefit from the low substrate dislocation density which, allows the effective dissipation of heat created during device operation.

Competing GaN production technologies such as HVPE or LPE use foreign (not GaN) seeds and the quality of the GaN material obtained in such processes produces devices, which in the long term, do not meet the quality targets set by device makers. This lower quality is reflected in many parameters. The most important is the dislocation density, which in the case of the Ammonthermal GaN is of the order of 10^4 cm^2 – other technologies are claimed to be at least two orders of magnitude worse.

Ammono and Unipress say they have shown that using hybrid HVPE-Ammontermal approaches allows the manufacture of GaN material, fulfilling the strict requirements of high-end applications.

In the framework of a grant received from the Polish National Centre for Research and Development (PBS1/B5/7/2012), it was shown that using ammonothermally grown GaN (as a seed), can obtain high quality free-standing HVPE-GaN. Smooth GaN layers up to 2.5 mm thick (crystallised with a stable growth rate of 240 μm/h) of an excellent crystalline quality, without cracks, and with low threading dislocation density (5 x 10^4 cm^{-2}) have been grown and then sliced from the Ammono-GaN seed wafers.

The structural properties of the free-standing HVPE-GaN do not differ from the structural properties of the Ammono-GaN seeds. This is a high purity material. According to the SIMS analysis the oxygen and carbon content is below 10^{16} cm^{-3}. The only silicon impurity is of the order of 3 x 10^{16} cm^{-3}. From the physical properties point of view, this HVPE-GaN is of a higher quality than one obtained using MOCVD-GaN/sapphire templates or GaAs crystals as seeds.Subsequently, the new material was used again as a seed for the ammonthermal process.

As a result, new kind of GaN crystals were grown (Ammono-HVPE-Ammono).

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DARPA closes in on high-speed wireless networks mounted on UAVs

MISSIONS IN REMOTE, forward operating locations often suffer from a lack of connectivity to tactical operation centres and access to valuable intelligence, surveillance, and reconnaissance (ISR) data.

The assets needed for long-range, high-bandwidth communications capabilities are often unavailable to lower echelons due to theatre-wide mission priorities. DARPA's Mobile Hotspots program aims to help overcome this challenge by developing a reliable, on-demand capability for establishing long-range, high-capacity reachback that is organic to tactical units.

The program is building and demonstrating a scalable, mobile millimetre-wave communications backhaul network mounted on small unmanned aerial vehicles (UAVs) and providing a 1 Gb/s capacity.

DARPA performers recently completed the first of three phases in which they developed and tested key technologies to be integrated into a complete system and flight tested in subsequent phases.

"We're pleased with the technical achievements we've seen so far in steerable millimetre-wave antennas and millimetre-wave amplifier technology," says Dick Ridgway, DARPA program manager. "These successes -and the novel networking approaches needed to maintain these high-capacity links - are key to providing forward deployed units with the same high-capacity connectivity we all enjoy over our 4G cell-phone networks."

Phase 1 accomplishments include:
Smaller, steerable millimetre-wave antennas: During field testing, the program successfully demonstrated steerable, compact millimetre-wave antennas that rapidly acquire, track, and establish a communications link between moving platforms.

Steerable millimetre-wave antennas will enable the formation of a high-capacity backhaul network between aerial and ground platforms

Low-noise amplifiers: Performers also demonstrated an advanced low-noise amplifier (LNA), which boosts the desired communications signal while minimising unwanted noise. The prototype achieved the record for one of the world's lowest noise millimetre-wave LNAs at about half the noise figure of a typical LNA.

More efficient and capable power amplifiers:Efficient millimetre-wave amplification is required to achieve the long ranges (> 50 km) desired in the Mobile Hotspots programme. During Phase 1, performers demonstrated output power exceeding 1 watt and 20 percent power added efficiency (PAE) from a single GaN chip operating at E-Band frequencies (71 GHz to 86 GHz).

Output powers exceeding 20 watts and approaching 20 percent PAE were also achieved using power-combining techniques.

New approaches for robust airborne networking: Mobile ad-hoc networking approaches were developed to maintain the high-capacity backhaul network among mobile air and ground platforms. Phase 1 performers developed unique solutions to overcome connectivity and network topology challenges associated with mobility and signal blockages due to terrain and platform shadowing.

Low-Size, Weight, and Power (SWAP) pod design to carry it all: Performers created engineering designs for small, lightweight pods to be mounted on an RQ-7 Shadow UAV. The pods, with all of the Mobile Hotspots components inside, are designed to meet the challenging program goals of widths no more than 8 inches, weight less than 20 pounds, and power consumption less than 150 watts.

Phase 2 of the program began in March 2014. Two performers, L-3 Communications and FIRST RF, were chosen to lead teams comprising several Phase 1 performers. Phase 2 goals include the integration of the selected Phase 1 technologies into Shadow-compatible aerial pods and ground vehicles.

Phase 2 will conclude with a ground demonstration of at least four Shadow-compatible pods, two ground vehicles and a fixed ground node. A planned third phase will encompass field testing of the Mobile Hotspot systems on networks of multiple SRQ-7 Shadow UAVs and mobile ground vehicles.

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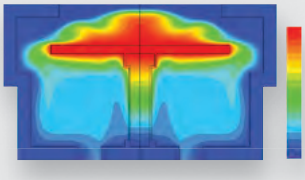

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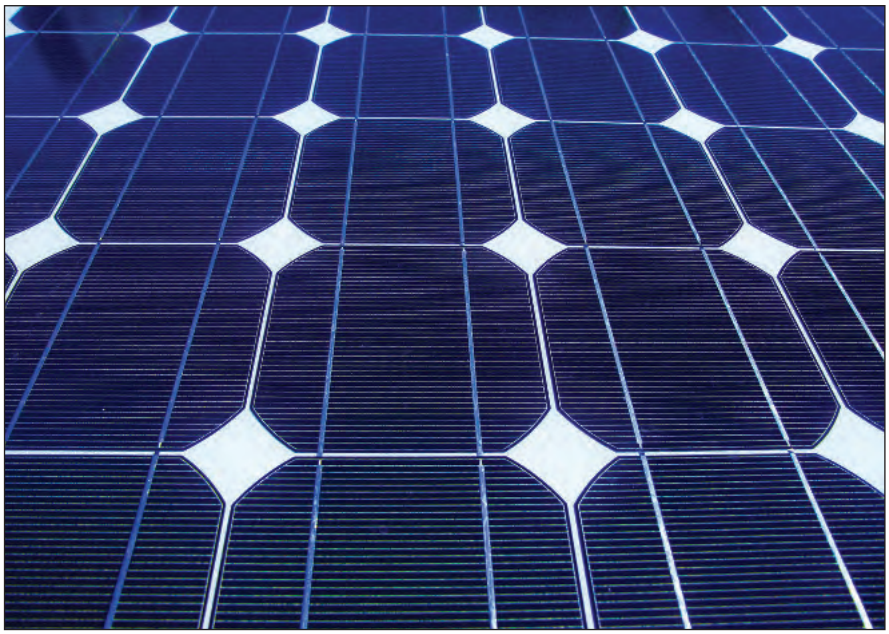
Soitec CPV cells selected for thirteen solar projects



RECENTLY, the French Energy Regulatory Commission (CRE, Commission de Régulation de l'Energie) announced the winning bids of the second call for tenders from the French Energy Regulatory Commission (CRE, Commission de Régulation de l'Energie).

This was for the creation and operation of solar power plants with installed capacity of more than 250 kWc. Soitec, a manufacturer of III-V and silicon semiconductor materials for electronics and energy, sees its concentrator photovoltaic (CPV) modules included in 80 percent of the projects selected.

Published in March 2013, the CRE's second call for tenders calls for allocation of a volume of 20 MWc for ground plants exclusively based on CPV technology, plus a volume of 80 MWc for ground plants based on at least 50 percent on CPV, with a total minimum of 60 MWc allocated to CPV technology.

The sixteen projects finally selected further to this call for tenders represent a volume of 102.94 MWc. Thirteen of them (more than 80 percent) plan to use CPV modules manufactured by Soitec.

José Bériot, vice president of Solar Projects Development with Soitec's Solar Energy division, explains: "Seeing our products present in a significant majority of the projects selected in this second call for tenders from the CRE is a great achievement for us. Overall, it represents a volume of more than 50 MWc for Soitec. This success is proof that our customers recognise the performance and reliability of our modules, and our ability to achieve profitability for future power plants."

Construction of the projects that have just been selected should be completed by spring of 2016, and the winning developers are now selecting the EPC contractors with whom they will partner on the construction sites. Soitec's CPV technology uses III-V triple junction cells mounted on glass support plates. Fresnel lenses (manufactured using silicone on glass) concentrate sunlight five hundred times before it reaches these cells, which convert it into electricity.

A metal frame holds two glass plates to form highly robust, durable and resilient modules. By combining several modules on biaxial trackers (based on a proprietary algorithm automatically optimising their position based on the path of the sun), Soitec maximises energy generation throughout the day and its modules achieve a yield of 31.8 percent.

European consortium to deepen photonic device knowledge

SCIENTISTS at Tyndall National Institute, Cork, Ireland, are leading a European research project which will develop a test environment to help create the photonic and electronic devices of the future. Led by Eoin P. O'Reilly, Head of Theory, Modelling and Design Centre, Tyndall National Institute, DEEPEN will involve Tyndall-based researchers working in close partnership with research teams from across Europe.

These are ETH Zurich (Switzerland), Osram Opto Semiconductors (Germany), Paul-Drude-Institut für Festkörperelektronik (Germany), Synopsys (Switzerland) and Tiberlab S.r.l. (Italy). The project will use the combined expertise in device design and nanomaterials of its members, to help revolutionise the design and implementation of future photonic and electronic devices.

Entitled 'DEEPEN' (from Atomic to Device Explicit simulation Environment for Photonic and Electronic Nanostructures), the three-year, EU-funded project is being formally launched this week in Athens, Greece at the Industrial Technologies 2014 Conference.

The conference integrates nanotechnology, biotechnology, advanced materials and new production technologies, and offers opportunities for developing valuable research and industry collaborations by showcasing cutting-edge research, latest innovations and rising companies from all around Europe.

DEEPEN is a direct response to industry's need to track and analyse performance at the atomic scale of a design process. To address this issue, researchers are looking to develop an efficient and robust framework that allows different computer codes to be merged. Using this open-source framework, the integrated simulation tools will enable developers to track a device's overall performance changes at a particularly detailed and precise level during testing. Speaking at the Industrial Technologies 2014 Conference, O'Reilly said, "The DEEPEN project gives us an opportunity to work with leading academic and industry partners in this challenging but highly rewarding area.

Our work will have a direct impact on future device design and optimisation. In addition, our development of open source codes will help to open up this field to the wider research community".

DEEPEN is part of a cluster of five, FP7-funded projects being launched today at the Multiscale Modelling workshop in Athens. The Cluster is intended to enable knowledge exchange, to foster adoption of novel approaches for multi-scale modelling.

With a network of two hundred industry partners and customers worldwide, Tyndall generates around €30 million income each year, 85 percent from competitively won contracts nationally and internationally.

Tyndall is also a lead partner in European research partnerships in its core areas of ICT, communications, energy, health and the environment worth €44 million, including €6 million accruing to industry in Ireland (from Framework 7).

Hosting what it says is the only full CMOS (metal oxide semiconductor) integrated circuit construction, Micro Electronic Mechanical systems (MEMS) and III-V Wafer Semiconductor fabrication facilities and services in Ireland, Tyndall is prototyping new product opportunities for its target industries - electronics, medical devices, energy and communication.

Three players monopolise MOCVD market

Driven by the fanfare over (and overestimation of) the LCD display market, the LED Front-End equipment market experienced an unprecedented investment cycle in 2010 to 2011.

The market surge was driven mostly by MOCVD reactor shipments to new Chinese entrants, who benefited from the generous subsidies of the Chinese central and local governments in a bid to stimulate domestic chip production. Following an eighteen to twenty-four month digestion period, the market is now slowly recovering and will experience another investment cycle in 2014 to 2016 driven by demand for general lighting applications.

However, this 2nd cycle will be limited in value due to improvement in equipment throughput and yields, increased competition and potential consolidation of the industry.

Indeed, LED manufacturers initially relied on old semiconductor systems designed for other applications. Now that the industry has reached a critical size, several LED-dedicated equipment (that take into account the specificities of LED manufacturing), has been commercialised. As a result, the equipment market will peak at nearly $580 million in 2015 with MOCVD reactors representing more than 80 percent of the business. The bulk of these reactors are still being shipped to Chinese manufacturers or Taiwanese players transitioning to 4-inch diameters. Lithography, plasma etching, PECVD and PVD equipment will follow a similar trend. This report presents major equipment used in LED Front-End Manufacturing. It describes market size and volume (2009 to 2020), trends per process steps (performance, ASP, emerging technologies and so on), key suppliers, and more.

The LED epitaxy equipment market (MOCVD reactor) is very concentrated under the control of the Big three (Aixtron, Veeco and Taiyo Nippon Sanso) who represented nearly 97 percent of market share in 2013. Comparatively, the lithography, plasma etching, PECVD, and PVD equipment markets are much more fragmented with several players battling to enlarge their market share. As an example, the top three suppliers of LED lithography equipment represented nearly 70 percent of market share in 2013 with the remaining 30 percent in the hands of more than ten competitors.

This situation is due to specificities of the different LED Front-End manufacturing process steps. LED epitaxy is quite specific and requires dedicated tools supplied by companies that have developed strong know-how. Also, other LED Front-End manufacturing processes can use older or refurbished semiconductor systems designed for other applications. And with the growth of the LED industry, suppliers of LED-dedicated systems have also appeared. This has further fragmented these markets, now both traditional semiconductor equipment suppliers and new LED-dedicated equipment suppliers compete.

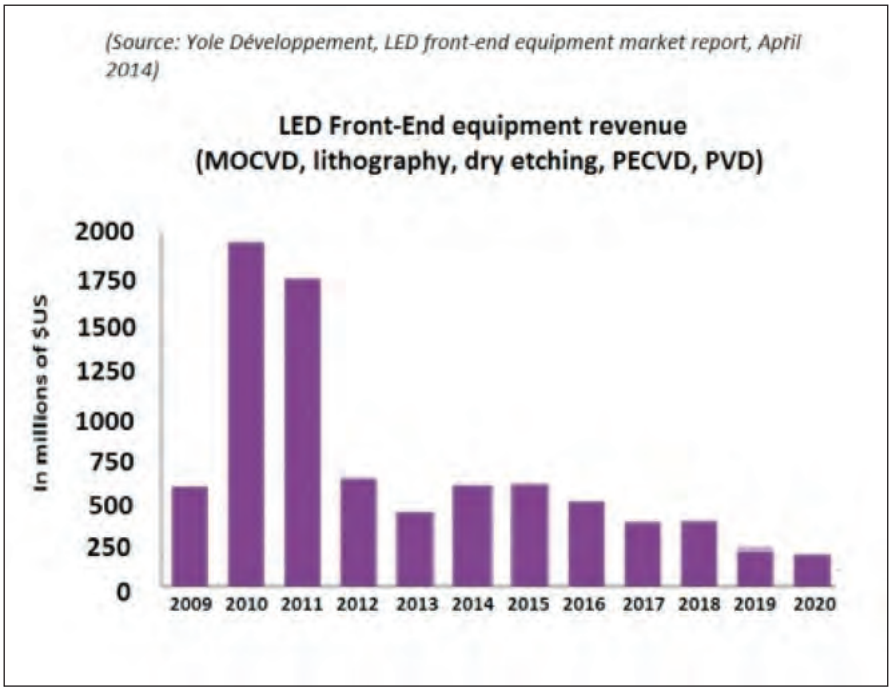
LED epitaxy equipment market has always been of central interest to equipment manufacturers due to its high ASP, strong profitability, and large market volume compared to other equipment markets.

Since 2010, following the explosion of the LED TV market, more than twenty players (mostly from Asia) have tried to enter the MOCVD reactor market but without real success: in 2013, these new suppliers represented only 3 percent of market share (only +2 percent compared to 2010).

This situation arises for two main reasons. The first is that new entrants have missed the first two LED growth cycles (small display and large display applications) that have allowed leaders to build their expertise and know-how as well as their networks (sales office, training centre etc.). Even big names, such as Applied Materials, did not achieve access to these markets. Secondly, revenue collected during the 2010 to 2011 investment cycle (a total of more than $2 billion for MOCVD reactors, with over 90 percent going to Aixtron and Veeco) have allowed Veeco and Aixtron to slash ASP and initiate a price war to lever further market entry barriers.

The current LED Front-End industry is largely driven by cost reduction (as technological evolutions are reaching their saturation point). The main strategy developed by a new MOCVD reactor supplier is to focus on decreasing Cost of Ownership through a new heating system, new gas flow design, and increased automation and so on. However, even if this is the best and only strategy to adopt, Yole does not expect new entrants to have a big increase in future market share as the finances and expertise of the Big two far surpass any of their competitors.

(Source: Yole Développement, LED front-end equipment market report, April 2014)



Peregrine unveils SOI products for RF

PEREGRINE SEMICONDUCTOR, a pioneer of SOI and advanced RF solutions, is debuting its new line of UltraCMOS based RF power limiters, including PE45140 and PE45450 slated for release as Compound Semiconductor goes to press.

According to the company, its silicon-on-insulator (SOI) power limiters represent turnkey, monolithic solutions to provide an alternative to discrete, PIN-diode limiters based on GaAs. The UltraCMOS power limiters are claimed to deliver simple, repeatable and reliable protection ideal for test-and-measurement, land-mobile-radio (LMR), wireless-infrastructure, military and radar systems.

"Peregrine makes best-in-class RF products, and we are pleased to extend that heritage into the new category of power limiters announced at EDI CON today," says Duncan Pilgrim, director of marketing at Peregrine. "Our customers continuously find that incumbent GaAs-based RF solutions do not rise to the challenge of new complexity in the market, and they are investing in Peregrine's SOI technology as fast as we can develop new options like this."

On a chip claimed to be eight times smaller than the board space required by discrete, PIN-diode solutions, Peregrine's new power limiters are claimed to provide a ten to one hundred times improvement in response and recovery time. The company also says they deliver greater than 40 dB improvement in linearity (IP3) and offer a twenty times improvement in ESD (electrostatic discharge) protection.

Of particular interest to RF designers, Peregrine's power limiters can save PCB space with a small form factor, reduce BoM (bill of materials) by eliminating the need for extra components and improve time to market by reducing in-design time and costs. Peregrine also says they beat existing solutions in RF performance, including higher linearity to eliminate signal distortion, high ESD to ensure high reliability, wide bandwidth to enable design flexibility and fast response and recovery times to ensure robust protection of power-sensitive components.

Osram orders Altatech's inspection and metrology system

ALTATECH, a subsidiary of Soitec, has received an order for its Orion LedMax wafer inspection and metrology system from Osram Opto Semiconductor.

Osram will use the tool to improve the performance, cost efficiency and yield of its LED-processing operations. The inspection system is suitable for both volume manufacturing and R&D applications and will perform production control and new product qualification of Osram's epitaxial wafers used in fabricating LEDs. Capable of inspecting wafers from four inches to eight inches in diameter, Altatech's Orion system combines the capabilities of 2D inspection, defect height measurement and dark-field inspection in one platform, producing the industry's most thorough and meaningful wafer-metrology results. "After a very extensive evaluation of available options, Osram's selection of our Orion system confirms both the performance and the cost efficiency of our solution," says Jean-Luc Delcarri, general manager of Soitec's Altatech subsidiary. "The integrated functions of our holistic inspection systems are unique and unmatched in any other suppliers' production tools."

Orion offers the full range of inspection and metrology capabilities for front-end manufacturing process flows including incoming wafer qualification, process development and line monitoring. Proprietary Orion modules are designed to conduct front side and back side surface inspection, edge inspection, bump and through-silicon-via (TSV) metrology by detecting, counting and classifying defects on patterned and unpatterned wafers.

Raytheon replaces SiC substrates with diamond for GaN RF power

RAYTHEON COMPANY has achieved another significant milestone for next generation gallium nitride) GaN Radio Frequency (RF) semiconductor technology.

Through the Defence Advanced Research Projects Agency (DARPA) Near Junction Thermal Transport effort under the Thermal Management Technologies program, Raytheon's team is replacing GaN's current substrate, SiC, with diamond, a material with three to five times higher thermal conductivity, to create GaN on diamond devices. Raytheon has demonstrated that GaN on diamond technology triples transistor power density over GaN on Silicon Carbide (SiC), overcoming a major barrier to unlocking the potential of GaN devices.

Data was obtained on a 10 x 125μm (1.25mm) GaN on diamond HEMT, a device representing a unit cell for constructing Power Amplifier Monolithic Microwave Integrated Circuits (MMICs), the foundation of solid-state RF transmitters and Active Electronically Scanned Arrays.

This result builds on prior successes, including Raytheon's first demonstration of GaN on diamond transistors in 2009, and GaN on diamond MMICs in 2011.

"Raytheon continues to be an innovator leading the development of GaN technology," says Joe Biondi, vice president of Advanced Technology for Raytheon's Integrated Defence Systems (IDS) business.

"We are now inserting GaN into DoD systems while remaining focused on continuing to increase performance of this revolutionary semiconductor to provide our warfighters with the most advanced sensing, communications and electronic warfare capabilities in the world."

GaN on diamond offers revolutionary performance improvement by reducing thermal resistance within the device and enabling GaN to be used at higher power densities, which will dramatically reduce the cost, size, weight and power of defence systems.

GaN is a core competency within Raytheon and an integral technology behind some of the company's major including Air and Missile Defence Radar and Next Generation Jammer. GaN's unique qualities allow radar, electronic warfare and communications systems to be smaller, more affordable and highly efficient.

Raytheon Company also recently announced that under the DARPA MTO Wide Bandgap Semiconductor Program, the company has systematically matured GaN from basic material to transistors, MMICs, Transmit/Receive (T/R) Modules and finally Transmit/Receive Integrated Multichannel Modules (TRIMMs), enabling game changing system performance for the DOD.

2014 IEEE Compound Semiconductor IC Symposium

October 19-22 at the Hyatt Regency La Jolla at Aventine, San Diego, California, USA

Paper submission deadline 2 May 2014.
See the Call for Papers for more details.

2014 IEEE CSICS Website

Plenary Speakers

Dr. Ichiro Fujimori (Broadcom), Mr. Joël Hartmann (STM), Dr. Daniel Green (DARPA/MTO), Dr. Hervé Blanck (UMS), Dr. Paul Saunier (TQS)

Sunday Short Courses

Short Course I: *GaN HEMT Device Modeling* taught by Dr. I. Angelov (Chalmers), Dr. R. Trew (NCSU), and Dr. D. Root (Agilent).

Short Course II: *Fundamentals of Power Conversion and Envelope Tracking* taught by Dr. Maksimovic (UC Boulder) and Mr. D. Kimball (MaXentric).

Primer I: *Fundamentals of A/D Converters* taught by Dr. H. Pan (Broadcom).

Primer II: *Introduction to Si RFIC Design* taught by Dr. W. Khalil (Ohio State).

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Advanced Registration Deadline: 26 Sept 2014

TOPIC AREAS

GaAs, InP, GaN, SiGe, and nanoscale CMOS technology
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A $10 revolution?

Does the release of the Philips' SlimStyle LED bulb for less than $10 suggest that the solid-state lighting market has reached its tipping point?

EARLIER THIS YEAR, Philips unveiled the world's first flat light bulb, called 'SlimStyle'. In an unusual move, designers have flattened the bulb to boost its surface area so individual LEDs can be sufficiently spaced out to remain cool. Crucially, this removes the need for the heatsink found at the base of most bulbs.

The 60 W-equivalent soft white lamp boasts similar credentials to Cree's rival bulb, producing 800 lumens using 10.5 W, offering 76.2 lumens per Watt with 25,000 hours of life. Admittedly, the 'SlimStyle' bulb doesn't provide the dazzling 93.8 lumens per Watt of its L Prize winning predecessor, but at $9.97, consumers can bask in an efficient and affordable glow.

Right now, Philips is waiting on Energy Star certification; Cree has pipped the Dutch technology giant to the post here. But with each hitting the all-important $10 price point, Philips' SlimStyle 60 W equivalent soft white bulb is Cree's only real, current competition in the US.

"A couple of years ago, I think there was this ambition to get the price of these bulbs to less than $20," says Todd Manegold, director of LED lamps at Philips Lighting. "Today, the ambition has been to get to the $10 barrier so we made a conscious choice to do this." The move is intended to trigger greater market demand, and as Manegold says: "These are significant price points for people."

"In the past people have had to think about buying an LED lamp – it's been a preconditioned purchase," he adds. "But at $10 and less, people can buy the bulb on impulse and will be more willing to try one and then come back and buy, four, six or ten, whatever the household needs."

And $10 is just the beginning. Energy Star certification from the US Environmental Protection Agency brings rebates, which Manegold reckons will push prices down to around $5.

"Later this year, thanks to the rebate dollars that are out there, consumers will see $5 price points on these bulbs, which is something we perhaps couldn't have imagined a few years ago," he says.

Indeed late last year, when Cree's soft-white 60 W and 40 W equivalent bulbs achieved Energy Star qualification, chief executive Chuck Swoboda asserted: "Cree LED bulbs can now be purchased with an instant utility rebate, delivering customers a quality LED bulb for under $5... [This] makes switching to LED lighting an easy choice for consumers."

Cutting costs

Pars Mukish, senior analyst at France-based semiconductor analysis business, Yole Développement, is certain the LED

Flat as a pancake: Using mid-power Luxeon LEDs, SlimStyle uses 10.5W of power to put out some 800 lumens

market has at last reached a tipping point on price. "Only price decreases will allow us to cross the chasm and drive mass adoption of LED lighting," he says "The $10 LED bulb has been on the mouths of all manufacturers for a few years... [though] at the moment only Philips and Cree are strongly competing on the sub-$10 bulb."

Indeed, other 60 W-equivalent bulbs on The Home Depot website, including Switch, Polaroid and TCP versions, cost around $13. However, Mukish is confident price erosion will continue.

As the Yole Développement analyst points out, packaged LED cost has been a key contributor to LED lamp prices, with cost reductions likely to continue. The analyst asserts manufacturers will also be looking beyond LED packaging to drive costs down; key areas include the development of cheaper materials for optics and heat sinks as well as higher integration to cut component count in, for example, IC drivers.

"Technology and research breakthroughs are not the only path to aggressive cost per lumen targets," he says. "Improved industry collaboration, supply and manufacturing chain performance and industry standards will all play a critical role."

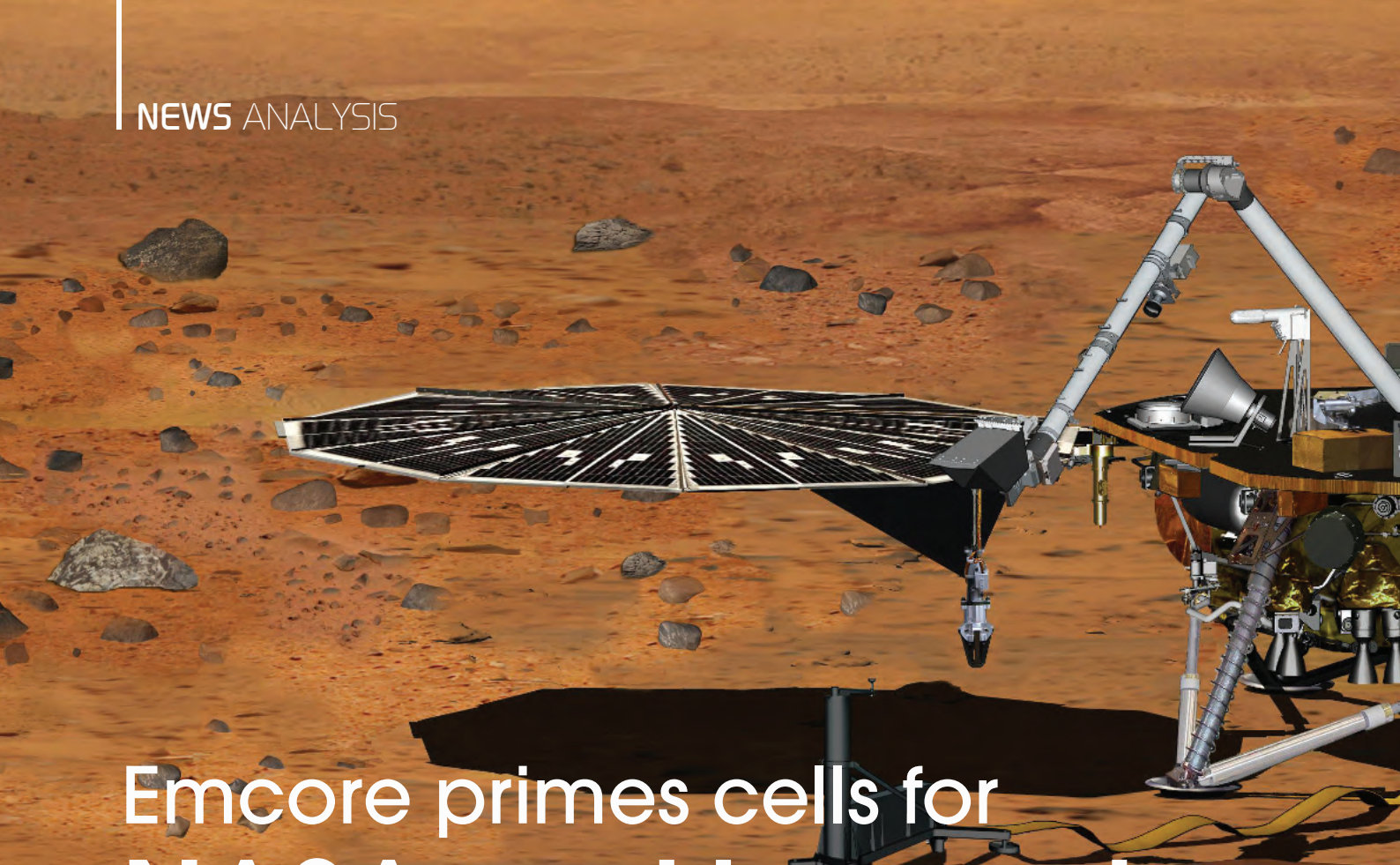
"However, it is no secret... that one way to save money is to use as few parts as possible, and to use these parts in as many products as possible," he adds. "It seems that this strategy has been used by both Cree and Philips."

Indeed, components reduction has clearly been a priority for Philips. As Manegold highlights, efficiency improvements in LEDs has allowed its designers to use fewer LEDs and experiment with new bulb form factors – hence the flat 'SlimStyle' shape. More efficient LEDs means fewer are required in a product, enabling smaller, more streamlined bulbs; in this case, the LEDs are arranged in a horseshoe shape around the outer edge of the bulb.

"Our engineers came up with this creative way to space the LEDs on a flat surface, rather than bunching them up as you do in the traditional bulb," says Manegold. "So the heat sink has become this flat PCB that's actually inside the lamp... and this piece now serves as a holder for the electronics and the optics."

And as the Philips director adds, fewer LEDs and less heat generated, mean fewer mechanical and electronics components, which all drive down product costs.

"The LED is new to a lot of consumers and requires folk to learn about the technology, which isn't something you can achieve overnight," he says. "But we're now going beyond this. We're challenging the form factor and we're challenging consumer experience with these new products. Philips is synonymous with lighting and we're now reinforcing our perception that we're also synonymous with the LED."



Emcore primes cells for NASA and beyond

With two hefty space contracts already in hand, this year is shaping up nicely for Emcore. Compound Semiconductor probes the III-V systems manufacturer on NASA, its elusive next generation inverted metamorphic solar cell and more

HAVING CELEBRATED more than a megawatt of power in space and a fistful of space contracts last year, Emcore looks set to serve up more of the same in 2014.

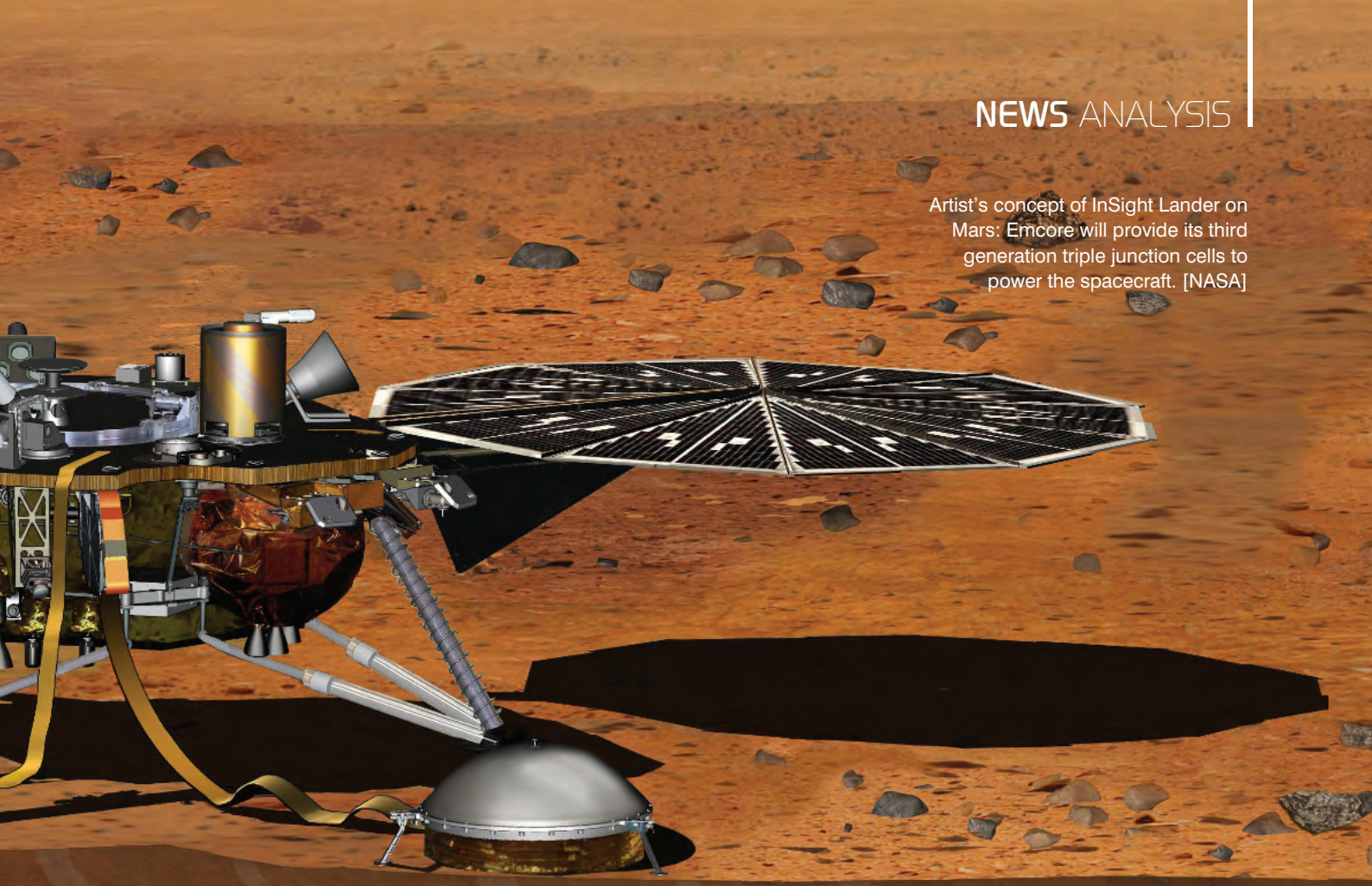
Already the US compound semiconductor-based product manufacturer has snared two major contracts, with US aerospace heavyweights ATK and Sierra Nevada to manufacture solar panels for NASA missions. And as vice president of business development, Navid Fatemi puts it: "Emcore provides solar panels to the vast majority of NASA missions, many more than our competitors. For example we've been working with ATK for more than a decade and had more than a dozen successful missions."

Both contracts will see Emcore populating solar panels with its third generation triple-junction (ZTJ) InGaP/InGaAs/Ge solar cells, but for very different applications; Mars and low Earth orbiting satellites. For ATK, Emcore will design and manufacture solar panels to power NASA's InSight spacecraft that will leave for Mars on March 2016, landing some six months later to study the planet's deep interior. Right now Emcore is manufacturing its ZTJ solar cells for integration to ATK's lightweight 'UltraFlex' fanfold solar array system, ready for final configuration on the spacecraft.

Meanwhile, Emcore will also design and manufacture ZTJ cells for Sierra Nevada that will be integrated to NASA's Cyclone Global Navigation Satellite System (CYGNSS) by the Southwest Research Institute. Launching in October 2016, CYGNSS comprises eight low Earth orbiting satellites that will measure ocean surface winds and predict hurricanes.

From Earth to Mars, the ZTJ cells will be subject to extreme, but very different environments. Earth orbiting satellites, for example, experience relentless radiation. Here, protons and electrons generated by solar wind trapped by the Earth's magnetic field impinge onto the craft, and its solar cells constantly. At the same time, satellites experience very wide and extreme temperature cycling; from an incredible -180°C to around 100°C depending on orbit.

In contrast, on Mars, there may be little radiation, besides ultraviolet radiation, but the rocky planet has atmosphere with wind and, again, significant temperature cycling.



Artist's concept of InSight Lander on Mars: Emcore will provide its third generation triple junction cells to power the spacecraft. [NASA]

Still, as Fatemi highlights, Emcore's solar cells serve all purposes and will survive all flight conditions. "The solar cells we have designed and are planning for Insight are the same solar cells that have been space-qualified for Earth orbiting satellites," he says. "There's no difference in construction and the very same cells are currently navigating the asteroid belt between Mars and Jupiter as part of the NASA Dawn mission."

But while Emcore busies itself with its latest ATK and Sierra Nevada contracts for triple junction ZTJ cells, whatever happened to its much-awaited inverted metamorphic (IMM) solar cell? Excitingly, this could be unleashed sooner rather than later.

A 33 percent efficient, novel architecture GaAs-based cell was first slated for delivery, by Emcore, back in 2010. Four years later, industry still waits but hopeful signs are emerging. In recent years Emcore has shifted its research focus from a three-junction IMM to four-junction IMM device in a bid to boost efficiency to 34 percent. Papers have been presented at conferences and now on its website, ATK claims: "UltraFlex is compatible with... IMM cells. anticipated to be ready for flight within the near future."

Fatemi won't commit to an absolute release date but is confident NASA would be a customer. "We've noticed that every time we introduce a new generation of solar cell with higher performance, NASA is one of the first organisations to use it," he says. "NASA spacecraft designers can always use more power within a limited area; this is something they will always take advantage of."

Space qualification awaits. While the individual junctions within the IMM structure are already used in Emcore's ZTJ cells, the entire cell is not yet qualified. Still Fatemi reckons 'a space qualification campaign' could start in the next year or two.

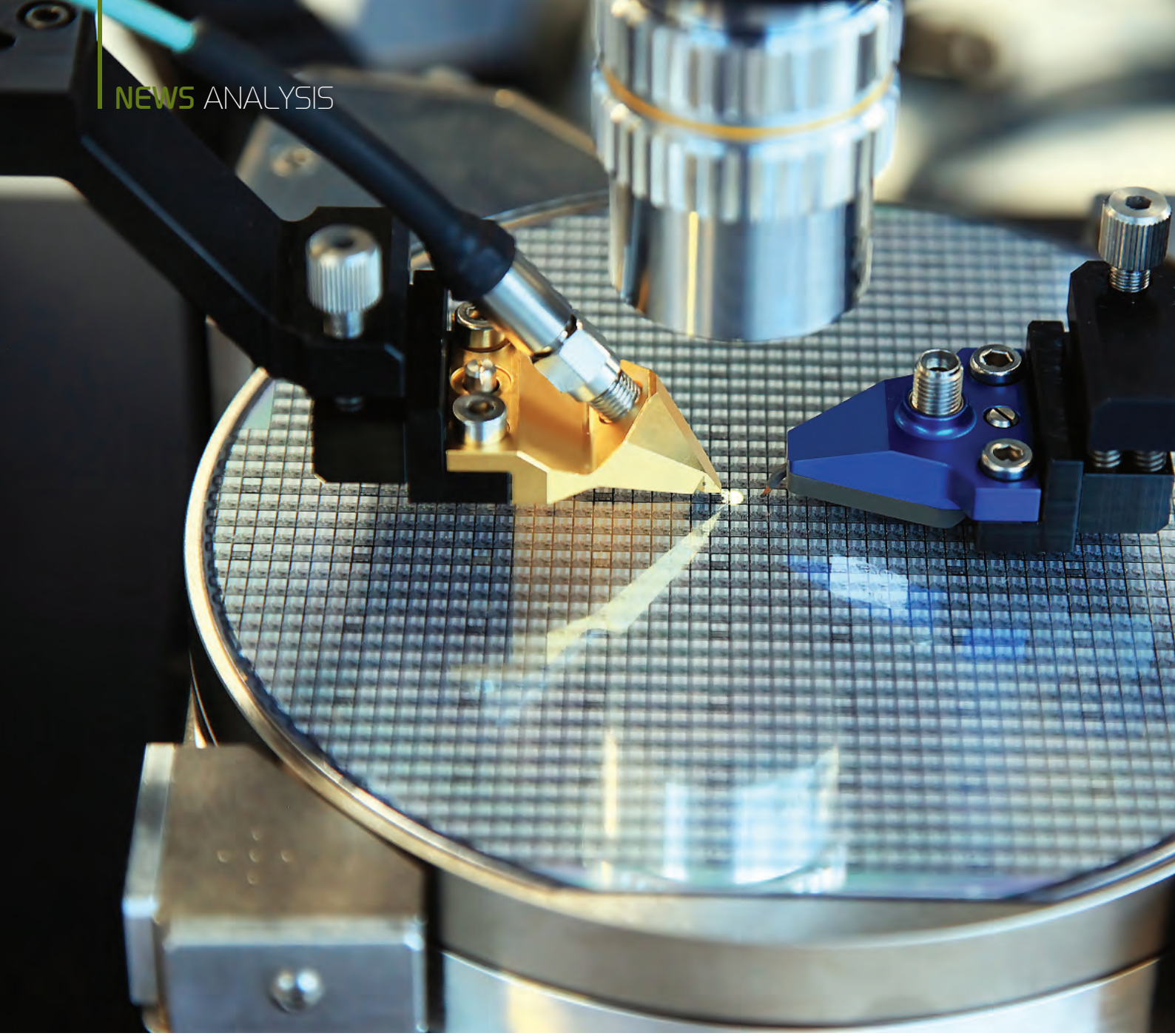
"The packaging of IMM is a little more challenging than that of your conventional triple junction solar cells; IMM is only a few microns thick and so is flexible yet very fragile," says Fatemi. "We're working on this, and once completed to our satisfaction that it will serve the needs of all customers, then space qualification will start."

Space and beyond

But while Emcore makes great strides on ZTJ cell manufacturing and IMM development, is NASA alone enough to ensure the space-based arm of the III-V systems developer thrives? Speaking last year to *Compound Semiconductor*, Fatemi outlined the slow but steady decline of the terrestrial CPV market. Having spent several years developing and manufacturing CPV modules based on its multi-junction solar cell for this sector, Emcore decided to step back and focus on space. But given NASA's very same slow but steady decline, surely Emcore is eyeing other space-based avenues?

Of course. According to Fatemi, commercial space markets – predominantly geosynchronous satellite missions for telecommunications – offer future promise. As he highlights, these missions typically involve large satellites, which of course demand more power. And of course, more power means many more solar cells than your average NASA mission.

"This market was not so healthy in 2013, but the indications are it will recover back to more than twenty orders, which is the norm. Last year the total order number was around seventeen," he says. "There's this potential to supply much larger panels, which is so important to the health of suppliers such as ourselves."



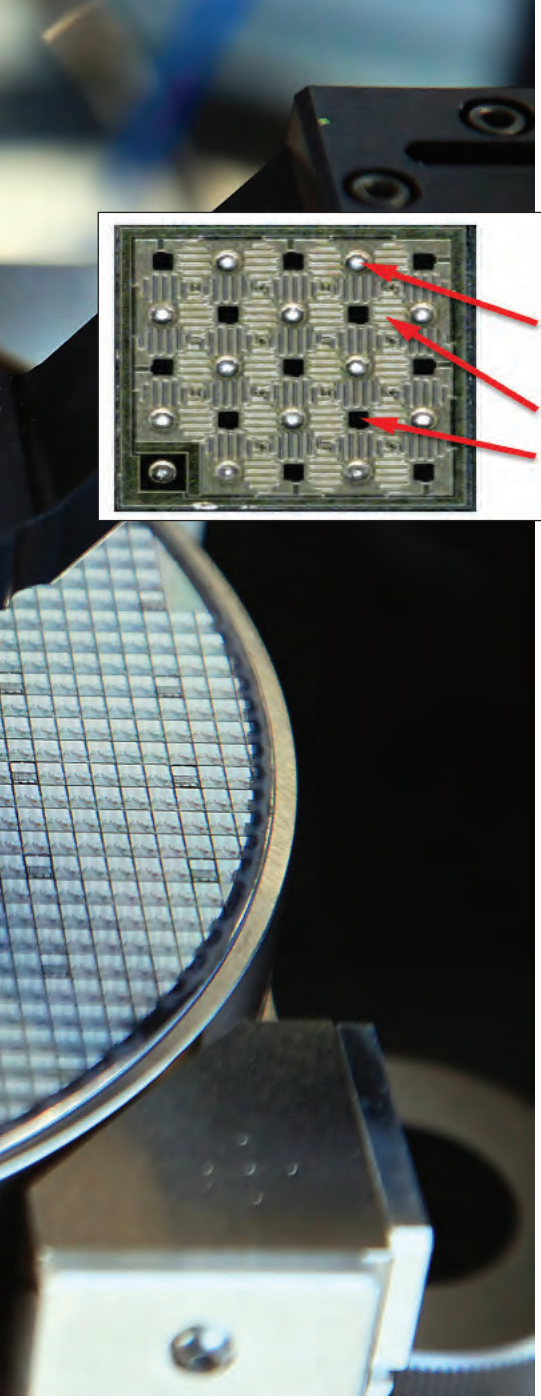
GaN Systems readies for market

Manufacturers of high voltage GaN-on-silicon transistors have yet to deliver, but GaN Systems promises a raft of products this year. Compound Semiconductor reports

AS INDUSTRIAL, power and communications industries demand semiconductors with faster switching speeds and unbeatable breakdown voltages, manufacturers of GaN-on-silicon devices are getting ready to deliver. Latest forecasts are edging towards a billion dollar market come the end of the decade, and one company keen to cash in is Canada-based GaN Systems.

"2014 is going to be a pretty big year for GaN Systems," says company chief executive, Jim Witham. "We've just announced our families of 100 V and 600 V parts, with a nice range from 10 A to 80 A, we're getting these into the market place, expanding our presence and gaining customer design wins."

While GaN Systems is hardly alone in the race to commercialise GaN-on-silicon



Left: 'Island Technology' promises to ease GaN transistor integration

technology, market-ready high voltage GaN-on-silicon devices have been a long time coming.

Right now design engineers can get their hands on a low voltage GaN-on-silicon HEMT from Efficient Power Conversion, via Digi-Key and International Rectifier has started to ship GaN-on-silicon products. But the only generic 600 V GaN-on-silicon HEMT device, publicly introduced by Transphorm, comes with a non-disclosure agreement.

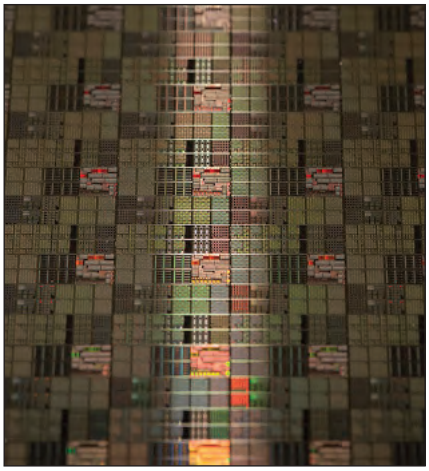
Witham thinks this will soon change. Having recently returned from this year's Applied Power Electronics Conference – APEC 2014 – in Fort Worth, Texas, he's excited.

"Several companies already have devices in customers' hands and at least four companies at APEC were showing devices in their booths," he says. "A lot of design engineers are now very excited about the prospect of GaN transistors as they know what the technology can do for their systems; they're saying, 'let me get these into the lab and run them, then I'm going to design them in and use them'."

New entries

Jim Witham, formerly chief executive at Neoconix and Fultec Semiconductor, joined GaN Systems only weeks ago, brought in by co-founders Girvan Patterson and John Roberts to take the company's products to market this year. Patterson and Roberts founded the company in 2008, after a decade of GaN research, gaining original support from the Ottawa Centres of Excellence for a project with Carleton University, and then capturing funds from clean-tech venture capital firms Chrysalix Energy Venture Capital and RockPort Capital.

From the outset, GaN Systems' goal has been to ease the adoption of GaN for design engineers. Researchers have honed the company's transistor structure, with its distinctive chequered arrangement of source and drain connections, branded 'Island Technology', and delivered several patented packaging methods.



Watch this space: GaN Systems intends to commercialise its GaN-on-silicon technology this year.

And as GaN power technology matures and the market readies for rapid growth, the management team is clearly prepping the company for commercialisation. Witham's very recent appointment comes hot on the heels of Charles Bailey, now senior director of technical marketing, Asia, as well as Tony Astley, appointed as director of European operations.

As Witham puts it: "This year is all about making devices. With our sales and marketing leadership in Japan and Europe, we're really investing in our sales channels. We want to get out to the [design engineers] and put products into their hands."

"My background fits exactly with this," he adds. "I've taken new products and done what I call the missionary sell. I take a new technology, explains to the customer why it's so much better than the existing, [silicon], and then get them to convert over to it."

But converted or not, don't GaN-on-silicon transistors – at least the high voltage versions – still have some serious hurdles to surmount before true commercialisation? Current collapse, especially at 400 V operation and higher has long been a research and development focus in industry and academia. Meanwhile many an oscilloscope manufacturer has highlighted the test and measurement challenges posed by high voltage, high bandwidth GaN devices.

Witham isn't fazed. "You know, [current collapse] was taken care of years ago. Ten years ago this was a huge issue but researchers have taken care of that," he says.

"But yes, test equipment design engineers come into GaN Systems quite frequently," he adds. "These equipment makers have some work to do but this is also an opportunity for them; once these problems are worked out, they will have some new equipment to sell."

LEDs: China readies for global domination

Following strong MOCVD reactor sales, analysts across the board predict LED manufacturers in China will rapidly ramp up production. Compound Semiconductor investigates

Today, China is the world's largest producer, consumer and exporter of electrical lighting. China-based high-tech analysis hub, *OfWeek*, claims more than 10,000 lighting manufacturers are based in China, accounting for a third of global incandescent lamp and more than 80 percent of global compact fluorescent lamps production.

But while the sheer market size is breath-taking, without a doubt the leading light is the LED. Generous government subsidies and strong domestic policy have triggered strong MOCVD reactor sales with LED development following suit. And while industry players have questioned the sustainability of this market, unwavering growth is now widely predicted. Earlier this year, *LEDinside* revealed LED chip revenues of China-based manufacturers reached $ 992 million in 2013 with production expected to rise by 17 percent in 2014, driving revenues up to $1.2 billion.

And now, in a report that will only fuel Chinese LED market expectations, IHS Technology predicts double digit growth for China LED production in 2014. Senior analyst, Alice Tao, reckons LED die production levels will grow by 36.6 percent to reach nearly $1.5 billion this year, with packaged LED growth coming in at 14.8 percent to reach $4.8 billion.

As she highlights: "World growth rate is much much lower; for example our forecast for packaged LED revenues is only around three to four percent for 2014."

"The highest growth rate in the LED supply chain belongs to chips simply because current capacity hasn't yet peaked," she adds. "Although China installed the most MOCVD tools in the world, average utilisation rate still remains low."

Beyond 2014, growth rates for both LED die and packaged LED production will slow down, but right now, and hardly a surprise, lighting is the major driving force for China LED market growth. Tao cites the falling costs of LED lamps in general, the rising acceptance of LED replacement T lamps and the phasing out of incandescent lamps as being key to current growth. Meanwhile, backlighting also continues to fuel LED die and packaged LED revenues as China-based companies loot to replace imported components from Taiwan and Korea. But as LED penetration increases, the market will change.

For starters, the 2014 driving forces will drop away. As Tao highlights: "When cost is no longer a problem, consumers will pay more attention to the advanced performance of LED technology."

Crucially, China's international sales – currently low – are expected to rise. Key players such as Sanan Optoelectronics are developing own-brands to bolster international presence, and according to Tao, the intellectual property issues that have hampered LED-related exports will soon be solved.

"The main issue for Chinese LED companies boils down to Intellectual Property," she says. "However, as these IP issues are resolved through better regulation and provisioning of protection for IP, international sales will grow. Although these won't grow significantly in the short-term."

Of today's key China-based LED players, Tao expects we will definitely see more of Sanan Optoelectronics. Having being cited on the Forbes Asia's 200 Best Under A Billion list, the LED wafer and chip developer currently leads the market for LED dies in China.

"Sanan is retaining its top position... and is by far the most important LED company in China given its hold on the market," says Tao. "This is not likely to change in the next year or two."

Meanwhile, for packaged LEDs, Tao reckons MLS Electronics is the clear leader while Elec-Tech and Nationstar are also dominant in the same market. But consolidation is imminent. Tao is not the first analyst to predict mergers amongst LED manufacturers, in what is ultimately a complex, over-crowded sector comprising more than 5000 players. Still the likes of Sanan and MLS should remain.

"The top players are likely to hold their leading positions for the near term," concludes Tao. "But market consolidation will follow as smaller companies give way to the strongest players."

Beijing Water Cube at night time on August 28, 2011. It hosted Olympic swimming and diving events

CMOS challenges SiGe radar chips

Could imec's CMOS car radar chip prompt industry to move to pure silicon?

JUST LAST MONTH, imec unveiled what it described as the world's first 79 GHz radar transmitter implemented in 28 nm CMOS and designed for automotive radar systems. While today's high-end vehicles may feature a two- or three-chip single SiGe radar system – typically used in adaptive cruise control – industry pundits predict strong market growth for such systems. And imec wants to be a part of it.

"High-end series vehicles such as BMW and Mercedes feature a single radar system but in the future we will see multiple radars in a car," says imec researcher, Wim Van Thillo. "We could see four radars in the front bumper, four in the rear bumper and this is going to be in all cars, not just high-end."

But what sets imec's chip apart from the millimetre-wave sensors developed by other radar chip manufacturers, Infineon and Freescale, is the fact it is fabricated in plain and simple CMOS. Could this tempt radar system suppliers away from SiGe?

The first commercial radar systems of the late 1990s were based on GaAs chips. But then Infineon jumped ship and started developing systems based on bipolar process SiGe chips.

These SiGe chips not only met the high speeds demanded by 77 GHz automotive radar, but enabled smaller and more cost-effective radar systems than had been possible with GaAs-based versions. Freescale has since delivered 77 GHz SiGe chipsets – fabricated in 0.18 μm BICMOS – for radar collision warning systems, and automotive radar developers have been keen to switch from GaAs to SiGe. But now CMOS is catching up.

"SiGe transistors are much faster than CMOS transistors at the same node, but CMOS is now possible because of more advanced [fabrication] processes," explains Van Thillo. "We're down to 28 nm for CMOS whereas the most advanced SiGe nodes are 130 nm. We've been focusing on implementing analogue functionality on plain digital CMOS and we believe we are the first in the world to present such an advanced chip."

Clearly imec's motivation for straight CMOS is integration. With researchers having demonstrated they can implement analogue transmitter functionality – analogue and mm-Wave – on CMOS, the race is now on to develop a single chip solution.

Admitting he and colleagues are 'not there yet', Van Thillo says: "We've also now taped the receiver to the transceiver... We're waiting on measurements and by the end of this year will have proof that it can be done in 28 nm CMOS."

With full transmit-receive functionality on CMOS - for a single antenna - in hand, Van Thillo then hopes to scale up to multiple antennas with higher resolution by 2015. "And once we have that we need to integrate analogue to digital converters and so on, to demonstrate this can all be integrated onto a single chip."

Clearly a single chip CMOS solution brings the promise of vast cost reductions at larger manufacturing volumes, but is CMOS actually going to be that cheap? The NRE costs of a 28 nm node process are very high - a single mask set can cost up to €2 million, but Van Thillo isn't fazed.

"We have several reasons to believe CMOS will be a good choice," he says. "[Process] costs are coming down rapidly and we are targeting products to hit the market in two to three years, depending on partners. And, of course, automotive radar is growing fast."

But will imec's 79 GHz radar chipset rival SiGe 77 GHz versions? For today's automotive radar developers, two key frequency bands exist; 77 GHz and 79 GHz. The former is well-established and used for the long range radar in automatic cruise control systems in high-end cars. Radar range reaches 200 m, with a resolution down to 30 cm and narrow field of view.

More recently, the 79 GHz band has been allocated in Europe, although worldwide harmonisation is expected. This band suits shorter-range, high-resolution radar systems, to be designed for relatively new functions that demand a smaller

depth resolution and wider field of view, such as stop-and-go, pre-crash alarm and blind-spot detection.

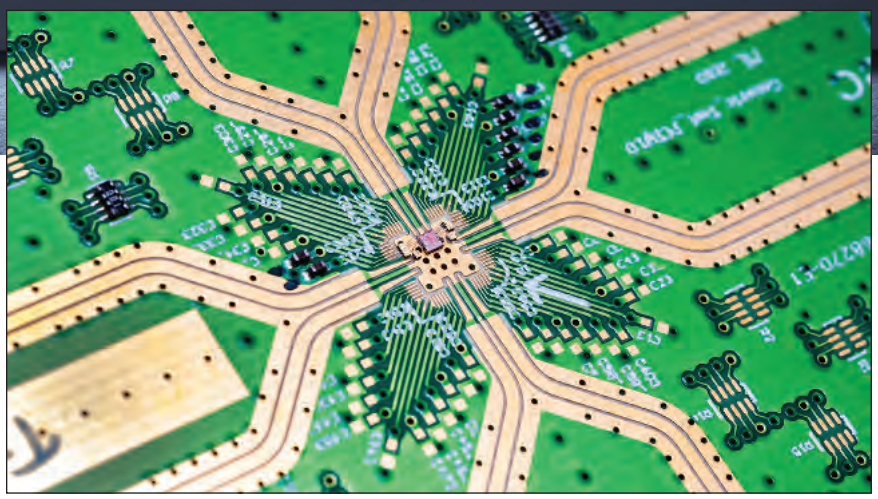
Existing 77 GHz SiGe solutions offer both the longer range and short-range functionalities, albeit across several chips, so why bother with the 79 GHz radar? As Van Thillo says: "The 79 GHz band offers the 4 GHz bandwidth that is required to bring the range resolution down to a couple of centimeters."

"For future systems, manufacturers will need shorter range radar with finer angular resolution which translates into more antennas," he adds. "So to scale up, systems will need more chip area, and in larger volumes CMOS is very attractive."

Clearly the SiGe versus CMOS debate has some way to go. As Van Thillo highlights CMOS could be used for non-critical radar applications until automotive manufacturers gain enough confidence to switch from SiGe. But then manufacturers could always stick with SiGe chips for longer-range radar and rely on CMOS for short-range applications.

However, he is clear that there is no future for the original GaAs radar chip. "The end of GaAs in automotive radar has already happened," he says.

"I see no reason to do things in GaAs that can be done in SiGe, there just isn't any competitive advantage here."



Implemented in 28nm CMOS and with a supply voltage of 0.9V, Imec's continuous wave radar transmitter only consumes 121mW and is fully compliant with the spectral mask imposed by ETSI. [imec]

Move over GaAs?

Peregrine Semiconductor's CMOS power amplifier promises GaAs-level performance in 4G phones. Will handset manufacturers now shift to silicon?

IN EARLY FEBRUARY of this year, Peregrine Semiconductor unveiled its UltraCMOS Global 1, described as the industry's first reconfigurable RF front-end system. Comprising the company's prized RF switchers and tuners, the system also houses a multimode, multiband power amplifier, which Peregrine describes as the first CMOS PA to match the performance of the GaAs equivalent.

Following in the footsteps of Qualcomm's CMOS front-end module, the RF360, released in February 2013, Peregrine has designed the system to challenge GaAs incumbents in 4G markets. However, Duncan Pilgrim, Director of Strategic and Technical Marketing at Peregrine claims this system is different; it really performs.

"When Qualcomm released the RF360 we thought this is great, it validates what we've been doing for the last fifteen years; integrating the front-end," he says. "But the big difference for us is there's no trade-off in performance."

"[The power-added efficiency of] GaAs PAs has traditionally been at least 10 percentage points higher than CMOS PAs... but our technology allows us to meet the same performance as GaAs for WCDMA and LTE standards," he adds. "There is no trade-off in battery consumption, network capacity; we truly believe we have hit the same performances as the GaAs equivalent."

According to Peregrine figures, the power added efficiency (PAE) of the UltraCMOS Global 1 PA, using a WCDMA waveform at an adjacent channel leakage ratio of -38 dBc, approaches 50 percent, on par with today's cutting-edge GaAs PAs. What's more, the PA is said to maintain the GaAs-equivalent PAE for LTE waveforms with varying resource-block allocations. And this is without performance enhancements from envelope tracking or digital predistortion, although the system supports all envelope-tracking modulators.

"Since 2006, we've worked on creating the most efficient amplifiers on a CMOS process, We've been working closely with Soitec and Global Foundries... and we have around 73 patents associated with the RF front end," says Pilgrim. "We've really been trying to tie in all of this with design techniques as well, and this has enabled the improvements in efficiency that we've now got."

Systems have been sampled and Peregrine is currently working on platform integration. Pilgrim reckons this will be completed within 12 months, so production will then start early next year. But will the handset manufacturers buy?

Pilgrim thinks so. Performance aside, he highlights how the reconfigurable system will allow manufacturers, busy grappling with LTE handsets to support more than 40 frequency bands, to save time and money by creating a single-SKU design that operates across global markets. "Look at the iPhone, the China Mobile rollout brought a 6th model and the only difference in all those phones was the RF front end," he says. "If you provide a front end that supports all the different regions... it simplifies the whole supply chain."

Still, the release of Qualcomm's CMOS RF360 has hardly displaced GaAs PAs from RF front-end markets, and some industry pundits are now questioning the need for the much-touted global SKU.

"This idea, that one part serves all bands and all regions, may not be as universally accepted as once thought," says Eric Higham, Director of GaAs and Compound Semiconductor Technologies, at Strategy Analytics. "Frequency allocation is regional and there is no single frequency used globally. We hear that with only one PA part number, any change requires requalification on a global, rather than regional basis and this will slow time to market and increase cost."

Still Higham is keenly watching market developments. As he highlights, CMOS PAs have been capturing market share in lower tier terminals for some time, but a shift in focus to LTE – from both Qualcomm and Peregrine – has taken the industry by surprise.

"The integration levels of Qualcomm's RF360 and the performance claims of Peregrine's Global 1 solution are impressive," he says. "Both companies represent formidable foes for the handset PA portion of the GaAs industry."

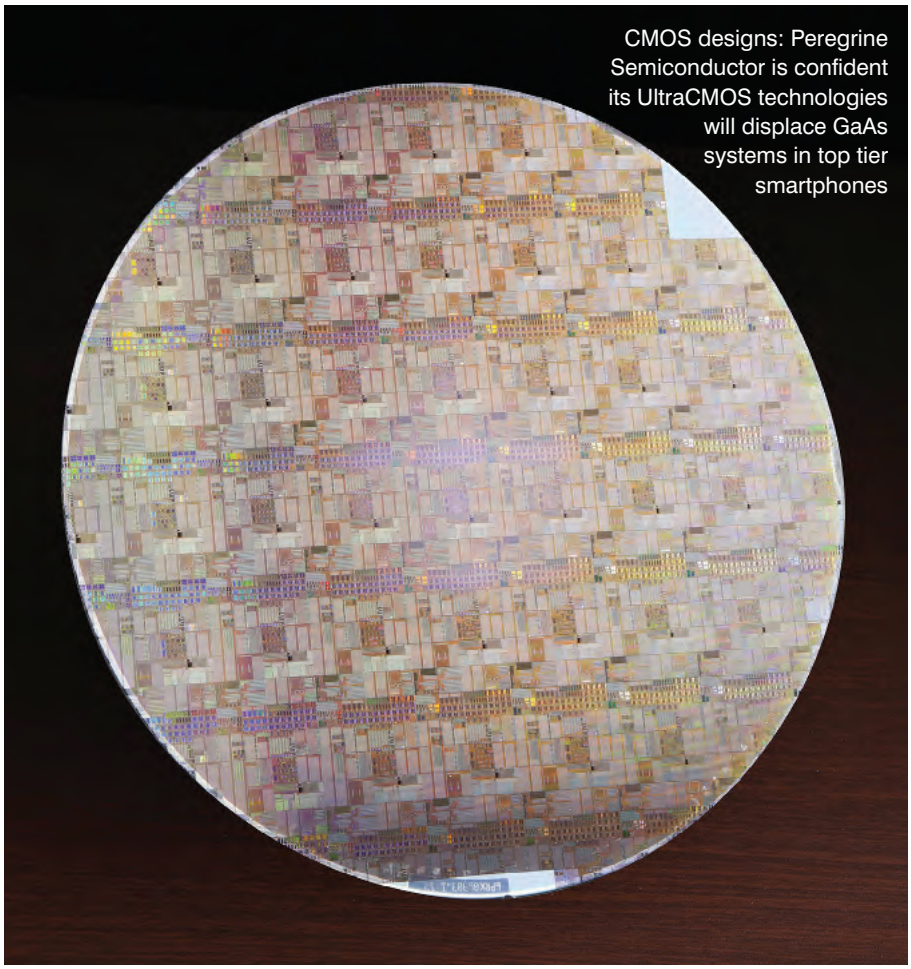
Indeed, Pilgrim describes the Global 1 system as a "game changer" that will accelerate a market transition from GaAs to silicon PAs.

"Back in 2011 we saw a real transition point for switches from GaAs to silicon on insulator. We've now hit that point again with power amplifiers," he says.

"In the next few years you are going to see a dramatic increase in the number of CMOS solution hitting the market... it wouldn't surprise me if we saw some consolidation [amongst GaAs device manufacturers] in the industry."

Higham concurs that manufacturers of CMOS PAs will now capture market share from GaAs players, with Qualcomm and Peregrine being well positioned to act. But he also emphasises how many GaAs device makers focus on markets beyond the handset sector that are likely to remain GaAs-dominated for the foreseeable future.

And as he asserts, Skyworks, RFMD and Avago all recently acquired CMOS PA design capabilities in preparation for a possible industry transition from GaAs to silicon PAs. "Peregrine has been the driving force behind the conversion of handset switches from GaAs to silicon, so is a recognised leader in this area," he adds. "But a challenge that the company now faces is, how long will it take for them to be recognised as an amplifier manufacturer? The performance of Global 1 will go a long way to minimise this concern but it will need to be addressed."



CMOS designs: Peregrine Semiconductor is confident its UltraCMOS technologies will displace GaAs systems in top tier smartphones

A destroyer equipped with Raytheon's Air and Missile Defense Radar leads a battle group in this artists' rendition. [Raytheon]

GaN takes a new line of defence

From radar to jammers, the defence industry has spent more than a decade developing GaN for US military applications. Compound Semiconductor asks Raytheon, where next for the technology?

LATE LAST MONTH, Raytheon celebrated taking GaN development from fundamental materials research to the demonstration of its X-band GaN transmit/receive integrated multichannel modules. On the way, the US defence contractor has built an array of more and more complex GaN-based devices, including transistors, monolithic microwave integrated circuits and transmit/receive modules.

These systematic developments have spanned more than a decade of development, leading to better radar, electronic warfare, navigation and communications systems. In the words of Joe Smolko, director of Microelectronics, Raytheon IDS Advanced Technology Programs: "In the late 1990s Raytheon started experimenting with the first GaN transistors and then we made a decision back then to have a sustained and substantial investment in GaN so we partnered with government."

"GaN has had such clear advantages for high performance systems in terms of its power density, efficiency and cost benefits." he adds. "It really has become a pervasive technology that we have looked to implement in many emerging applications."Indeed, today the technology can be found in the company's air and missile defence radar (AMDR) and next generation jammers, which are being snapped up by US defence.

For example, Raytheon recently batted back-entrenched competitors Lockheed Martin and Northrop Grumman to win a $380.7 million contract from the US Navy to develop S-band AMDR and radar suite controller, for its Flight III Arleigh Burke-class destroyer ships. The company's AMDR uses existing X-band horizon search radar and the latest S-band integrated AMDR designed for long-range detection of threats. The two radars are brought together through the radar suite, which coordinates the system.

This contract followed a similar US Navy contract, worth $279.4 million, in which Raytheon is designing new tactical jammer systems for advanced electronics. The jammers will block enemy radar, communications and other RF systems, and again the company won the development contract over defence

“So now this program is over, what next for Raytheon’s GaN development? Right now defence manufacturers, Lockheed Martin, Northrop Grumman and Raytheon, eagerly await the US Air Force’s final decision on its latest multi-million dollar contract, to develop Three Dimensional Expeditionary Long Range Radar.”

heavyweights, BAE, Northrop Grumman and ITT Exelis.

Crucially, both systems rely on Raytheon’s GaN transmit/receive modules, which make up the transmitter of an active electronically scanned array radar, and are rapidly succeeding GaAs-based systems found in older generation radars. Given its back-to-back US Navy deals, beating established competition, Raytheon is clearly succeeding in its GaN research and development programmes.

Proving manufacture

A crucial part of this development has been Raytheon’s work with the US Air Force Research Laboratory’s to put in place a ‘low rate initial production” (LRIP) manufacturing process for its X-band GaN MMICs. As part of the Department of Defense’s ‘Title III’ program, this ensures the ICs have achieved a production capability defined as a manufacturing readiness level of 8; in other words, the ICs are ready to be inserted into defence systems.

Title III contracts have also been awarded to other key GaN players; TriQuint, Cree and Northrop Grumman, each to increase yield, lower cost and improve time-to-market cycles for defence and GaN integrated circuits.

Raytheon is the first to complete its Title III program – it started first – and during this time, the company has demonstrated its GaN MMIC manufacturing yields are in line with mature GaAs processes and has also cut costs by 76 percent.

Gene Himes, an AFRL program manager for the initiative is confident these projects will ensure the US retains a competitive edge in defence applications, as dominated by GaAs technologies, and ease the technology’s entry to commercial applications.

“I don’t know that GaN will ever supplant GaAs as many applications are well served by GaAs,” he says. “However, by demonstrating improved manufacturability, the Title III contracts will eventually culminate in decreased cost... and will go a long way in terms of a transition to commercial applications.”

But for Raytheon, the project’s success gives the company manufacturing kudos. “Certainly MRL8 is a level of maturity that is consistent with us being able to insert it into all of our high performance military systems,” says Smolko. “It shows a manufacturing maturity that is comparable or exceeds the tried and true GaAs, and really does give users the confidence to use it in crucial military applications.”

So now this program is over, what next for Raytheon’s GaN development? Right now defence manufacturers, Lockheed Martin, Northrop Grumman and Raytheon, eagerly await the US Air Force’s final decision on its latest multi-million dollar contract, to develop Three Dimensional Expeditionary Long Range Radar (3DELRR). Designed to replace the decades-old TPS-75 radar system, this ground-based radar will detect, identify and track enemy aircraft, missiles and drones.

Raytheon’s system is a C-band radar, again based on GaN, and as Smolko says: “We continue to carry out research and development into GaN... our current microwave process is still finding pervasive applications in many systems – some I just can’t get into – but beyond this we’re extending it to work at higher frequencies.”

“You know, we will continue to mature this technology and eke out the last bit of performance cost benefit out of it,” he adds.

Raytheon air and defence missile radar comprises a GaN S-band radar, X-band radar and a radar suite controller. [Raytheon]

RFMD-TriQuint: Now what?

RF chip rivals, RFMD and TriQuint, have combined to create a multi-billion dollar industry giant. What does the merger mean for the rest of the industry? Compound Semiconductor investigates.

DESCRIBED by its leaders as the 'perfect combination for dense RF integration', the recent merger of RFMD and TriQuint creates a formidable presence in the RF chip industry. With a combined revenue of more than $2 billion, and a stunning portfolio of filters, antenna control, switches and amplifiers - be they GaAs or CMOS - the new company is primed to capture market share in mobile devices, network infrastructure and defence markets.

As RFMD's Bob Bruggeworth – now chief executive of the new business – puts it: "We bring under one roof all the critical RF building blocks necessary to simplify handset and equipment design, reduce size and conserve power while improving system performance. The new company will be a leader in the technologies that are at the heart of what makes mobile, mobile."

And clearly investors and shareholders agree. Amid speculation that the pairing is TriQuint's response to activist investor Starboard Value's suggestion it restructures its mobile power amplifier business and focuses on networks and defence, both RFMD and TriQuint shares have soared. So what next?

Regulatory approval will take three to six months. And as TriQuint's James Klein tells *Compound Semiconductor*: "We're forming an integration team, from both sides of the companies, that will have to really drive integration... and we will be able to pick the best from each company as we drive this together."

News of the RFMD-TriQuint merger saw shares spike but now industry waits to see what will happen to each company's fabs. [RFMD]

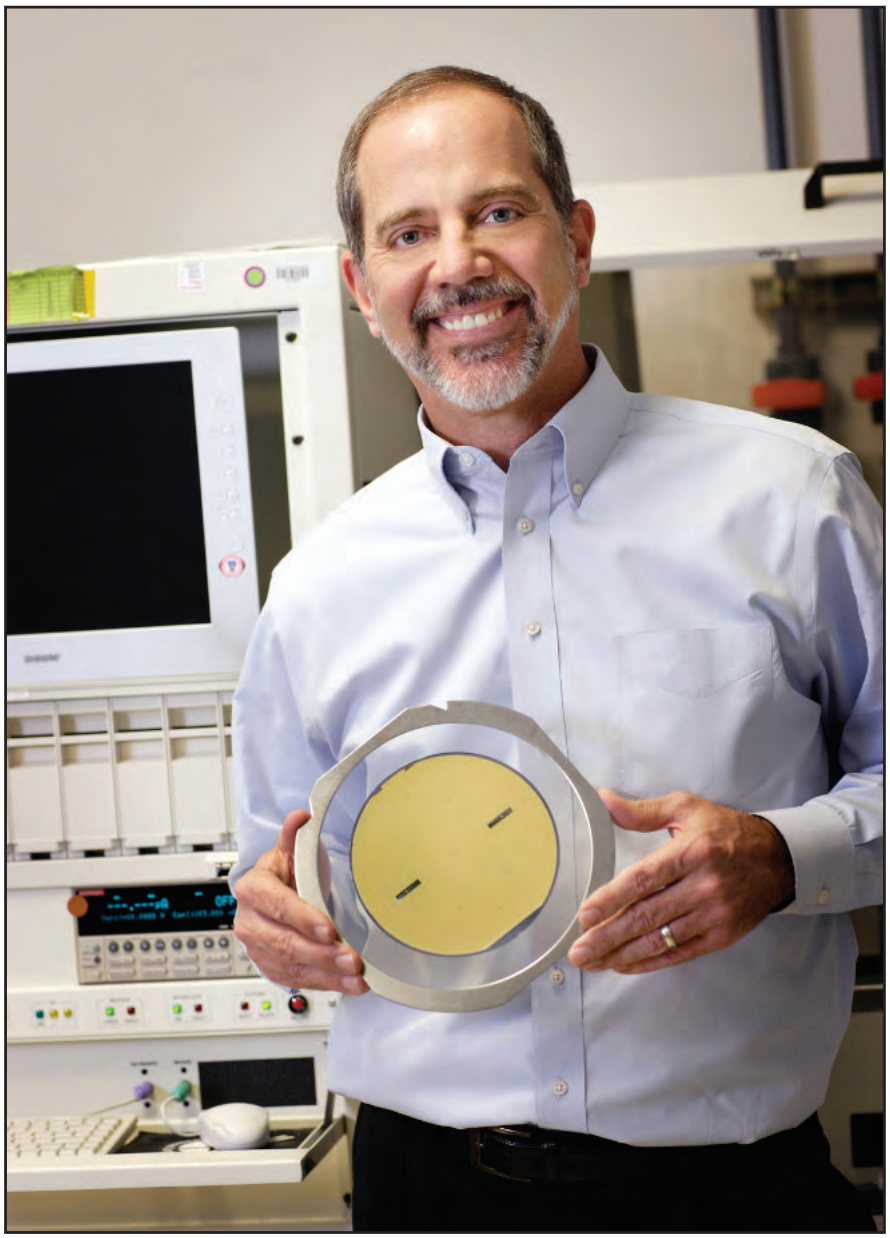
Indeed, in a post-merger announcement conference call Bruggeworth talked about 'blending roadmaps' while TriQuint's Ralph Quinsey emphasised the new company's 'fairly awesome R&D team' twinned with a new-found manufacturing scale, all of which add up to an 'industry-shaping transaction'.

The rhetoric is compelling but clearly headcount reductions come first. According to Bruggeworth, the next three to six months will see each business focusing on closing its company with factory rationalisations coming in at the tail-end of this.

And as Klein confirms: "We've been pretty public in that we have more capacity than the industry needs today. We will be rationalising our GaAs capacity now but this isn't necessarily the case for our filter capabilities and some of the other technologies. But for GaAs, we will have to go through a process of how to scale back our footprint."

In the short-term, Eric Higham from Strategy Analytics believes integration of operations for the RFMD acquisition will be a challenge, as it is for any such deal.

"The companies are talking about a pretty quick integration path but the jury is out on when we will see the results of this process, and facility integration and rationalisation," he says. "TriQuint has just been through the process of replicating foundry capabilities from Oregon to its Texas facility, so they would seem to have a handle on this, but then again... you just don't know how much of a challenge this will present."



TriQuint's Ralph Quinsey (above) and RFMD's Bob Bruggeworth have emphasised the manufacturing scale the merger will bring. [TriQuint]

Assuming swift success, Higham reckons the merger of the two RF chip heavyweights could trigger further industry consolidation. "This could force other companies in the GaAs space to think about consolidation, just from concerns over scale... the scale of the top two companies could limit the size of a second source opportunity," he says.

Indeed, in the recent conference call, both Bruggeworth and Quinsey reiterated the sheer research, manufacturing and product scale their combined companies bring to an industry desperate to meet today's mobile data growth.

"This market is going towards dense RF integration and the suppliers that aren't able to integrate in terms of performance, size and scale will be left not having the right products for sale," says Bruggeworth. "Phones are getting much more crowded and so our roadmap is going towards dense RF integration."

Bruggeworth's words are backed by the recent RFMD launch of RF Fusion, described as a complete front-end solution for global 4G phones and tablets. As the future RFMD-TriQuint company chief executive emphasises: "We're bringing all these features into a small package, it's a full system and that's how we see the industry going."

Industry change

But what does the merger mean to other RF industry players? Higham expects the yet-to-be-named RFMD-TriQuint combo to lead the sector in terms of GaAs and total revenue, jumping ahead of Skyworks, currently at pole position. Meanwhile Avago will remain the fourth largest GaAs manufacturer.

"Avago is a diverse technology company with focuses in many other markets – optical LEDs, automotives – and here, where TriQuint and RFMD don't participate strongly, I see little change," says Higham. "But in the RF space, Avago has concentrated on cellular power amplifiers and will face the issue of scale [following the RFMD-TriQuint merger]."

Higham also believes outsource foundries such as WIN Semiconductor will be eagerly watching the new company's moves in coming months.

"Will the inevitable rationalisation of foundry resources hurt them as there is more captive foundry capability or will the new company decide outsourcing is the best way to go?" he asks.

And then there's the impact on rival infrastructure and defence businesses, such as Hittite, Aeroflex and MA-COM.

According to Klein, the merger is creating a $500 million 'leader' in these sectors that will, for example, bring in RFMD's SiGe technologies to TriQuint's existing defence and infrastructure strengths.

"We will have a very broad portfolio to address big product areas such as the radar business in defence and next generation optical drivers for fibre networks. This really does drive significant scale for us and will make us even more competitive," he says.

While only time will reveal the true impact of the merger's scale, Klein claims "the first 24 hours have looked really great".

"I'm excited about the scale, the technology and also the limited overlap RFMD and TriQuint has on the defence and infrastructure side," he adds. "I think we're going to make a very powerful combination."

A FUNDAMENTAL QUESTION faced by all the makers of GaN chips is this: What substrate should I use for the foundation of my device?

If lasers are being made, there is only one option: A GaN substrate must be used, because this is the only platform that enables the growth of very low defect density epistructures required to form a working device. But for the makers of LEDs, power electronics and RF devices, this native platform is often ruled out, due to its limited availability, small size and high cost – a 2-inch GaN substrate can sell for thousands of dollars.

For these chipmakers, there are three common substrates to choose between: sapphire, SiC and silicon. Sapphire is the first choice for LED manufacturers, thanks to its relatively low cost and transparency, but its poor heat spreading capability has encouraged many developers of power and RF electronic devices to build their devices on SiC or silicon. Of these two, SiC has the superior thermal conductivity, but it is far more expensive. So several firms are

GaN-on-silicon gathers momentum

In the RF and power electronic sectors, a silicon foundation is a great way to increase the competitiveness of GaN devices

RICHARD STEVENSON REPORTS

working within the thermal limitations of silicon, dealing with its significant lattice and thermal mismatches with GaN, and using this to foundation to develop power and RF devices. This approach may not be easy, but the rewards include wafer processing in depreciated 150 mm and 200 mm lines, which open the to the door to manufacture of very competitively priced products.

Such devices were discussed in a talk given by Philip Roussel, an analyst at Yole Développement, at the recent CS International conference. He is anticipating tremendous growth for all forms of GaN RF and power devices, including a ramp in shipment of products built on a silicon foundation.

Roussel believes that the RF GaN market is current valued at $224 million, should increase at a compound annual growth rate of 15 percent between 2015 and 2020, and is expected to be valued at $565 million by 2020.

Meanwhile, the GaN power electronics market will rocket by a compound annual growth rate of 91 percent over that time frame, blossoming from just $24 million next year to $600 million by the end of the decade. And sales of GaN-on-silicon wafers for power electronics market, which were worth just $2 million in 2010, should grow to $18 million this year and by 2020 will be valued at $318 million.

Some of these GaN-on-silicon epiwafers will be grown in-house, while others will be produced at external foundries.

Roussel weighed up the pros and cons of both approaches. He pointed out that firms buying in their epiwafers benefit from not having to invest in expensive MOCVD tools, while still being able to make products that differ from their competitors, due to differences in front-end steps and device design. However, companies that are fully integrated have the advantage of full control of their intellectual property, but to do this they require strong research and development efforts to bring their products to market, due to the need to develop both a growth process and a device.

Vertical integration

One of the pioneers of the fully integrated approach is the power electronics giant International Rectifier. At CS International, Mike Briere detailed the company's development of GaN-on-silicon power devices on large diameter substrates.

"Ten year's ago we realised that silicon was running out of gas," revealed Briere, who explained that back then the company was considering a wide range of other materials, including carbon nanotubes and diamond.

The conclusion of this quest for a new material that would combine superior performance with the ability to satisfy the demands of the market was that GaN would lie at the heart of the next generation of power devices.

At that stage, the development team did not know whether threading dislocations would be an issue, whether GaN-on-silicon could be cost effective, or whether it was possible to carry a high enough current in the two-dimensional electron gas.

With the benefit of hindsight, it is clear that these issues have been addressed, and that the engineers at IR have made much progress: the breakdown voltage for III-N epiwafers has increased from 50 V to more than 1kV; the process for producing crack-free epiwafers has been extended from a 1 μm-thick film on 100 mm silicon to a 5 μm-thick film on 200 mm silicon; yield has rocketed from below 1 percent for devices with a gate width of 1 mm to more than 80 percent for a HEMT with a gate width of around 1 m; saturation current has rocketed from typically 300 mA to in excess of 300 A; and dynamic on-resistance, which can overshadow the static on-resistance, has been slashed from more than 1000 percent to less than 10 percent. What's more, the reliability, determined by a 480 V bias stress, has lengthened from a minute or so to more than 10,000 hours.

All these gains have enabled IR to transfer its processes used to develop GaN-on-silicon HEMTs to a high-volume 150 mm production line. The devices

EpiGaN's development of GaN-on-silicon wafers for RF and power electronics products is led by co-founder and CEO Mariane Germaine.

are formed with compositionally graded AlGaN layers, which bridge the different in lattice constants and address the thermal mismatch between GaN and silicon. This epitaxial technology is protected by a strong patent portfolio, which includes intellectual property acquired from Nitronex.

During his presentation, Briere also revealed the requirements for a commercially viable 600 V HEMT, which include an epiwafer cost of below $3 cm^{-2}, so that it is comparable to that for silicon. Other requirements are a current leakage of less than 0.1 μA/mm, an I_{on}/I_{off} ratio greater than 10^6, a current handling capability of more than 350 A cm^{-2}, and a bow across a 150 mm epiwafer of less than 20 μm.

Additional requirements include a manufacturing process that realises a yield of more than 80 percent for 10 mm^2 devices, which would have to be produced in lines capable of running tens of thousands of wafers per week, in order to support market demand. What's more, the GaN device would have to outperform the silicon equivalent, in terms of cost, by a factor or at least two-to-three.

“If the makers of GaN RF and power devices wish to outsource the MOCVD deposition process, they can consider turning to epiwafer provider EpiGaN. This imec spin-off is just starting a capacity expansion programme, and is currently offering 150 mm GaN-on-silicon wafers for high-voltage products, plus GaN-on-silicon and GaN-on-SiC wafers with diameters of 75 mm and 100 mm for RF products.”

IR is focusing on these targets. Using standard silicon substrates, it is capable of producing 150 mm epiwafers with a warp below 20 μm – and 200 mm versions, which will be used when 150 mm lines are no longer commonplace, that have a warp below 40 μm. The ratio of I_{on}/I_{off}, for a 30 V HEMT with a gate width and length of 850 mm and 0.3 μm, is greater than 10^{12}, while the leakage is below 100 nA; and the breakdown voltage for its 600 V device is more than 1.4 kV. “That’s not overly designed – that’s properly designed,” claimed Brier, who argued that devices should operate at half their critical field or less to ensure excellent long-term performance.

Ommic CEO Marc Rochi believes that GaAs does not have a role to play in the high-frequency RF markets of tomorrow. The company is developing a 100 nm GaN process, using epiwafers supplied by EpiGaN.

To form a normally off device, engineers at IR pair the normally on GaN transistor with a silicon diode to create a component with a far lower reverse recovery than a silicon switch. The penalty to pay for this is a decline in performance, but this falls by less than 10 percent.

Even with this reduction in performance, the 600 V cascaded GaN device still delivers a far better performance than a best-in-class silicon super-junction FET from 2012: for a DC-to-DC converter with a 300 V input, 30 V output and a 400 kHz switching frequency, the wide bandgap device delivers a 17 percent gain in efficiency at 10 percent load and a 3 percent improvement in efficiency at full load.

Briere also compared an IR GaN device with a silicon IGBT, considering conditions of a power of 400 W at 6 kHz. Losses for the IR device were below 4 W at 2 A, making it three-to-four times as efficient as the silicon equivalent. What’s more, the GaN device does not require a heat sink, and takes up one-tenth of the volume of the silicon IGBT.

Outsourcing

If the makers of GaN RF and power devices wish to outsource the MOCVD deposition process, they can consider turning to epiwafer provider EpiGaN. This imec spin-off is just starting a capacity expansion programme, and is currently offering 150 mm GaN-on-silicon wafers for high-voltage products, plus GaN-on-silicon and GaN-on-SiC wafers with diameters of 75 mm and 100 mm for RF products.

Speaking at CS International, co-founder and CEO Marianne Germain claimed that one of the strengths of EpiGaN is its unique *in-situ* SiN passivation process, which trims the dynamic on-resistance and improves device reliability, thanks to optimal surface control. “If the SiN is on top, and the silicon is on the bottom, it’s very close to what the silicon industry knows,” explained Germain, who has worked with colleagues to ensure that the start-up’s epiwafers are suitable for processing within the silicon industry.

EpiGaN, like IR, has one eye on the future, having already developed growth processes for 200 mm silicon. These epiwafers are suitable for making high-voltage devices and have a SiN cap thickness uniformity, in terms of a standard deviation, of 1.7 percent for a 39 nm-thick film; while the 24.4 nm-thick barrier in this structure has a standard deviation of just 0.7 percent.

For RF devices on silicon, EpiGaN is combining an AlN barrier that maximises polarisation charge with its *in-situ* SiN deposition process. Germain claimed that with this approach it is possible to control surface charges and stabilise the highly strained barrier. By exceling in these areas, devices benefit from a high electron-mobility and the absence of leakage through the barrier.

One of EpiGaN’s epiwafer structures involves a 3 nm-thick SiN cap and a 6 nm-thick AlN barrier. This leads to a sheet carrier density of 2×10^{13} cm^{-2} and a mobility of 1250 $cm^2 V^{-1} s^{-1}$, and it enables the fabrication of devices with a transconductance of 600 mS/mm. Values

for the cut-off frequency and maximum oscillation frequency are 85 GHz and 103 GHz, respectively.

Working with a supplier

One company receiving shipments from EpiGaN is French firm Ommic, which is developing a 100 nm GaN-on-silicon millimetre-wave foundry service.

Speaking at CS International, Ommic CEO Marc Rocchi explained the rationale for this move: "Gallium arsenide will be dead. So, in our foundry, we are moving from gallium arsenide to gallium nitride." Rocchi argued that the migration from GaAs to GaN allows an increase in the operating voltage of the device, which is turn leads to higher operating frequencies.

Ommic has chosen to work with GaN-on-silicon, rather than GaN-on-SiC, because this material can be sourced within Europe. Even though the thermal conductance of silicon is not as good as SiC, it is still about three times higher than that of GaAs, and is thus suitable for making devices producing up to 20 W.

The engineers at Ommic are looking to replace all their GaAs processes with GaN-on-silicon for frequencies up to 100 GHz, while cutting the cost per unit area. The first step towards this is to replace a 135 nm GaAs power process, D01PH, with a 100 nm GaN-on-silicon process called D01GH.

With the D01GH process, the ohmic source and drain contacts are added by MOCVD re-growth of heavily *n*-doped GaN, which is covered with a Ti/Pt/Au stack. These regrown ohmic contacts – which enable a high transconductance in devices that can also feature a 'mushroom' 100 nm or 60 nm gate – have, according to transmission line measurements, resistances of just 0.17 Ωmm between the metal and two-dimensional electron gas, and 0.02 Ωmm between the metal and *n*-doped GaN. Devices resulting from these processes have a source-to-drain current of 650 mA/mm, a maximum transconductance of 600 mS/mm, values for f_T and f_{max} of 100 GHz and 180 GHz, respectively, and a saturated power output of more than 2.5 W/mm at 30 GHz.

Rochi believes that this should enable GaN-on-silicon devices to replace those made from GaAs and InP in applications requiring 1 W at 94 GHz, 6 W at 45 GHz and 12 W at 30 GHz.

Efforts by engineers at Ommic, as well as those at EpiGaN and IR, will help to drive growth in the sales of GaN-on-silicon devices for power and RF applications. And if Roussel from Yole Développement has his market prediction correct, revenues will rocket throughout the remainder of this decade.

Cost-competitive CPV

Increasing cell efficiencies, trimming material costs and replicating manufacturing processes employed in the LED industry could cut CPV's electrical generation costs to below those of silicon

RICHARD STEVENSON REPORTS

THE CONCENTRATING PHOTOVOLTAIC (CPV) industry is in poor shape. A sharp decline in the price of silicon cells and the failure the thin-film pioneer Solyndra have scared away investors in all emerging solar technologies, and led to the death of many makers of CPV systems and their components. Big names to fall by the wayside include the US firms GreenVolts and SolFocus, and many smaller outfits have fared no better, including UK start-up Circadian Solar that has just shut its doors.

Given this sorry state of affairs, and the combination of a rail strike and gloomy skies, it would not have been surprising to see many glum faces at *Advances in Photovoltaics*. But that was certainly not the case: optimism permeated throughout this meeting.

During this conference on 5 February at Imperial College London, several speakers began their talks by highlighting the encouraging report from market analyst GTM Research, which suggests that CPV should fall from $3/W in 2011 to below $1.2/W by the end of this decade, a decline that is large enough to make this technology competitive with other forms of photovoltaics.

Bringing down the cost of CPV will hinge on the introduction of cheaper, more efficient multi-junction cells and lower-cost modules and tracker systems. Several options are available for succeeding in all these endeavours, and some were outlined at the meeting: Andy Johnson, director of CPV technology at the global epiwafer provider IQE discussed approaches to bringing down chip costs; Geoff Duggan, CTO at module developer Fullsun Photovoltaics outlined the cost-savings that could be realised by switching from robotic-heavy processes to those used in the LED sector; and several speakers from academia and industry detailed modifications to cell architecture that could catapult efficiencies to 50 percent and beyond.

Today, IQE, a company with around 90 multi-wafer MBE and MOCVD tools, nets four-fifths of its sales from wireless products.

Right: Some makers of CPV modules are adopting a similar approach to automakers by employing robots for many manufacturing steps. A switch to a manufacturing process that is similar to that used in the LED industry could enable a reduction in capital expenditure by a factor of up to ten.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By 2020, CPV systems could deliver lower generating costs than those based on silicon, according to GTM Research

So why is it interested in CPV? Because, according to Johnson, the potential sales are huge. He pointed out that installations of PV are rising, should hit 50 GW by 2015, and if CPV captures just a tiny fraction of that market, it will equate to many, many wafers – just 1 GW of power from CPV will require the production of approximately 300,000 6-inch wafers. "In terms of wafer volumes, a small proportion of the global solar market will be bigger than the entire III-V market of today."

IQE has two keys roles to play in the CPV industry: bringing down costs and increasing efficiency.

To cut costs, the company is promoting growth on larger substrates. Johnson argues that if an epiwafer foundry performs deposition of multi-junction cells on state-of-the-art, multi-wafer tools, savings result from a combination of lower cost-of-ownership, a longer campaign length between maintenance breaks and higher yields.

Today, the conventional multi-junction cell is formed by depositing (In)GaAs and GaInP on germanium substrates. This foundation is available in 6-inch and 8-inch formats, but the latter, which is not an established product, is very expensive. Note that it is possible to accommodate both sizes of substrate in the latest multi-wafer tools, such as the Aixtron 2800 G4: this MOCVD reactor is capable of housing eight 6-inch wafers or five 8-inch wafers.

Cost savings can also result from depositing layers at faster growth rates, because this boosts the throughput of the reactor. IQE's process engineers have succeeded in increasing MOCVD growth rates while maintaining high crystal quality, and can now deposit InGaAs and GaInP epilayers on germanium substrates at 15 μm/hr and 5 μm/hr, respectively. The company is targeting a growth cycle time of 90 minutes, and has long-term ambitions to eventually shortening this to just an hour.

Commitment to providing the CPV industry with state-of-the-art chips is highlighted by IQE's seven-year exclusive manufacturing agreement with US multi-junction cell provider Solar Junction. IQE is to provide all the epitaxy for the US firm, and is also supporting efforts to get the cells qualified for use in space.

Growing the epilayers for Solar Junction's cells presents new challenges for IQE, due to the insertion of a lattice-matched dilute nitride rather than germanium for the bottom junction. This switch to a quaternary cell ups the output voltage from around 3.2 V to 3.5 V, and is the key to the company's record-breaking triple-junction cells. What's more, this device architecture offers a promising path to four, five and six junction cells with ever higher efficiencies.

Development of these novel devices at Solar Junction involved growth by MBE. This is the starting point for IQE. However, the company is considering whether it is better to deposit the dilute nitride by MBE before growing the remaining layers by MOCVD – and ultimately, whether it is possible for MOCVD to form the entire structure.

Taking the strain

Introducing dilute nitrides is by no means the only option for modifying the conventional triple-junction cell so that it can reach higher efficiencies. Another way forward, detailed by Ned Ekins-Daukes from Imperial College London, is to turn to strain-balanced layers for each cell. These can all be lattice-matched to the substrate.

This approach has been pioneered by researchers at Imperial College, and led to the launch of spin-off company Quantasol, which was acquired by JDSU in the summer of 2011. Success by the start-up included a world record efficiency of 28.3 percent for a single-junction cell, which laid the foundations for JDSU's construction of a triple-junction cell operating at 42.5 percent. This featured optimisation of absorption and current matching.

In addition to highlighting these record-breaking cells, Ekins-Daukes outlined various opportunities to reach efficiencies of 50 percent or more. He claimed that it is possible to realise a 50.1 percent efficiency with a four-junction cell based on bandgaps of 1.99 eV, 1.55 eV, 1.15 eV and 0.66 eV.

According to Ekins-Daukes, fabricating a cell with a bandgap close to 1 eV presents the biggest challenge. If InGaAs were employed, this layer would be relaxed and riddled with threading dislocations that drag down the output voltage and impair efficiency. However, it is possible to overcome this issue by growing the structure upside down, before turning to wafer bonding and substrate removal processes.

Alternatives for a 1 eV layer are dilute nitrides and dilute bismides. Echoing the thoughts of Johnson, Ekins-Daukes said that MBE is the superior growth method for depositing dilute nitrides, but dilute bismides, such as GaAsBi – which are also lattice-matched to GaAs – can be deposited by both MBE and MOCVD. Another option for realising absorption

“Geoffrey Duggan, CTO of Fullsun Photovoltaics argued that those firms that have built production lines with robotic processes, such as market leader Soitec, should continue on that path. However, he advises newcomers to try and adopt the assembly methods used in the microelectronic and optoelectronic industries. This means using surface mount components and turning to smaller cells.”

at around 1 eV was discussed by Tony Krier from Lancaster University: Add GaSb quantum dots to a GaAs solar cell. He and his co-workers have pursued this, fabricating cells with a ten-layer stack of GaSb nanostructures. They form rings rather than dots, with outer and inner diameters of around 23 nm and 10 nm.

Photoluminescence measurements reveal a peak associated with the GaSb rings at 1.4 μm. However, the associated gains in increased spectral coverage come at the expense of a decline in the open circuit voltage at one sun from 1 eV to 0.6 eV. Krier blames this on the trapping of holes, which then act as recombination centres. Encouragingly, increasing concentration from 1 sun to 2500 suns boosts the open circuit voltage to around 0.9 eV. What's more, the addition of the GaSb rings produces a 6 percent gain in short-circuit current to 27.9 mA cm^{-2}, indicating that these nanostructures may be able to deliver an increase in cell efficiency.

Switching to InAlAs/InGaAs multi-junction cells with a lattice constant close to that of InP offers yet another opportunity for increasing device efficiency. Donagh O'Mahony from University College Cork is pursuing this. He explained that the efficiency sweet spot is at 5.80-5.81 Å, so it is nearer to the lattice constant of InP (5.87 Å) than that of GaAs (5.65 Å). Manufacturing devices on InP is not viable, however, argued O'Mahony, because chip costs would be prohibitively expensive. Instead, he believes that engineers must start with a GaAs substrate and employ multi-stage grading layers.

The promise of these novel devices is yet to be fulfilled. Initially the single-junction cells that had an alternative lattice constant and were grown on GaAs had an efficiency of 6-7 percent, compared with 12.8 percent for those formed on InP. This difference is partly due to a fall in output voltage by up to 0.3 eV. It is also worth noting that even the cell on InP falls short of what should be possible – O'Mahony claims that greater than 20 percent efficiency is to be expected.

Mirroring LED production

Another area where there is room for cutting costs is the manufacturing approach for making the modules. According to Geoffrey Duggan, CTO of Fullsun Photovoltaics, today several firms within the industry are using many robots for module manufacture. The capital expense required to build a module production plant is then very high, and this prevents many start-ups from entering the CPV sector, due to the challengers of obtaining finance.

Duggan argued that those firms that have built production lines with robotic processes, such as market leader Soitec, should continue on that path. However, he advises newcomers to try and adopt the assembly methods used in the microelectronic and optoelectronic industries. This means using surface mount components and turning to smaller cells – dimensions of less than 2 mm by 2 mm are recommended.

Several companies, including Fullsun, Panasonic and Semprius, are pursuing this alternative approach that can slash capital expenditure by a factor of five to ten. The latter has developed a module with an output of more than 90 W, which features hundreds of microcells, weights just 6.5 kg, employs a silicone-on-glass lens array and operates at a concentration of 1100 suns.

Given the difficulties of launching a CPV firm today – the collapse of a high proportion of the 50 or more companies formed between 2005 and 2008 has led investors to shy away from this industry – newcomers will need far lower capital expenditure than before to enter this sector.

Winning CPV deployment contracts would be aided by more efficient cells produced at lower costs, but success on all fronts is possible, thanks in part to the efforts of those that attended *Advances in Concentrator Photovoltaics*.

Power amplifiers:

Silicon CMOS will slowly weaken the vice-like grip of GaAs

Speakers at CS International reveal how the introduction of envelope tracking will help silicon CMOS to wrestle a share of the power amplifier market from GaAs

RICHARD STEVENSON REPORTS

IF YOU GO TO CONFERENCES that encompass the entire silicon industry, you may have been taunted by the saying: 'If it can be done in silicon, it will be done in silicon'.

Like many sweeping statements, there is more than an element of truth in this – but there are also discrepancies. While everyone accepts that silicon is a very mature, low-cost semiconductor technology, there are times when it fails to deliver the performance that engineers are looking for. This accounts for the inferiority in its bang-per-buck in some types of device, and explains why the power electronics market, which was once utterly dominated by silicon, is starting to witness growing sales of wide bandgap devices.

The performance-cost equation also explains why mobiles phones are packed full of GaAs power amplifiers, which combine substantial gain with high linearity. But in this market the dominance of GaAs is under threat, due to engineers within the silicon industry getting more out of their power amplifiers with every passing year. Leading the charge are industry heavyweights Qualcomm and Peregrine, which have recently unveiled silicon CMOS components with comparable levels of performance to the incumbent GaAs technology.

Differing perspectives

How the ensuing battle between GaAs and silicon CMOS will unfold was a hot topic at the CS International conference held at the Frankfurt Sheraton Airport

Talks related to handsets front-ends included presentations from Strategy Analytics, Nujira and TriQuint.

Hotel on 18th and 19th March. At this gathering Eric Higham, Director of the GaAs and Compound Semiconductor Technology service at Strategy Analytics predicted growth for silicon CMOS power amplifier shipments over the next few years; Thomas Meier, Vice President of Engineering at TriQuint Semiconductor gave his reasons for why GaAs and silicon can co-exist in the wireless sector; and Jeremy Hendy, Vice President of Sales and Marketing at Nujira, explained how the introduction of envelope tracking is helping silicon CMOS to close its performance gap with GaAs.

Higham began his presentation by reviewing sales in the GaAs market since the turn of the millenium. Worth $2.5-2.6 billion in 1999, this market shot up in value the following year by the largest growth rate ever to top $3.5 billion, thanks to the deployment of fibre networks. According to Higham, the pursuit of greater bandwidth fuelled this growth in GaAs sales, but a “killer application” was never uncovered, leading to lots of “dark fibre”.

When the bubble associated with dot.com boom burst in 2001, the GaAs market entered a period of weaker revenues that persisted throughout the first half of the last decade. “But 2006 saw the dawn of the wireless era,” said Higham, and since then sales have climbed every year, apart from 2009, when revenues were brought down by the global economic crisis. This growth is behind a GaAs device market that was worth $5.3 billion in 2012, and tipped to have grown another 8 percent the following year, according to Higham. Some of this production is performed in house, and some is carried out in pure-play foundries, which have seen a drop in market share by around 9 percent in 2013.

In recent times, GaAs device revenue has been driven by sales to handsets manufacturers: In 2011 this accounted for 55 percent of the market, rising to 59 percent in 2012. And there is no sign of this trend petering out. Although shipments of handsets are rising slowly and should hit 1.8 billion this year, the key statistic is that smartphone sales are increasing and should be in the range 1.1-1.2 billion in 2014. GaAs is in many entry-level, mid-price and top-of-the-range handsets, but its strong credentials are particularly valued in smartphones –

and this is good for the industry, because these devices require a higher GaAs content.

Higham also discussed Qualcomm's RF360 Front End Solution, which was unveiled at the 2013 Mobile World Congress in Barcelona. The RF360 covers all bands and all modes from 700 MHz to 2700 MHz, while boasting features such as an antenna-matching tuner, envelope power tracker and power amp and antenna switch, all in a package with a relatively small footprint.

When Qualcomm unveiled the RF360, share prices of the leading GaAs power amplifier makers nosedived. However, according to Higham, the promise of this all-CMOS front-end is yet to fully live up to its billing. He pointed out that although Qualcomm's product is impressive, it does not cover every band and there are challenges with duplexers. That is not stopping this front-end module from getting tracking in the market place, but its impact is not as fast as one might have expected.

Possibly even stiffer competition for the GaAs power amplifier will come from the Peregine UltraCMOS Global 1. Compared to the Skyworks SKY77729 GaAs amplifier, this device, which features envelope tracking, delivers very similar levels of performance, equipping it with the capability to support high-end smartphones.

However, the Strategy Analytics analyst does not expect CMOS devices to lead to the extinction of the GaAs power amplifier any time soon. "The history of GaAs shows that it is nimble and resilient," argued Higham, who pointed out that with mask sets for silicon costing between $0.5 million and $1 million, it can be expensive to develop CMOS products. What's more, he argued that the move toward higher spectral efficiency favours GaAs. In his view, this combination of factors will enable silicon CMOS to start to erode the market share for GaAs in the handset business, but it will only capture about 10-15 percent of the business in the next five years.

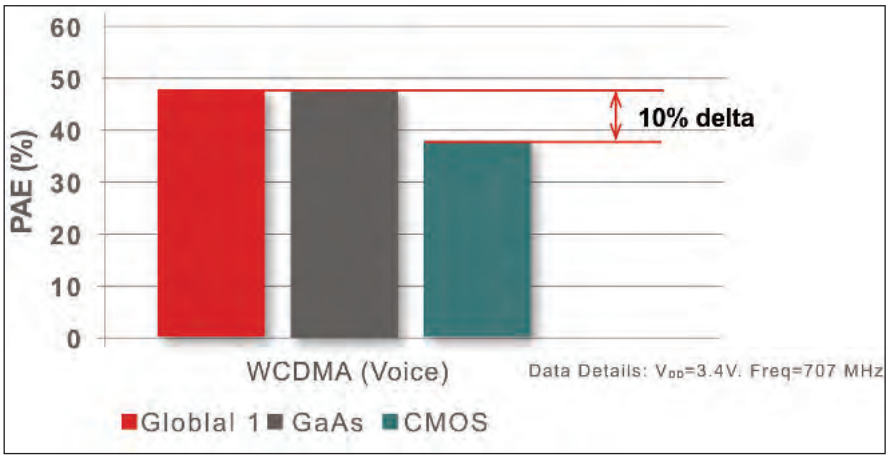
Moving to modules

Meier from TriQuint offered a similar vision to Higham for the future of the power amplifier market. He argued that GaAs should dominate for at least the next three-to-five years, and could even be the incumbent technology

in the middle of the next decade. But he believed that CMOS will grab some market share, due to its ease of integration and recent improvements to its performance.

According to Meier, for transmission at 1950 MHz using WCDMA modulation, a GaAs power amplifier is 5-10 percent more efficient than one based on silicon CMOS. Although this gap can be shrunk by turning to envelop tracking, which can boost silicon efficiency by 5-10 percent – it can be re-opened by applying envelope tracking to the GaAs amplifier.

Meier expects the cellular market to shift to more modules incorporating various materials. For example, a module could contain a GaAs power amplifier, a silicon-on-insulator switch, a CMOS power management chip, and filters based on surface acoustic wave and bulk acoustic wave technologies. If that happens, handset manufacturers will not concern themselves with what material is in the amplifier. "Silicon verses gallium arsenide will not be a question, and we will just use the technology for the best performance."



Peregrine Semiconductor claims that its UltraCMOS Global 1 power amplifier is the first of its kind to match the performance of a GaAs power amplifier.

Tracking performfmance

A more detailed insight into envelope tracking was provided by Hendy, who described the technology as "simple, but difficult." It enables more efficient amplification by replacing a fixed supply voltage with one that varies with the input signal, so that the ideal voltage is used all the time, trimming heat generated by the amplifier.

These gains in efficiency are more important than ever before. Increases in data rates are driven by the introduction of new transmission technologies sporting greater spectral efficiency, thanks to not only using the phase, but also the amplitude, to encode information (in 4G transmission the peak-to-average ratio can be as high as 7 to 1).

This trend has meant that the migration from 2G to 3G, 4G and beyond is pegging back the efficiency of the power amplifier, which in the absence of envelope tracking could be less than 10 percent in a 5G phone with a GaAs power amplifier. Such a low efficiency would result in a very short battery life.

With envelope tracking, this weakness can be addressed: "You can get 2G battery life with 4G performance," said Hendy. But this is only possible by tracking the waveform accurately, which requires fast modulation and thus a bandwidth of 30-40 MHz.

Linearity also improves with the introduction of envelope tracking. One hallmark of a GaAs power amplifier is its high level of linear gain, which can occur for output powers approaching 30 dBm, before sharp compression kicks in.

In comparison, CMOS power amplifiers are plagued by "soggy" compression – gain can be reasonably linear up to 15 dBm, before rapidly declining at higher output powers. This non-linearity is highly undesirable, leading to high levels of distortion.

It is possible to minimise this non-linearity with Nujira's IsoGain envelope tracking linearization. This has been applied to a 4G CMOS power amplifier developed by Peregrine that delivers a mean efficiency of 57 percent – and according to Hendy, more recent designs can be even more efficient.

Increases in gain also result from Nujira's envelope tracking. This pays dividends with a range of data transfer technologies, such as LTE QAM, LTE QPSK, HSUPA and WCDMA, with the latter delivering almost 3 dB more gain thanks to envelope tracking.

In short, Hendy believes that envelope tracking enables CMOS power amplifiers to be competitive with their GaAs cousins. However, based on the presentations given at CS International, it seems that GaAs will remain the dominant technology for some time to come.

Scrutinising VCSELs by SIMS

An advanced form of SIMS identifies dopants, impurities, compositions and thicknesses in various layers of VCSEL structures

BY TEMEL BÜYÜKLIMANLI, CHARLES MAGEE, JEFFREY SERFASS AND JEFFREY KIPNIS FROM EVANS ANALYTICAL GROUP

THE VCSEL HAS SEVERAL advantages over its edge-emitting cousin. Its strengths include a higher modulation speed, on-wafer testing and the emission of a symmetrical emission pattern that is oriented perpendicular to the surface. This form of emission, which is also produced when devices are configured in a two-dimensional array, is ideal for coupling into other optical components.

However, all these merits over the edge-emitting laser come at the expense of a more complex device architecture. With a VCSEL, resonator mirrors have to fulfil two roles: like an edge-emitter, they have to control the extent of optical feedback and light output; but in addition, they also have to be electrically conducting, so that they can aid the injection of carriers from the contacts into the active region.

This set of requirements is often met by forming a stack of semiconductor layers, which have thicknesses that are carefully chosen to create a distributed Bragg reflector (DBR). To produce a high performance VCSEL, the DBR is formed from alternating layers with a sufficiently high refractive index contrast to realise high levels of reflection. Engineers must also ensure that the conductivity of the mirrors is sufficiently high to prevent current injection into the active region from causing excessive ohmic heating.

High-efficiency VCSELs are possible when these mirrors form part of a structure with a high degree of optical and electrical confinement. Such a device may be built from more than 200 layers, some of which can contain grading of both the doping level and the alloy composition. Growth of such a structure is very challenging, so process engineers support their efforts by using a variety of characterisation techniques to uncover

Right: A SIMS scientist places a sample into the SIMS tool.

details associated with the epilayers, such as their thickness, doping and composition. While some approaches can only offer insights into a few of these characteristics, one is capable of delivering a great deal of detail about these structure – it is a variant of secondary ion mass spectrometry, known as Point-by-point CORrected SIMS, or PCOR-SIMS. Pioneered by our team at Evans Analytical Group, this technique can measure layer thickness, composition and doping profile more accurately than regular SIMS, where calibration with respect to alloy composition is not made at every data point (see Figure 1).

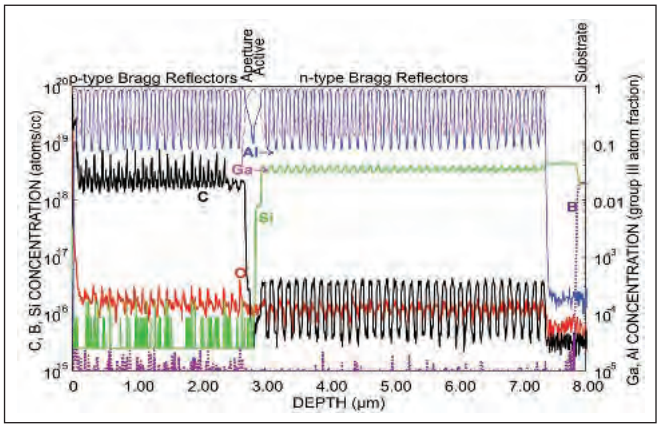


Figure 1. PCOR-SIMS pioneered by Evans Analytical Group can provide a depth profile of a full VCSEL structure. All of the profiles were acquired in a single analysis. Boron profile marks the beginning of the substrate.

Our development of PCOR-SIMS can be traced back to the late 1990s when we were faced with acquiring accurate profiles for both dopants and matrix elements in SiGe materials. Previous to this time, it was commonly assumed that SIMS could not quantify matrix-level concentrations, and there was no way to change dopant sensitivities continuously based on matrix composition (because it was thought that SIMS could not measure matrix composition). While PCOR-SIMS did not require any instrument modifications, many test samples had to be fabricated and analysed by other techniques. These samples formed the basis for the empirical relationships between sensitivity and concentration that are the underpinnings of the PCOR-SIMS methodology. In addition, other techniques, both nuclear and TEM-based, were used to verify the accuracy of the final PCOR-SIMS results.

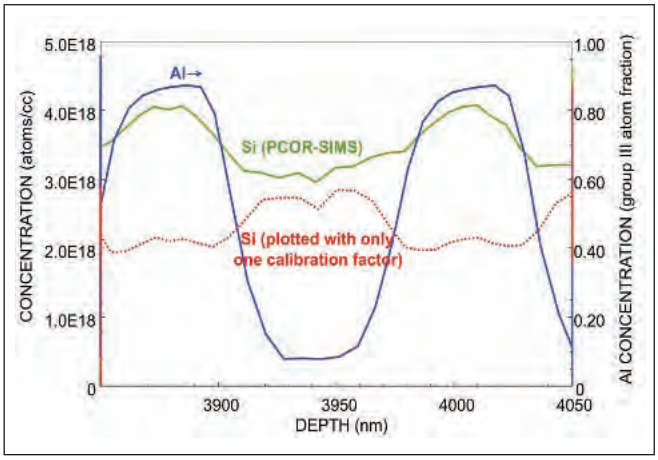


Figure 2. The PCOR-SIMS technique pioneered by Evans Analytical Group is capable of accurate measurements of the silicon concentration, independent of the proportion of aluminium in an n-DBR layer.

One of the biggest challenges associated with the application of SIMS to the analysis of AlGaAs/GaAs VCSELs is that variations in aluminium content impact the sensitivity of aluminium. This means that the quantitative analysis of aluminium content is not straightforward. Complicating matters further, changes in alloy composition affect the sensitivity of the dopant species measured in the depth profile.

PCOR-SIMS addresses these issues by employing empirically derived analytical functions to correct for the well-known 'SIMS matrix effect', which comes into play when one deals with materials that are dissimilar in nature. In addition, this advanced variant of SIMS can account for changes in dopant sensitivity – these can be as much as a factor of two. The difference between traditional SIMS – where a single sensitivity is used in all layers – and PCOR-SIMS is illustrated in Figure 2. This shows the results of attempts to measure the silicon doping profile in an *n*-type DBR.

Perfecting the VCSEL

Producing a very high performance VCSEL requires optimisation of various aspects of the device, including: the aluminium composition and gradient between high and low refractive index mirror layers; the dopant profile between mirror layers; the composition of the aperture layer (assuming it is an oxide-confined VCSEL); the active layer impurity content; the aluminium grading on either side of the active layer; and, of course, the thicknesses of all of the layers within the structure.

An example of a PCOR-SIMS depth profile of a complete VCSEL structure is shown in Figure 1. This particular wafer uses a carbon-doped *p*-type AlGaAs DBR, a silicon-doped *n*-type AlGaAs DBR and an un-doped, low-aluminium AlGaAs active layer with multi-quantum well.

If the DBR is to provide good current injection, it must have a low electrical resistance. Realising this in a manner that produces a good device is not trivial. Large energy band offsets between the low and high index semiconductor layers of the DBR can inhibit current flow, particularly for *p*-type DBRs – and the obvious solution of increasing the doping to trim resistance is not an option because this increases optical absorption.

A far better approach is to grade the AlGaAs composition at the interfaces, while varying the doping profiles at these points. In due course we will show how PCOR-SIMS is uniquely capable of measuring subtle alloy grading and interface doping profiles.

To obtain a high efficiency and low threshold current, the VCSEL has to confine both the carriers and the transverse optical modes. Today, this is often realised in AlGaAs VCSELs through the selective oxidation of an AlGaAs layer, which is near the active layer (this creates so-called 'oxide-confined' VCSELs). One challenge with this design is to control the oxidation of these layers: to form the confining aperture correctly and reproducibly, the composition of the $Al_{0.98}Ga_{0.02}As$ layer must be controlled to 1 percent. Later in this article, we will demonstrate how PCOR-SIMS can aid the wafer grower, by measuring the composition of the AlGaAs layer with sufficient precision and accuracy.

Obviously, another pre-requisite for the successful growth of a VCSEL epiwafer is to accurately control the thicknesses of the many layers that make up a working device. Nowhere is this more important than in the DBR, where the thicknesses must be correct to tailor the optical properties of the mirrors.

However, one must not neglect the importance of obtaining the correct thickness for the cladding and active layers, because this is needed to place the lasing mode optimally with respect to the boundaries of the 1λ-optical cavity. As we will soon see, if the growth engineer turns to PCOR-SIMS, they can correctly measure the composition of each layer, and use this to determine the correct layer thicknesses.

Scrutinising the structure

We have used our novel PCOR-SIMS technique to analyse a VCSEL structure with a carbon-doped *p*-type AlGaAs DBR, a silicon-doped *n*-type AlGaAs DBR and an un-doped, low-aluminium AlGaAs active layer containing a multi-quantum well. In the remainder of this article, we will show how our technique can offer insights into the alloy composition profile, the DBR dopant profiles, and various details associated with the active layer.

As previously mentioned, grading the alloy composition between the low and high index layers can trim the resistance of the DBR. With our PCOR-SIMS technique, it is possible to hone in on this part of the structure – see Figure 3 for a higher-depth-resolution profile of the top 200 nm of the sample – and reveal the compositional grading.

This occurs because the aluminium and gallium are not simply 'switched on or off', but varied in a precisely controlled manner to optimise the optical and electrical properties of the interfaces. Measurements with PCOR-SIMS have determined the aluminium content correctly over the entire range of composition, from 8 percent to 83 percent aluminium. The accuracy of these measurements has been verified against Standard Reference Material 2841 ($Al_{0.1982\pm0.0014}Ga_{0.8018}As$) from the National Institute of Standards and Technology and a Rutherford Backscattering Spectrometry calibrated, multi-composition AlGaAs reference material.

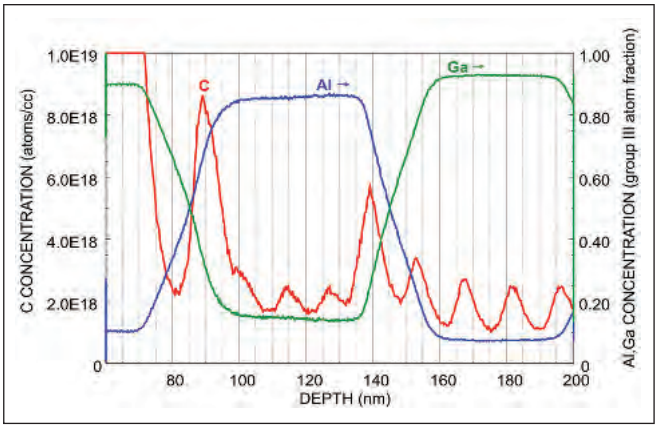


Figure 3. Accurate carbon concentration and depth placement in AlGaAs layers with a graded composition.

Further reductions in the resistance of the *p*-type DBR are possible by doping the mirrors with carbon, which has a sensitivity that is significantly affected by the alloy composition. However, with PCOR-SIMS we can correct for these effects at every data point, because the aluminium composition is measured for every carbon data point. Such an approach uncovers a high-concentration carbon-doping spike in some structures, which is near, but not exactly at, the interface between the low index layer with a higher aluminium content and the high index layer (see Figure 3).

We are confident that the placement of the carbon-doping spike is correct, because all of the profiles were acquired in the same analysis. Note that the low-level carbon dopant peaks may originate from a non-uniformity in doping, while the wafer was rotated during layer growth.

To provide current and optical confinement, producers of VCSELs tend to introduce a high-aluminium-content aperture, which is oxidised from the outside inwards. Halting the process at an appropriate point leaves an unoxidized 'aperture' through which current and light can pass. Obviously, to have a repeatable oxidation process, the rate of oxidation must not vary. This implies that there must be stringent compositional control and uniformity for the AlGaAs layer, because oxidation rates can vary by more than two orders of magnitude when aluminium content is increased from $Al_{0.82}Ga_{0.18}As$ to $Al_{1.0}Ga_{0}As$.

With PCOR-SIMS, the aluminium composition in high-aluminium-content AlGaAs layers, such as those used in forming aperture layers, can be determined with a high level of precision (see Figure 4). In these samples, the difference in aluminium content is only 1.8 percent of the of the Group III composition – or 0.9 percent of total atoms – but the spread

> "Another strength of PCOR-SIMS is its ability to profile unwanted contamination species. The most ubiquitous of these is oxygen, which can produce contamination spikes at the growth transition between the low index and the higher index layers of a p-type DBR."

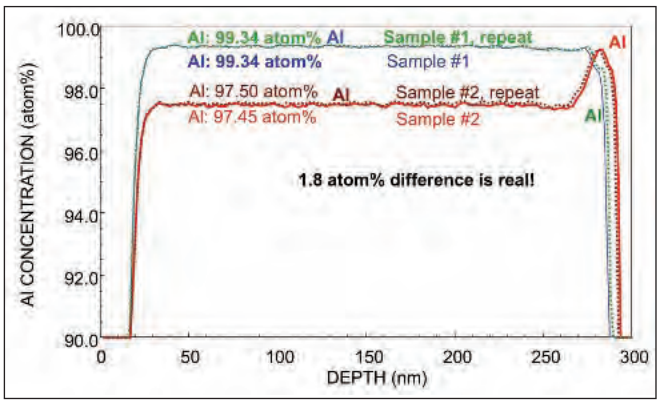


Figure 4. PCOR-SIMS is capable of determining the composition of AlGaAs with high precision.

in the measurement values of either film is much less. This degree of precision is crucial in perfecting these aperture layers.

PCOR-SIMS can also offer insights into the structure of the active region (see Figure 5). It can reveal the aluminium profile, which varies on both sides of the active layer. There is grading from the *p*-type aperture layer, and also from the *n*-type DBR to the cladding layers, where it is followed by a steep drop in aluminium content, which is lower in the barrier layers immediately surrounding the AlGaAs active layer. A detailed picture of the active region is also helpful for assessing whether the lasing mode in the optical cavity is in the optimal position. The profile of the active region in Figure 5 also details the carbon doping for the active region and the mirror pairs nearby. By measuring carbon and silicon concentrations accurately in the *n*-type DBR with PCOR-SIMS, it is possible to determine the amount of *p*-type counter-doping that the inadvertent carbon contamination causes in the *n*-type layers.

Another strength of PCOR-SIMS is its ability to profile unwanted contamination species. The most ubiquitous of these is oxygen, which can produce contamination spikes at the growth transition between the low index and the higher index layers of a *p*-type DBR (see Figure 6). Knowing the exact location of the oxygen spike in the growth sequence is often helpful when

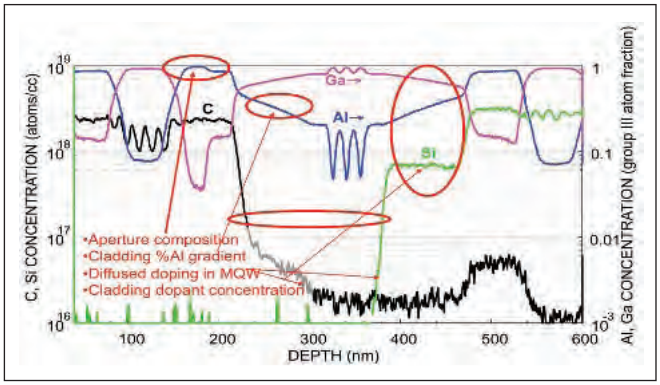


Figure 5. Depth profile of the active region detail: (a) aperture layer composition; (b) gradient in cladding layer aluminium content; (c) cladding layer dopant concentration; (d) diffused doping in a multi-quantum well. Note, the carbon prfile is seen more clearly in Figure 2.

trying to isolate and eliminate the source of contamination.

Occasionally, VCSELs contain sulphur impurities, which are believed to affect performance. The level of sulphur is higher in *p*-DBRs than *n*-DBRs, because it tracks the proportion of aluminium content (see Figure 7). The peak in the upper graded AlGaAs cladding layer is easier to spot in higher resolution reanalysis of the active region (Figure 8).

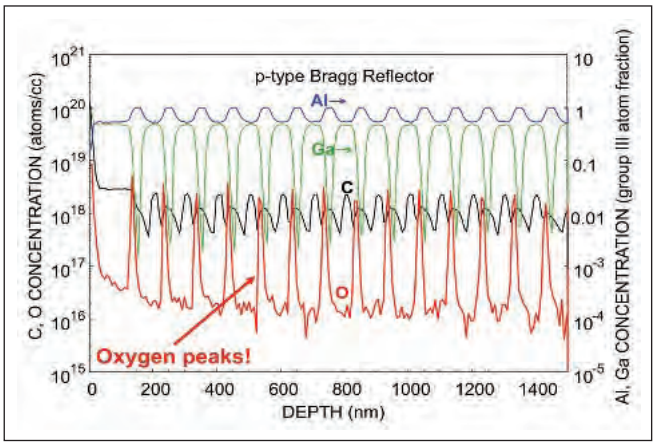


Figure 6. PCOS-SIMS can reveal oxygen contamination spike at DBR interfaces.

Determining the correct layer thickness with conventional SIMS is not easy, because changes in alloy composition alter the sputtering rate at the surface. If no corrections are made, the plotted layer thickness can be in error by 20 percent for an AlGaAs VCSEL (see Figure 9).

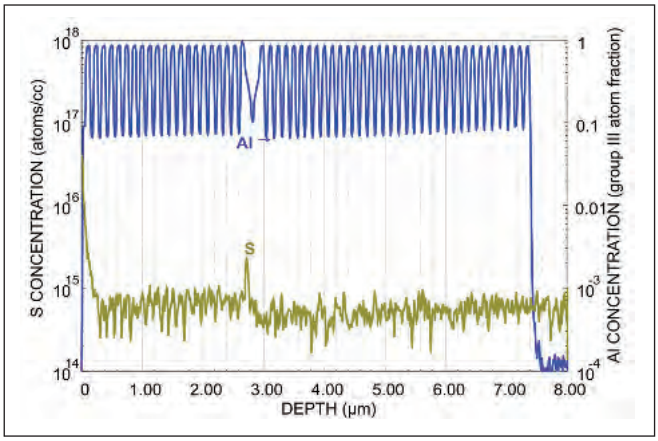


Figure 7. Sulphur impurities, which may degrade VCSEL performance, can be detected in many layers of this VCSEL structure.

With PCOR-SIMS this weakness is addressed with an empirically derived sputtering-rate function. This determines the instantaneous sputtering rate for each data point based on the measured aluminium content – or indium content for InGaAs active layers – for that data point. Armed with this approach, compensation corrections are made for variations in sputtering rate throughout the VCSEL.

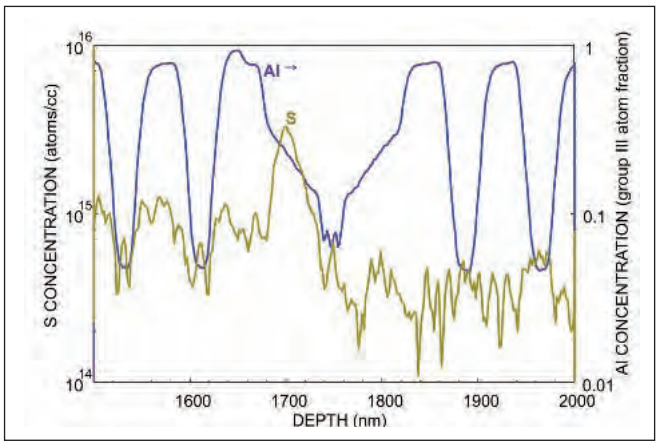


Figure 8. A peaking sulphur impurity is detected in upper AlGaAs cladding layer.

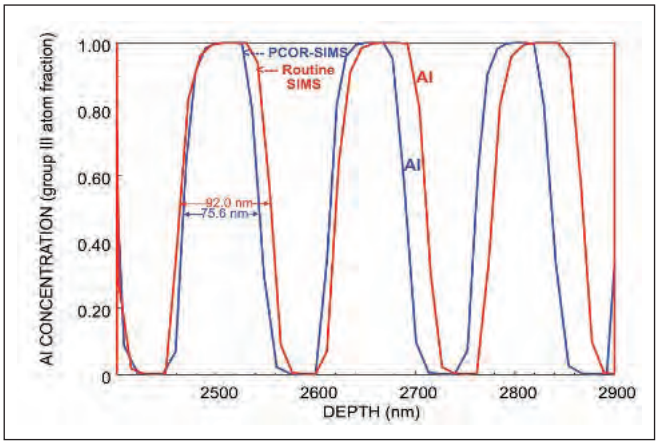


Figure 9. A depth profile of an AlGaAs DBR layer, showing the PCOR-SIMS layer-thickness correction.

Our development of an advanced form of SIMS has opened up the capabilities of this technique so that it is no longer limited to impurity and dopant analyses of semiconductor materials. This effort has enabled PCOR-SIMS to be the most valuable tool for the growers of VCSELs: It can used for various important tasks, including uncovering doping levels in graded layers and delivering precise values for the aluminium composition in AlGaAs aperture layers.

Further reading

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CS MANTECH

2014

INTERNATIONAL CONFERENCE ON COMPOUND SEMICONDUCTOR MANUFACTURING TECHNOLOGY

May 19th – 22nd, 2014

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CSindustry awards2014

The CS Industry Awards 2014 were presented in Frankfurt in front of 300 delegates at the fourth CS International Conference.

The Awards cover all aspects of the industry, and the winners show the diversity and technological excellence of the market.

The question we ask every year is which pioneering companies from around the globe created the best opportunities for the compound semiconductors industry?

This year you voted in your thousands and the winners for 2014 represent the best in class for their category according to the readers of Compound Semiconductor.

The 2014 CS Industry Awards Winners:

Substrates & Materials Award
- **IQE, Plc**
  150mm GaN on SiC
-

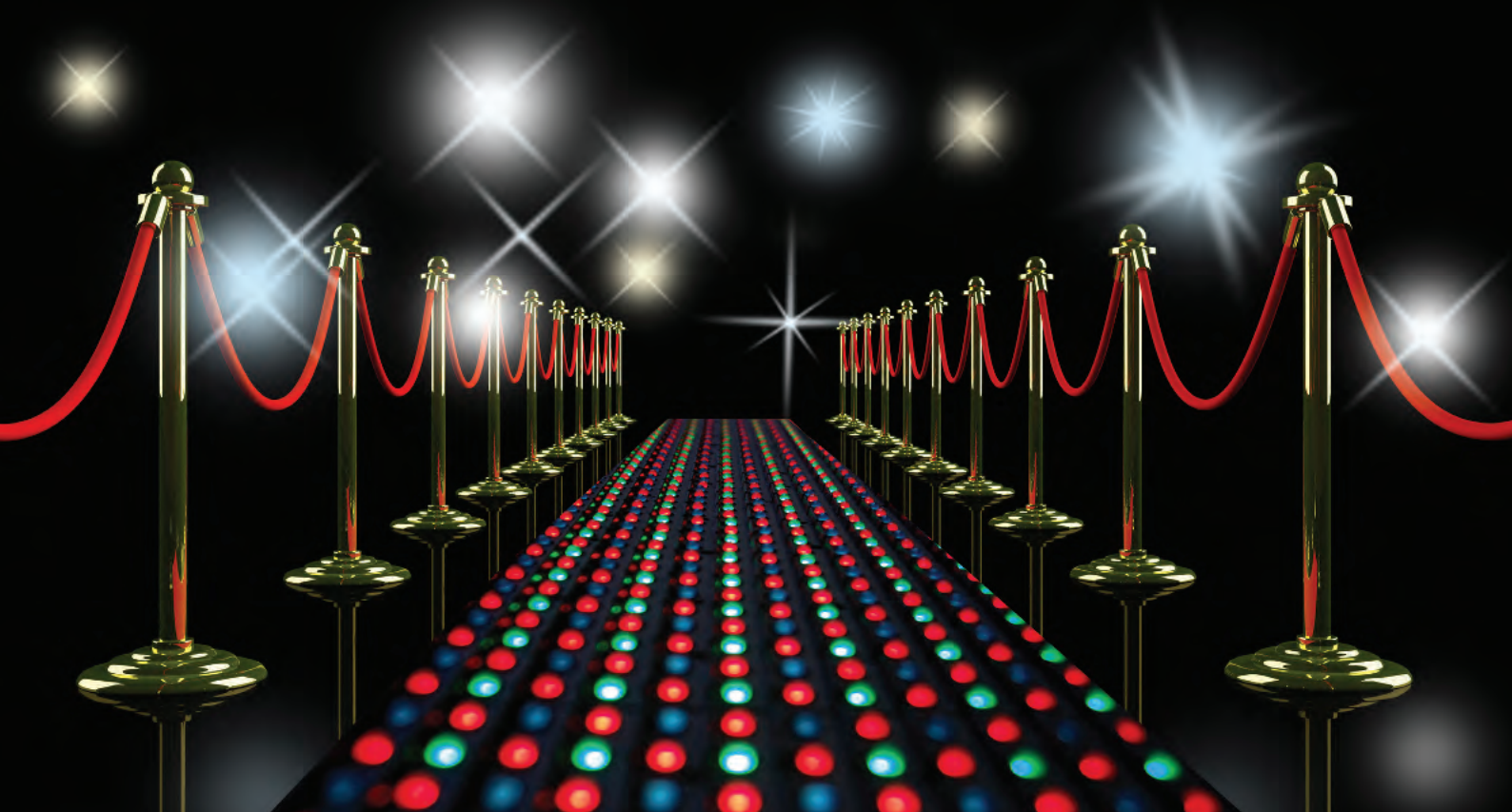
Compound Semiconductor Manufacturing Award
- **EV Group**
  EVG®PHABLE™
- **Veeco Instruments, Inc**
  GENxplor MBE Deposition System

Metrology, Test and Measurement Award
- **Lake Shore & Emcore**
  8500 Series THz System
- **Tektronix, Inc**
  PA1000 Single-phase Power Analyser

Device Design and Packaging Award
- **Cree, Inc**
  45mm SiC Six-Pack Power Module

Most Innovative Device Award
- **Infineon AG**
  Direct Drive for CoolSiC

R & D Award
- **Imec**
  III-V FinFETs



CSindustry awards 2014

WINNER

EVG®

Compound Semiconductor Manufacturing Award

The PHABLE (Photonics enabler)

The PHABLE (for "photonics enabler") is a patented technology that is targeted for low-cost fabrication of periodic nanostructures. PHABLE is a mask based UV photolithography technology, enabling full advantage of existing photo resist and photomask infrastructure. It enables the creation of periodic structures, such as arrays of holes or pillars on a hexagonal or square lattice, or linear gratings over large areas, with high throughput.

The unique feature of PHABLE is the large depth of focus for optical printing. Unlike any conventional proximity, contact or projection lithography technologies, the printed features are independent of the exposure gap over several hundred micrometers. Therefore printing on non-flat surfaces, such as LED wafers, is easily accomplished. The EVG PHABLE exposure system is the first fully-automated production equipment to feature PHABLE ("photonics enabler") technology from Eulitha AG. Integrating Eulitha's full-field exposure technology with EVG's well-established nanolithography production platform provides a unique solution for the automated fabrication of photonic nanostructures.

The EVG PHABLE system combines the low cost-of-ownership, ease-of-use and non-contact capabilities of proximity lithography with the sub-micron resolution of lithography steppers to provide low-cost automated fabrication of photonic patterns over large areas. This makes it suited for patterned sapphire substrates (PSS) or to enhance the light extraction (and thus the efficiency) of LED devices. The EVG PHABLE system broadens the micro- and nanopatterning process portfolio, providing a unique, very cost-efficient solution to customers in the LED, optics and photonics markets. The novel equipment clearly demonstrates the synergies of Eulithas and EVGs respective technologies.

The EVG PHABLE system includes a unique Displacement Talbot Lithography approach, enabling to produce features ranging from three microns down to 200 nm with effectively no depth-of-focus limitation or stitching effects that can arise for steppers on substrates with rather poor total thickness variation. Thus, it can be used to pattern substrates up to six inches in diameter in a single exposure step. This approach also enables the EVG PHABLE system to maintain consistently high patterning throughput independent of the wafer size, as well as maintain very large exposure gaps between the mask and wafer, thereby avoiding process-related mask contamination. The EVG PHABLE system can produce both one-dimensional patterns, such as lines and spaces, as well as two-dimensional patterns, such as hexagonal or square lattices. Thus, it supports a variety of approaches to enhance the light extraction from LEDs. These include LED surface structuring, PSS, photonic crystal applications, nano-wire LEDs and optical gratings. The system can also be configured for photovoltaic, optics or biomedical manufacturing applications. The EVG PHABLE exposure system is designed specifically for the manufacturing of photonic components. Leveraging EVG's expertise in photolithography, the EVG PHABLE system incorporates a contactless, mask-based lithography approach that enables full-field, high-resolution and cost-efficient micro- and nanopatterning.

The unique property of PHABLE is the down to 150 nm printing resolution of regular patterns in a single exposure step. Nonetheless, a mask-substrate separation gap of several tens of micrometers is kept while the image depth can be extended to cover the multiple micrometer thick resist without resolution deterioration. This very high aerial image aspect ratio allows printing of the same high-resolution patterns onto large and highly warped surfaces.

Editor's note:
"LED manufacturers are striving to increase device efficiency through improvements in light extraction. The EVG PHABLE can play a key role in their quest," says Richard Stevenson, Editor of Compound Semiconductor magazine.

CSindustry awards 2014

WINNER

Veeco

Compound Semiconductor Manufacturing Award

GENxplor MBE Deposition System

The GENxplor is a new molecular beam epitaxy (MBE) deposition system developed for university-based compound semiconductor researchers. Starting from a completely new, architectural concept, the GENxplor system records a number of firsts.

The GENxplor packages all elements into a single platform. Combining the growth/process chamber, buffer chamber, load-lock chamber, and the electronics and controls into a single monolithic frame reduces its footprint by 40% compared to similar MBE systems. The system platform is capable of growing on up to 3" wafers with a wider variety of compound semiconductor materials than before including: nitrides, arsenides, phosphides, antimonides, oxides, and novel materials such as graphene. In addition, a modular transfer backbone allows the system to be expanded to add other deposition and metrology technologies.

The GENxplor is able to accommodate more configurations. The process chamber contains new technologies that expand flexibility and capabilities. The system is specifically designed to work with a full complement of bellows-free retractable sources, sources can be maintained, refilled, or changed in isolation from the growth chamber, allowing customers to use the system continuously for years or perhaps even decades without venting. In addition, the single-frame design with cantilevered growth chamber allows users convenient access and easier maintenance. Inside the process chamber, water-cooling is integrated to efficiently remove heat from the system. This reduces liquid nitrogen consumption and lowers the operating cost of the system.

Today's university-based researchers are under more constraints than ever. Funding is hard to obtain, lab space is at a premium, time is limited, and the materials science requires increasingly sophisticated equipment to push into new frontiers. The GENxplor incorporates technologies to increase uptime by 80% or more, reduce footprint by 40%, reduce operating costs by thousands of dollars a year, incorporate other deposition or metrology techniques, and increase usability and improve serviceability compared to competitive systems – all at a reduced capital cost.

The GENxplor is a fully-integrated 3" MBE system designed into a single frame, reducing the footprint by 40%. The only system designed for use with a full complement of bellows-free retractable sources, the GENxplor can be operated by retracting and isolating sources from the growth chamber, increasing uptime. Additionally, differential source pumping allows users to grow in regimes never before possible. Use of water-cooling throughout the system reduces the need for liquid nitrogen, saving money. Finally, the novel construction with a cantilevered growth chamber provides customers with unparalleled access for usability and serviceability.

Veeco is the only company to develop a 3" MBE system fully-integrated into a single platform. The concept of combining the MBE hardware with the electronics and controls to reduce footprint while improving accessibility and serviceability is unique within the industry. Similar MBE systems on the market have three separate modules (MBE hardware, electronics cabinet, and software control computer) with hardware and cabling running along the floor connecting them. Veeco is also the only MBE vendor to offer retractable sources – Knudsen cells that are able to be used at normal working distance from the substrate, retracted behind a gate valve while maintaining electrical connections, and then isolated from the growth chamber for refill and maintenance, all without the use of a bellows (which are prone to failure, potentially resulting in a catastrophic vent of the chamber).

Editor's note:
"I believe that many readers voted for the GENxplor because they understand that university researchers are looking for a tool that is robust, relatively small, and capable of allowing them to carry out their research as quickly and successfully as possible," says Richard Stevenson, Editor of Compound Semiconductor magazine.

CSindustry awards 2014

WINNER

IQE

Substrates & Materials Award

150mm GaN on SiC

IN MAY 2013, IQE launched gallium nitride based; high electron mobility transistor (GaN HEMT) epitaxial wafers on 150mm diameter semi-insulating SiC substrates.

The substrates are supplied by the WBG Materials subsidiary of II-VI Inc.
IQE say that GaN power amplifiers offer superior power capability, efficiency, bandwidth and linearity compared to silicon or GaAs-based technologies. They provide significant benefits in terms of higher performance and lower overall system costs.

GaN-based low-noise amplifiers also exhibit improved robustness, noise figure and dynamic range when compared to incumbent solutions.

In addition, GaN-based transistors can operate at high temperatures, thus reducing system cost, size and weight. As a result, GaN transistors are now established as a leading new technology for a wide range of defence applications.

The 150mm GaN HEMT epi wafer products also enable cost reduction, production capacity and yield improvement, as well as potential for insertion into a wider range of chip fabrication facilities.

To date, commercial market penetration of GaN HEMTs has been limited by the higher cost of epitaxial material grown on 100mm SiC substrates.

GaN HEMT fabrication using LDMOS (laterally diffused metal oxide semiconductor) process lines has been demonstrated by IQE's customers and the firm's 150mm products are compatible with existing LDMOS processing lines that have been made available as a result of the silicon industry's transition to 200mm technology.

Editor's note:
"For amplifiers serving defence applications, engineers want products built from GaN-on-SiC," says Richard Stevenson, Editor of Compound Semiconductor magazine. "There are concerns over the cost of these wide bandgap materials, but IQE's move to 150 mm products will help to address this."

CSindustry awards 2014

WINNER

Lake Shore CRYOTRONICS

emcore empower with light

Metrology, Test and Measurement Award

8500 Series THz System for Material Characterization

THE LAKESHORE 8500 Series THz System for Material Characterization is a measurement platform that provides the materials development community with a fully integrated solution for exploring THz frequency electronic, magnetic, and chemical properties of materials in cryogenic and magnetic field environments. The system features a coherent, variable frequency continuous wave (CW) THz spectrometer from EMCORE and specially designed THz emitter and detector components which offers high spectral resolution THz-transmission measurements of materials in these extreme environments.

Integrated software operates the temperature controller, helium level monitor, superconducting magnet supply, and spectrometer for automated turn-key experimental control.
In the quest to develop high-speed computing, storage, imaging, and communications applications, novel and existing electronic and magnetic materials with favourable high frequency material properties will need to be identified and characterized.

The Lake Shore 8500 Series THz System addresses the challenge of the development community seeking to explore the THz-frequency properties of bulk and thin film semiconductors, organic electronics and oxides. Cryogenic temperatures and high magnetic fields are used to tune the THz-frequency response in order to help elucidate the physical mechanisms underlying the material's electronic or magnetic properties. The continuous-wave THz source offers a more cost effective approach, compared to the more conventional time-domain THz (TDS) spectroscopy, for THz materials characterization. The fully integrated Lake Shore THz system is offered at a cost-point comparable to a stand-alone pulsed-laser source.

The system provides a solution for researchers who do not have the means to build a custom THz characterization system and who lack off-the-shelf software for management and analysis of their experiments. One of Lake Shore's primary objectives was to develop software that was easy to use. The company knew this would be key to adoption – particularly for scientists and engineers who do not consider themselves terahertz experts.

Conventionally, low-temperature, high field THz measurements would be performed by placing a sample in the beam path of an optical cryostat and then painstakingly align the terahertz source and detector onto the sample. Lake Shore, in close collaboration with EMCORE, developed robust THz emitter and detector components that have proven to operate well at liquid helium temperatures and in magnetic fields up to 9 T. In the 8500 Series THz system, fiber-coupled THz source and detector are mounted within the cryogenic environment and in proximity to the sample.

Custom designed optical stages maintain good optical alignment of the THz devices over temperature and multiple thermal cycles. The Lake Shore system uses CW measurements to enable variable temperature measurements of electronic and magnetic materials in two distinct sample types — semiconducting wafers (like InSb or InP) and thin conductive films supported by an insulating substrate (like ZnO/sapphire, graphene on silicon, or 2DEGs). By replacing terahertz time domain technology with less costly, higher resolution CW spectroscopy, instrumentation cost can be reduced by 50 to 75%, opening the technology to a much broader market. These capabilities are provided in a completely integrated platform that has the software to conduct proceduralized experimental methods and reliably analyse the spectral results.

Editor's note:
This terahertz analysis system is a valuable edition to the toolkit of every engineer and researcher looking to uncover the properties of their semiconductor materials," says Richard Stevenson, Editor of Compound Semiconductor magazine.

CSindustry awards 2014

WINNER

CREE

Device Design and Packaging Award

45mm SiC Six-Pack Power Module

CREE'S CCS050M12CM2 is the industry's first commercially available silicon carbide (SiC) six-pack power module in an industry standard 45mm package. When replacing a silicon module with equivalent ratings, Cree's six-pack module can reduce power losses by 75 percent, which leads to an immediate 70 percent reduction in the size of the heat sink or a 50 percent increase in power density.

The new six-pack SiC module unlocks the traditional design constraints associated with power density, efficiency, and cost, allowing designers to create high performance, reliable, and low cost power conversion systems.

When compared to state-of-the-art silicon modules, the SiC 1.2 kV, 50A modules deliver performance equivalent to silicon modules rated at 150A. The efficient switching of the SiC module also allows for significantly less derating than silicon IGBTs. This enables significantly higher frequency operation, which both increases fundamental output frequency and reduces passive component size in applications like motor drives, solar inverters, uninterruptible power supplies, and industrial power supplies. Even when designers simply substitute Si modules with SiC in motor drive applications, the improved performance of SiC reduces power losses, leading to reduced cooling requirements and, in turn, to a reduction in size, weight, complexity, and the overall cost of the power electronics system.

The CCS050M12CM2 six-pack modules from Cree are the industry's first commercially available silicon carbide (SiC) six-pack power module in an industry standard 45mm package and are available for immediate shipping through Digi-Key Corporation and Mouser Electronics.

Editor's note:
"Gains in efficiency in the power electronics sector are more valuable than ever before," says Richard Stevenson, Editor of Compound Semiconductor magazine. "Cree is one of the pioneers, helping to save energy with its SiC power modules."

CSindustry awards2014

WINNER

imec

R & D Award

III-V FinFETs

IN 2013 IMEC successfully demonstrated the first III-V compound semiconductor FinFET devices integrated epitaxially on 300mm silicon wafers, through a silicon fin replacement process.

The achievement illustrated progress toward 300mm and future 450mm high-volume wafer manufacturing of advanced heterogeneous CMOS devices, monolithically integrating high-density compound semiconductors on silicon. The breakthrough enables continual CMOS scaling down to 7nm and below, and also enables new heterogeneous system opportunities in hybrid CMOS-RF and CMOS-optoelectronics.

IMEC believe this is the world's first functioning CMOS compatible III-V FinFET device processed on 300mm wafers an accomplishment which demonstrates the technology as a viable next-generation alternative for the current state-of-the-art Si-based FinFET technology in high volume production.

The proliferation of smart mobile devices and the ever growing user expectations for bandwidth and connectivity will drive the continual need for software and hardware advancements that extend from networks to data servers and mobile gadgets. At the core of the hardware will be new process technologies that allow for more power-efficient CMOS transistors and increased integration, enabling a higher level of functionality. This prompts process technologies that enable heterogeneous devices spanning operating ranges for targeted circuits, maximizing the system performance. During the last decade, transistor scaling has been marked by leaps in process technologies to provide performance and power improvements. The replacement of poly-silicon gate by high-k metal-gate in 45nm CMOS technology represented a major inflection in new material integration for the transistor. The ability to combine scaled non-silicon and silicon devices might be the next dramatic transistor next step ending the all-silicon reign over digital CMOS.

This work could represent an important enabling step. At the finest grain, co-integration of high-density heterogeneous transistors has been challenged by the ability to combine disparate materials and structures while maintaining low enough complexity and defectivity.

IMEC's breakthrough process selectively replaces silicon fins with indium gallium arsenide (InGaAs) and indium phospide (InP), accommodating close to eight percent of atomic lattice mismatch. The technique is based on aspect-ratio trapping of crystal defects, trench structure, and epitaxial process innovations. The resulting III-V integrated on silicon FinFET device shows an excellent performance.

IMEC's research into next-generation FinFETs is performed as part of IMEC's core CMOS program, in cooperation with IMEC's key partners including Intel, Samsung, TSMC, Globalfoundries, Micron, SK Hynix, Toshiba, Panasonic, Sony, Qualcomm, Altera, Fujitsu, nVidia, and Xilinx.

Editor's note:
"Silicon CMOS is finally running out of steam, and higher mobility materials hold the key to maintaining the march of Moore's Law," says Richard Stevenson, Editor of Compound Semiconductor magazine. "Introducing these new materials will not be easy, but the approach that Imec has developed is very promising."

CSindustry awards 2014

WINNER

Innovation Award

Direct Drive for CoolSiC

Infineon's CoolSiC transistor is a normally on JFET device, combining the well known low ohmic performance of high voltage SiC transistors with an extraordinary level of ruggedness since no susceptive gate oxide with questions about interface quality and lifetime is used in the component.

However, the device is normally on and thus, a way to make it familiar with system requirements must be identified. For comparable wide band gap devices like earlier JFETs or today's normally on GaN HEMTs the traditional cascode arrangement is used. This simple concept offers by a series connection of the normally on component with a normally off low voltage silicon MOSFET (the blocking voltage of the MOSFET must exceed the voltage required to block the device) and connecting the gate of the normally on transistor with the source of the MOSFET. The concept can be easily derived from the equivalent circuit of each DMOS today.

However, this concept has some disadvantages like potential dynamic avalanche stress on the MOSFET or limited controllability of the switching slopes. Thus, a modified setup was developed at Infineon, sill being based on the series connection of the two devices, but now controlling each gate separately.

To enable an easy implementation a driver IC was developed to operate the setup. In this mode, the switching is no longer performed via the MOSFET gate, but directly via the JFET. The MOSFET is passive in this configuration and just acts as a safety switch for start up or failure mode in which the original cascode idea is maintained. The concept is called Direct Drive.

The idea deals with the challenge of operating a normally on device safely under modern system aspects and securing lowest losses at the same time. It addresses as well ruggedness problems of competing solutions and requirements from the application with respect to the dv/dt control in PWM operation.
The idea extends the original cascode idea in a way that their negative points are diminished. By disconnecting the gate contact of the normally on JFET from the MOSFET source we can access the main switching devices directly for easy dv/dt control. Furthermore, the MOSFET is no longer switched in each dynamic cycle and thus, no additional MOSFET losses have to be considered. Finally, the MOSFET is not driven in each cycle into avalanche what increases the ruggedness of this circuit.

The novelty of the concept is the extended cascode concept into a direct drive mode which offers a lot of additional advantages and lowest losses combined with high operational stability. Since the control philosophy is integrated into a corresponding driver IC the efforts on the user side is minimized, they can operate the device as they are familiar with from earlier power switches, but taking full advantage from the outstanding performance.

Editoir's note:
"Infineon's engineers have come up with a clever way of getting the best out of their normally on JFET, while giving customers the characteristics that they cherish," says Richard Stevenson, Editor of Compound Semiconductor magazine.

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Are electron-blocking layers always beneficial?

Simulations unravel the interplay between the design of the electron-blocking layer and extent of LED droop

BY Z. SIMON LI AND CHANGSHENG XIA FROM CROSSLIGHT

IF YOU PERUSE the lighting section of a good hardware store, you'll find plenty of bulbs to choose from. Those with the most impressive performance figures will be based on LEDs, which hold the key to higher efficiency, a lifetime of a decade or more and an output that hits its maximum in the blink of an eye. However, the price you'll have to pay may put you off – a 60 W-equivalent from a well-known brand can retail for tens of dollars.

Given this state of affairs, it is clear that prices must plummet before solid-state lighting becomes the obvious choice for everyone. This will require a trimming of the cost of many of the components in the bulb, including the biggest contributor to expense, the packaged LED, which accounts for about half the total bill of materials. To drive this down, chipmakers can improve their manufacturing efficiencies, so the cost of making the devices tumbles; or LED bulb makers can drive the devices harder while maintaining their efficiency, so far fewer are needed.

There is much to recommend the latter option, including the potential to slash costs and shrink the dimensions of the light

engine. However, this pathway is thwarted by a mysterious malady known as LED droop – a decline in device efficiency as the current through the chip is cranked up (see Figure 1). What causes droop is highly controversial, but two of the primary culprits are believed to be electron leakage and a poor hole injection efficiency.

To address these transport-related issues, many groups insert a thin AlGaN layer – called the electron-blocking layer (EBL) – between the multiple quantum well region and the top *p*-contact (see Figure 2). But not everyone does this, because some do not believe that the EBL is beneficial. Their reasoning may be based on some published experimental data, which indicates that LEDs without an EBL perform better than those with it (see for example, the paper from researchers at Gwangju Institute of Science and Technology and Samsung Electro-Mechanics: S. H. Han *et. al. Appl. Phys. Lett.* **94** 231123 (2009)). In addition, experimental reports of the varied effectiveness of EBL have appeared, adding to the controversy surrounding the employment of the *p*-type AlGaN EBL in GaN-based LEDs. So it is now critical to clarify what the role of the *p*-type AlGaN EBL is, and to explicitly answer the question of whether it is useful – and if so, under what conditions.

At Crosslight Software, a leader in compound semiconductor device simulations based in Vancouver and Shanghai, we have sought answers to this question by performing a series of systematic simulations on GaN-based LED structures. This investigation has clarified the physics behind the operation of the EBL in a GaN-based LED.

For this work, we have considered a typical InGaN/GaN LED: a structure with six quantum wells (see Figure 2) and a 20 nm-thick, *p*-doped EBL. To ensure a realistic simulation study, we use our APSYS models to fit a reference device that had an EBL with an aluminium composition of 0.15 (see Figure 1).

Key features of our effort, which ensure that we simulate a realistic device structure, are the inclusion of a polarization compensation factor and a band-offset ratio for the EBL. The polarization compensation factor offers a mechanism for scaling down the ideal theoretical polarization interface charge, and it can account for partial compensation of the polarization charge by defects and other interface fixed charges. Meanwhile, the band-offset ratio provides a means to tune the ratio between conduction band discontinuity and total band discontinuity.

Note that both quantities are difficult to measure experimentally, and making matters worse, the polarization compensation factor may depend on interface quality and growth conditions.

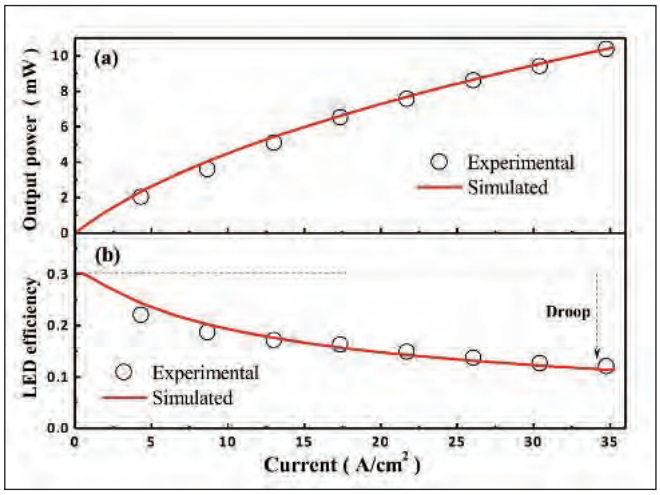

Figure 1. Simulations of the LED using Crosslight APSYS software were fitted to the performance of a reference LED. Plots show (a) light output power and (b) efficiency, which reveals the level of droop in the device.

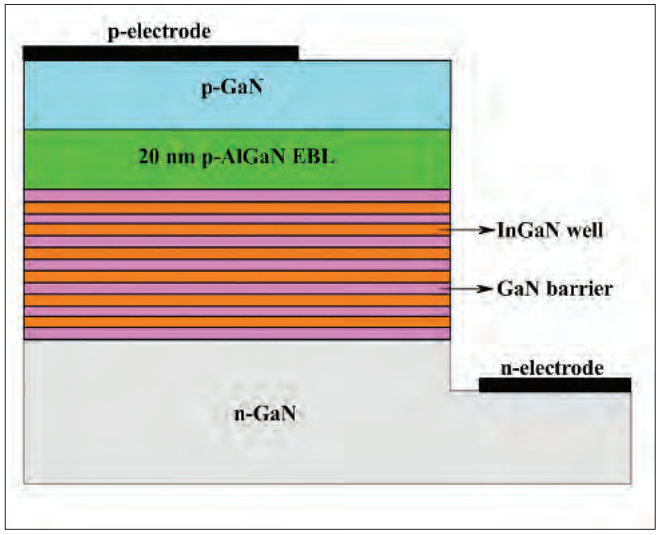

Figure 2. Crosslight simulations considered a six quantum well GaN LED with an electron blocking layer (EBL) on the *p*-side.

It is believed that a reasonable value for the polarization compensation factor is between 0.2 and 0.7, while that for the band offset ratio could span 0.5 to 0.65.

Fitting real data

When we fitted the experimental data, we obtained a polarization compensation factor of 0.3 for all the interfaces and determined a value of 0.5 for the band offset ratio for the EBL (between AlGaN and GaN). To better focus on the impact of the EBL, we then fixed the polarization compensation factor for the entire device, allowing it to only vary at the EBL.

Using a reference value of 0.3 for the polarization compensation factor and 0.5 the band offset ratio, we simulated LED performance for various $Al_xGa_{1-x}N$ compositions to reveal whether the EBL is useful or not. These simulations showed that the output of the LED initially increases with aluminium composition (x) up to a maximum at 0.05, before decreasing continuously thereafter.

At first glance, these results are at odds with experimental findings, which show that the LED with the EBL had poorer performance than the one without. However, the LEDs that had an EBL had aluminium compositions of either 0.22 or 0.32 – values that are not close to the optimal alloy formulation. So we can conclude that the EBL is useful, but only at a small range of aluminium compositions, which were unfortunately missed in the experimental report.

To gain further insights into droop and device behaviour, it is imperative to understand the reasons behind an optimal aluminium composition. We have investigated this, beginning by considering energy band diagrams for LEDs with different aluminium compositions under an EBL polarization compensation factor of 0.3 at 120 A cm^{-2} (see Figure 4).

Improving hole injection

For the LED without an EBL, the energy band within the active region is bent due to polarization charges – and this is to blame for the large electron leakage and poor hole injection efficiency. However, when an AlGaN EBL with an aluminium composition of 0.05 is introduced, an electron barrier forms in the conduction band, with the triangle barrier for holes at the last well/barrier interface pushed upwards by the polarization charges. This leads to an increase in the effective barrier height for electrons from 423 meV to 478 meV, and a corresponding cut in hole barrier height from 299 meV to 267 meV. This explains the suppression of electron leakage and the improvement to hole injection efficiency. These results reflect that as aluminium composition of the EBL increases, there is a rapid rise in the energy of the EBL valence band barrier and a strong polarization-induced downward bending effect. Consequently, the valence band of the EBL becomes the dominant barrier impeding the injection of holes.

This scenario is highlighted by simulations considering an aluminium composition of 0.3 (see Figure 4(c)). In this case, the effective barrier height for holes is increased to 413 meV, while that for electrons falls to 365 meV, even though the EBL conduction band barrier is also increased with higher aluminium composition. A poorer performing LED results, due to the combination of increased electron leakage and inferior hole

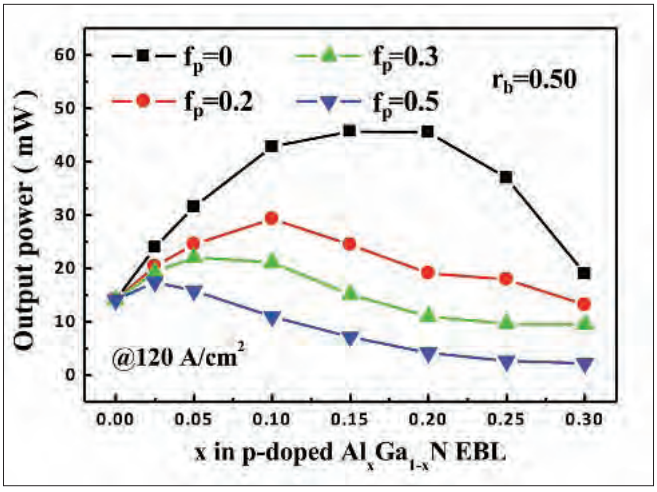

Figure 3. Light output power for the LEDs with differing EBL polarization compensation factor as a function of aluminium composition at 120 A cm^{-2}.

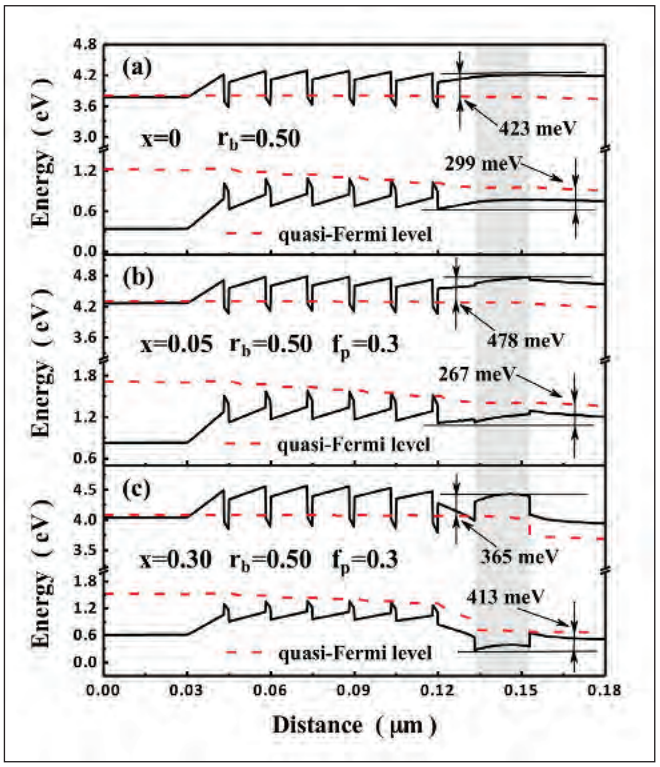

Figure 4. Energy band diagrams of the LEDs (a) without an EBL, (b), (c) with aluminium composition of 0.05 and 0.3 in the EBL under an EBL polarization compensation factor of 0.3 at 120 A cm^{-2}.

injection.To prove that polarization charges play a central role in the aluminium composition dependence, the polarization compensation factor was varied from zero to 0.5 (see Figure 3). These simulations show that LED behaviour is highly sensitive to the polarization charges: if they were absent, the EBL would be mostly beneficial in a wide range of aluminium compositions; but if the polarization charges are significant (a polarization compensation factor of 0.5 or more), the EBL would be mostly useless, and only aid performance for a very narrow range of aluminium compositions. These findings explain why some reported experimental data failed to uncover the benefits of using an EBL.

We have also considered the impact of the band-offset ratio on electron leakage, hole injection and the effectiveness of the EBL. Turning to a higher value of band-offset ratio of 0.6, we investigated how variations in the composition of the EBL influence LED performance. At the higher band-offset ratio, the EBL always enhances LED output power (see Figure 5). This is not surprising, since a high electron barrier suppresses electron leakage, while a low hole barrier enhances hole injection

Thanks to its name – the electron blocking layer – the capability of the EBL to block the overflow of electrons is rather well understood. But this moniker may also be partly to blame for a less well known, but equally important consequence: the blocking of hole injection. To illustrate this, we have plotted the hole concentration in the last quantum well as a function of aluminium composition for band offset ratios of 0.5 and 0.6 (Figure 6). It is clear that at a band offset of 0.5, increases in aluminium composition produce a substantial decrease in hole concentration. However, at a higher offset of 0.6, a consistently

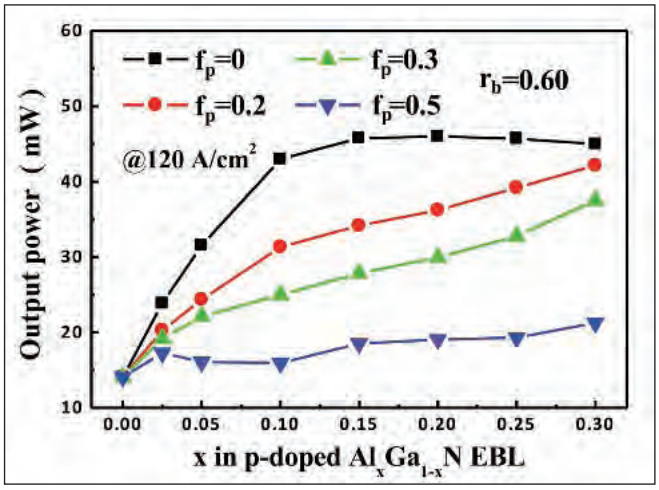

Figure 5. Light output power of the LEDs with different EBL polarization compensation factors as a function of aluminium composition at 120 A cm^{-2} with an EBL band offset ratio of 0.6.

higher hole concentration is possible for all aluminium compositions.

Our simulations of LED behaviour for a range of devices – different EBL compositions, polarization compensation factors and band offset ratios – explain the apparently conflicting reports on the usefulness of the EBL. We have shown that the polarization compensation factor and the band offset ratio play critical roles in determining the performance of the LED. Learning how to optimise them will help to minimise droop and spur the adoption of solid-state lighting.

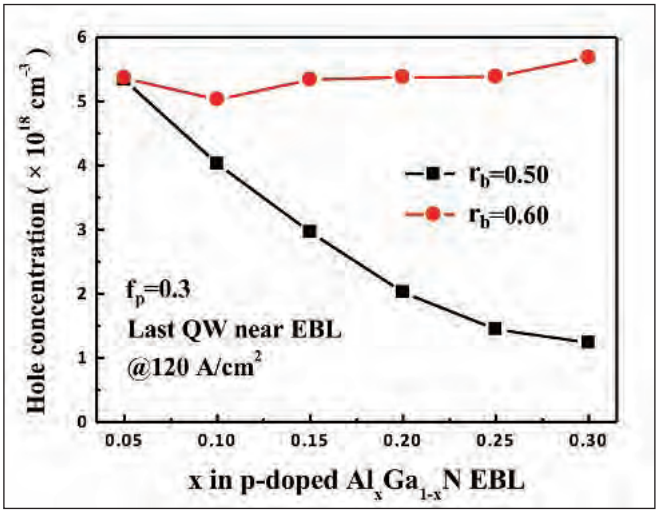

Figure 6. Maximum hole concentrations at the last quantum well as a function of aluminium compositions at different band offset ratios. Calculation at 120 A cm^{-2} with polarization factor of 0.3.

Further reading
C. S. Xia *et. al.* Appl. Phys. Lett. **103** 233505 (2013)

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Better buffers for III-Vs-on-silicon

A two-step buffer based on GaAs and InP creates a foundation for quantum well structures with very high mobility

ENGINEERS at Hong Kong University of Science and Technology have advanced the development of III-V-on silicon devices by inventing a buffer technology with a relatively high thermal conductivity.

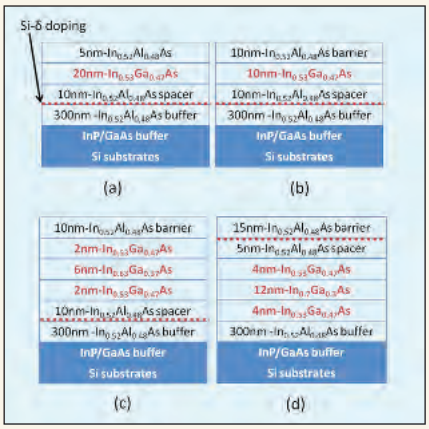
Their work could aid the development of III-V-on silicon heterostructures, which are attracting much interest because they could help to maintain the march of Moore's law – they could allow the silicon channels in transistors to be replaced with III-V material sporting a higher mobility.

One attraction of this switch in channel material is a reduction in power consumption, which results from a fall in the operating voltage of the IC without compromising the transistor's current. Reduced IC power consumption is highly valued: It cuts cooling requirements and can extend the battery life of mobile devices.

Forming high-quality III-V epistructures on silicon is not easy because these two types of material have an 8 percent lattice mismatch, significant differences in thermal expansion coefficients and different crystal polarities. Due to these differences, III-V layers can be riddled with defects that degrade device performance.

However, if engineers turn to sophisticated buffer structures, they can grow high-quality layers. This approach, which has been pioneered by a team including engineers from IQE, has shown that a ternary buffer allows the formation of InAlAs quantum wells with a mobility as high as equivalent wells grown on lattice-matched InP. The downside, however, is the relatively poor thermal conductivity of the III-V ternary alloys.

Kei May Lau, who leads the group at Hong Kong University of Science and Technology, has addressed this with binary buffers of InP and GaAs: "They have a ten-to twelve times better conductivity than indium aluminium arsenide." Encouragingly, the quality of the devices grown on these structures appears to be similar to those grown on InP, according to sheet resistance measurements at various temperatures.



The researchers grew four heterostructures, featuring different channel and barrier designs, as well as differences in delta-doping. Structure (d) produced the highest mobility.

Lau and her co-workers produced their high-mobility quantum well structures on 100 mm *p*-type silicon (111) substrates, which were chemical-cleaned prior to loading in an Aixtron AIX-200/4 low-pressure MOCVD reactor. Before growth, the substrate was heated to 800 °C and annealed for 30 minutes at 100 mbar in hydrogen gas. This step removed any remaining native oxides and promoted the formation of double steps on the silicon surface.

Growth of the epistructure began with deposition of a GaAs nucleation layer between 390 °C and 420 °C, followed by the addition of a 0.5-1.0 μm-thick GaAs buffer, while temperature was ramped from 550 °C to 630 °C. On this the researchers deposited an InP layer at 450 °C, plus another InP layer at 630 °C. The latter featured a 10 nm-thick interlayer of $In_{0.58}Ga_{0.42}As$ that led to dislocation bending and surface smoothing.

Cleaving the epiwafer into quarters enabled evaluation of four different $In_{0.52}As_{0.48}As/In_xGa_{1-x}As$ ($x \geq 0.53$) heterostructures (see figure for details).

Insights into how to optimise buffer quality were provided by atomic force microscopy and transmission electron microscopy (TEM). The former revealed that the nucleation temperature plays a critical role in self-annihilation of antiphase domain boundaries and the elimination of deep pinholes on the GaAs surface. 410 °C is the sweet spot, leading to atomic-step flow and a root-mean-square roughness of just 1.1 nm over a 5 μm by 5 μm scan area.

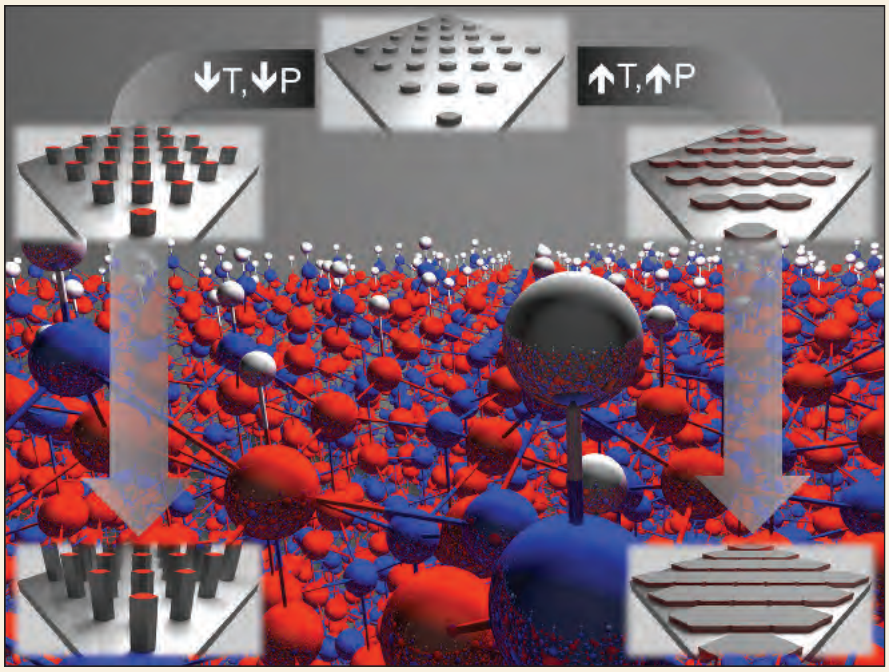
Meanwhile, TEM revealed the high density of dislocations at the GaAs/silicon and the InP/GaAs interface, which both arise due to 4 percent lattice mismatch. The good news, however, is that many defects vanish after intersecting with one another in the buffer layer, and the $In_{0.58}Ga_{0.42}As$ interlayer in the InP buffer prevents some dislocations propagating into the upper active layers.

Of the four samples, heterostructure D, produces the highest mobilities: 10,080 cm^{-2} V^{-1} s^{-1} at 300K and 39,600 cm^{-2} V^{-1} s^{-1} at 77K. These values led to a sheet resistance of just 157 Ω/☐ at 300K, and 48 Ω/☐ at 300K.

It is not yet clear whether a trimming of the buffer thickness is required to make it suitable for transistor production – but it may already be suitable for photonics.

"Photonic devices do not have a similar demand, as integration on silicon photonics is yet to be well defined," comments Lau. "We have reported both normal-incidence and edge-waveguide-coupled photodetectors grown on similar InP/GaAs/silicon buffers, and the buffer thickness does not seem to be a concern."

Q. Li *et. al*.
Appl. Phys. Express **7** 045502 (2014)



Right: The surface structure and the energy of different facets that are present during semiconductor growth significantly influences the morphology of films, bulk crystals and nanostructures. State-of-the-art calculations of surfaces can provide insight into the effects of growth conditions such as temperature (T) and pressure (p). Image Credit: Cyrus Dreyer, UCSB

Aiding nitride growth with accurate surface energies

Calculations offer insights into nitride growth conditions for different planes.

GROWERS OF NITRIDES have been held back by a lack of knowledge of this material's surface energies, which determine how stable particular planes are and how fast growth will occur on them. But this weakness has now been addressed by calculations by Chris Van de Walle's team from the University of California, Santa Barbara.

One of the key findings of this work is that the non-polar *a*- and *m*-planes have similar stability, and thus growth rates, even when the deposition conditions are changed substantially. However, when it comes to polar planes, growth rates vary a great deal with growth conditions.

These findings have implications for selective MOCVD re-growth. This often involves the growth of stripes in the *c*-direction for lateral overgrowth, in order to then obtain low-defect-density material in the wings – that is used to make lasers. To succeed with this technique, lateral overgrowth taking place on the non-polar planes must occur at a faster rate than the vertical growth.

"According to our calculations, you would want to grow under more nitrogen-rich conditions, with lower pressure and higher temperature," explains Van de Walle. "Alternatively, if you are trying to grow nanowires, you would like faster growth on the *c*-plane and slower on the non-polar planes. For that purpose, our calculations suggest higher pressure, lower temperature, and more gallium-rich conditions."

The West-coast team says that accurate values for nitride surface energies have been hard to come by, due to: the absolute energies for polar or semi-polar planes being fundamentally ill-defined for crystals with low symmetry, such as the wurtzite crystal structure of GaN; and limitations in the computational methods used by previous research groups. Van de Walle's team addresses the flaws associated with low crystal symmetry by calculating values for a zinc blende structure, which differs only in its stacking sequence from a wurtzite structure. "You have to move three atoms below the surface before you see any difference between wurtzite and zinc blende," argues Van de Walle, "and since surface energies depend on properties such as bonding between atoms that are very local in nature, we expect the results to be very similar between the two polytypes."

The researchers also improve the methods used to calculate the surface energies, by switching from traditional variants of density functional theory – such as the local density approximation or the generalised gradient approximation – to the use of a 'hybrid functional' form.

According to Van de Walle, although the local density approximation and the generalised gradient approximation do a "good job" for structural properties, they fail to predict the bandgap correctly. "In some cases, this also affects energies: for instance, surface energy depends on the position of surface states within the bandgap, and if the bandgap is wrong, the surface energy will be affected."

The West-coast team normally employs periodic boundary conditions, because this allows the use of computational approaches, such as fast Fourier transforms, that speed up calculations. However, for the recent work on surface energies, they had to consider a surface. Ideally, they would perform calculations for a semi-infinite solid, but this is not a periodic structure. So instead they look at a slab – a layer of finite thickness, surrounded by a vacuum on both sides.

"If the layer of vacuum is wide enough, interactions between the surfaces across the vacuum layer are negligible," explains Van de Walle, who adds that by making the slab sufficiently thick, surfaces on either side do not interact with each other.

Plans for future work include modelling the surface energy of III-nitride semi-polar planes and investigating other materials, such as complex oxides.

C. Dreyer *et. al*.
Phys. Rev. B **89** 081305R (2014)

DBR boosts the brightness of vertical GaN-on-silicon LEDs

Brighter, cheaper LEDs are promised by inserting a mirror between the LED and its silicon substrate

RESEARCHERS from Sun Yat-sen University, China, have developed a novel GaN-on-silicon LED that combines high light extraction with a low operating voltage.

High values for light extraction are known to result from the insertion of a reflecting stucture known as a distributed Bragg reflector between the LED and the silicon substrate.

However, up until now, the addition of this reflector mirror paid a big penalty: A high operating voltage. The team from China have addressed this by inserting holes through the entire structure, which are subsequently filled with metal.

This revolutionary design will be of interest to the solid-state lighting industry, which views the GaN-on-silicon LED as a promising devices for reducing the cost-per-lumen. Silicon is a low-cost substrate, and the processing of GaN-on-silicon wafers in depreciated 200 mm silicon lines could lead to a significant reduction in LED production costs.

GaN-on-silicon LED fabrication traditionally involves removal of the silicon LED, which is light absorbing, and the transfer of the stack of nitride epilayers to a new carrier. According to the team from China, however, performing out this task is tricky, and it results in high yields and low costs.

Baijung Zhang from Sun Yat-sen University told *Compound Semiconductor* that one of the reasons behind these weaknesses is that GaN-based LEDs grown on silicon have a bowed surface that is induced by lattice and thermal mismatch. "This affects the wafer-bonding process, resulting in low yields."

In 2012, Zhang and co-workers reported the production of vertical LED structures transferred from a 2-inch silicon substrate to copper.

"Although the yield was increased by using the mature electroplating technique, the substrate transfer technique needed some additional processing steps in comparison with the normal LED fabrication process." These included chemical wet etching, sub-mount protecting and metal reflector forming, which resulted in a complex, costly fabrication process.

To form the team's latest LEDs, which avoid any silicon lift-off processes, silicon (111) substrates are chemically cleaned and loaded into an MOCVD tool. Growth begins with deposition of aluminium for 5s, to prevent the formation of SiN, followed by the addition of a 100 nm-thick AlN seeding layer that prevents melt-back etching caused by Ga-Si alloys.

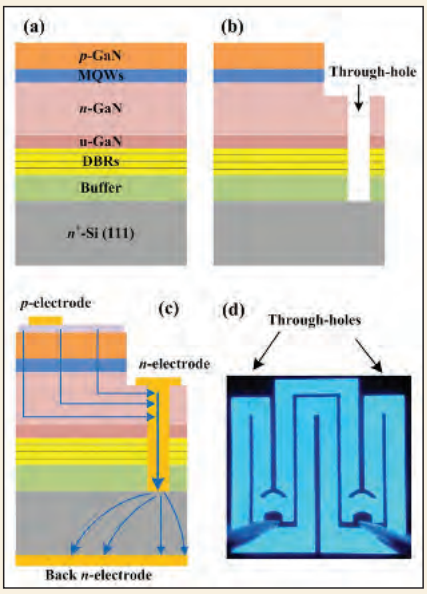
Engineers then grow: a 660 nm-thick graded AlGaN buffer; a distributed Bragg reflector, which is formed from five pairs of 56 nm-thick AlN and 48 nm-thick GaN; a 300 nm-thick cap; and an LED comprising 800 nm of *n*-type GaN, a six period multiple quantum well, and 240 nm of *p*-type GaN.

Plasma etching forms 100 μm-wide holes in the LEDs, which are filled with metal during the fabrication of the *n*-type and *p*-type wire bonding pads. This addition addressed the resistance induced by the AlN/GaN distributed Bragg reflector and the high resistivity of the AlGaN buffer and AlN seeding layer.

Driven at 20 mA, the LED made in this manner had an operating voltage of 3.96 V and produced 2.1 W at 350 mA – which is 24 percent more power than that of a conventional LED.

However, the operating voltage and light output of the vertical chip are inferior to those of an equivalent GaN-on-silicon LED with a lateral conduction path.

Zhang blames the relatively poor output compared to the lateral device on the contact resistances between the *n*-type electrode and silicon, and the high resistance of the silicon substrate.



The researchers from Sun Yat-sen University fabricate LED chips by depositing an epitaxial structure on silicon (a), dry etching to expose n-GaN and form through-holes (b) and depositing metals, which fill the holes and provide electrodes (c). Emission intensity is fairly uniform at an injection current of 100 mA (d).

"We will optimise the process conditions to improve the ohmic contact," says Zhang.

According to hom, the team will also try to increase the reflectivity of the distributed Bragg reflector by adding more pairs of AlN and GaN, while trying to improve the interfaces between these materials.

Y. Yang *et. al*.
Appl. Phys. Express **7** 042102 (2014)

Polarisation-free GaN shows promise for visible photonics

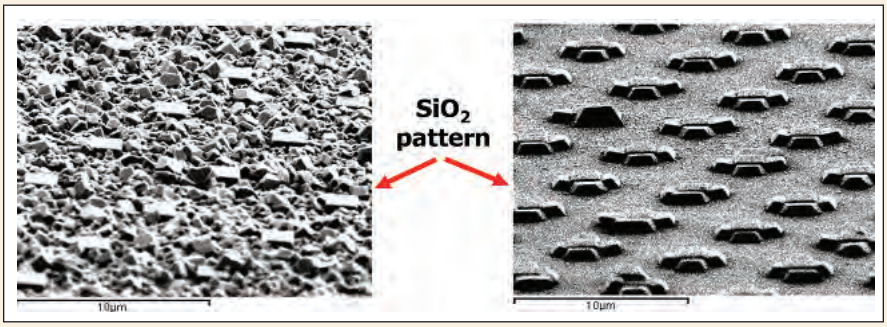
A new development at IBM culminates in a stress-free GaN that is ideally-suited for enabling polarisation-free visible light emitters

GAN-ON-SILICON LEDs promise to cut the cost of solid-state lighting and accelerate its adoption, but they suffer from a high dislocation density that stems from significant lattice and thermal mismatches between substrates and epilayers.

However, scientists at IBM have shown that these issues can be addressed by growing a unique nanopattern on a CMOS-compatible silicon substrate – a cubic phase of stress-free GaN can result in a dislocation density of less than 10^8 cm^{-2}, which is three orders of magnitude below that of conventional GaN-on-silicon.

What's more, turning to the cubic phase can improve LED performance. Conventional GaN is grown on three- or six-fold base-symmetric substrates such as sapphire, SiC, and silicon (111). As such, conventional GaN devices are hexagonal (wurtzite) phase structures that are plagued by very high polarisation fields, which produce shifts in wavelength and current, and are thus detrimental to the performance of both photonic and vertical-transport electronic devices. So, if these polarisation fields could be eliminated, it is possible that the performance of GaN devices could hit a new high.

GaN formed by Can Bayram and co-workers from IBM could enable this, because it is polarisation-free along the common growth direction. However, until now, this phase was thermodynamically unstable and required low-temperature deposition conditions and unconventional substrates, such as GaAs.



SEM images of (left) conventional and (right) selective MOCVD growth processes on the same groove structures.

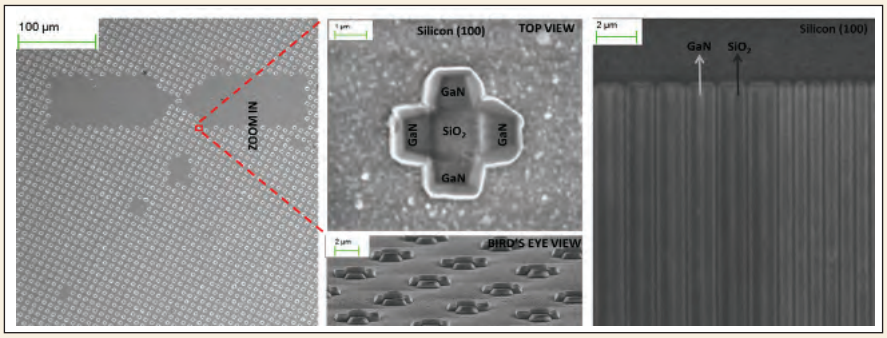
To overcome this thermal instability, Bayram developed novel nano-groove patterning and MOCVD-compatible, maskless selective-area-epitaxy processes. After the integration of thermodynamically-stable, stress-free, and low-dislocation density-GaN on CMOS-compatible on-axis silicon, InGaN/GaN multi-quantum-well structures were grown.

The material showed strong room-temperature luminescence in the visible spectrum – promising polarisation-free visible emitter applications for this technology. Furthermore, cubic phase GaN-on-silicon (100) has a cleavage plane suitable for mirror formation and shows promise for laser diodes.

Another strength of the IBM process is its compatibility with CMOS processing. Conventional GaN-on-silicon LEDs are formed on silicon (111), but this cannot be used, because the GaN that is formed has six-fold symmetery. It is essential to grow GaN-based devices on on-axis silicon (100) substrates to integrate GaN devices with already-established silicon-based CMOS technology.

The performance of GaN devices is ultimately determined by the quality of the GaN. For many applications it would be ideal if one could achieve low dislocation densities (< 10^6 cm^{-2}) and stress-free GaN over wafer-sized areas. However, according to Bayram, no such material has been demonstrated on CMOS compatible on-axis silicon (100). Meanwhile, GaN-on-silicon (111) suffers from dislocation densities of greater than 10^{11} cm^{-2} and wafer bow. Although single-crystal GaN can be epitaxially grown on off-cut on axis silicon (100) substrates, such substrates are not CMOS-compatible and GaN re-growth suffers from similar issues.

In comparison, the efforts at IBM have resulted in material growth compatible with conventional CMOS processes, and have provided a novel roadmap for making GaN-based visible emitters cost-competitive.



Selective GaN regrowth on Silicon (100) substrate could be useful for interconnects as well as novel device architectures. Oxide pattern can be used to locate GaN layers along the periphery.

Can Bayram *et. al.*
Advanced Functional Materials (2014)

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News Digest Contents

LEDs

QuantumClean achieves single ISO 9001:2008 certification

In the past, the firm's facilities were either individually ISO 9001 certified, or certified in groups of facilities under different registrars

QuantumClean, has announced that all of its global Advanced Technology Cleaning Centres are now certified under a single ISO 9001:2008 certificate.

The firm is a provider of high-purity outsourced process tool parts cleaning, surface treatment, refurbishment, analytical and engineering services to the semiconductor, solar and LED industries.

Previously, QuantumClean's facilities were either individually ISO 9001 certified, or certified in groups of facilities under different registrars.

"This achievement is another significant step forward in our global integration plan, ensuring that customers receive the same high quality service across our vast network of Advanced Technology Cleaning Centres," says Tim Burrows, QuantumClean's Director of Global Quality.

Burrows goes on to say, "QuantumClean's Quality Policy states that the Company is dedicated to consistently delivering The Perfect Order to its customers through the application of rigid standard operating procedures, well-trained technicians, quantitative metrics and analytical methods, and continual improvement practices. Achieving global ISO 9001:2008 certification under one certificate is an important accomplishment to delivering the highest standard of services to our customers, i.e. The Perfect Order."

Lumileds rates Mouser top of the sales

Mouser is selling Lumileds' optimised III-nitride LEDs to a broad group of new and innovative companies

Mouser Electronics, an engineering resource and global distributor of semiconductors and electronic components, has been named Top Catalogue Distributor for 2013 by Philips Lumileds.

Mouser was cited specifically for 'Point of Sales Top Performance'.

The global design-fulfilment distributor says it holds the largest market share industry-wide, and has the greatest number of new customers. Mouser also says it is the fastest with new product introductions of any catalogue distributor for Philips Lumileds.

"We want to congratulate Mouser for reaching this honour as Top Catalogue Distributor. With Mouser's help, we have the opportunity to bring our comprehensive portfolio of application optimised LEDs to an even broader group of new and innovative companies," says Kris Keuser, Sr. Director WW Distribution, at Philips Lumileds. "Our business union provides the perfect avenue for our extensive product line to quickly meet the demands of our rapidly growing customer base."

Mouser Electronics receiving the 2013 Top Distributor Award from Philips Lumileds. Pictured (l to r) are Jeffrey Raggio and Adam Osmancevic of Philips Lumileds, along with Eric Flodstrom and Jeff Newell of Mouser Electronics

"We are honoured to be recognised by Philips Lumileds as a top distributor in their sales channel," enthuses Russell Rasor, Mouser Vice President of Supplier Management. "In addition to demonstrating a highly collaborative effort in marketing, Lumileds continues to launch leading edge, high-quality lighting components. That fits perfectly with the Mouser model to deliver the newest products and advanced technologies to lighting designers."

Philips Lumileds focuses on creating the world's highest performing LEDs. The company pioneered the use of solid-state lighting in products such as the first LED backlit TV, the first LED flash in camera phones, and the first LED daytime running lights for cars. Today, the firm offers one of the most comprehensive portfolios of high quality LEDs and uncompromising service. Mouser stocks all of the products from Philips Lumileds.

Philips Lumileds brings LED's qualities of energy efficiency, digital control and long life to spotlights, downlights, high bay and low bay lighting, indoor area lighting, architectural and specialty lighting as well as retrofit lamps. Their products are engineered for optimal light quality and unprecedented efficacy at the lowest overall cost. By offering LEDs in chip, packaged and module form, they deliver supply chain flexibility to the inventors of next generation illumination.

Plessey included in the Lux Magazine Power List 2014

The firm has been shortlisted for its gallium nitride on silicon MaGIC LED technology

Plessey has been named in this month's edition of Lux Magazine featuring the top twenty-five innovative lighting companies.

Robert Bain, Editor of Lux Magazine says, "The Power List is Lux's pick of the most exciting lighting companies in the UK. When we heard Plessey was manufacturing LEDs right here in the UK, we had to find out more. Plessey is using GaN-on-silicon technology to unlock manufacturing efficiencies and drive down the cost of LED lighting - and they're doing it in Devon. This is unique and has the potential to bring real benefits to the world of LED lighting. Plessey has earned its place on our Power List, and we'll be keeping our eye on them."

Joe Lopez, Chief Commercial Officer for Plessey adds, "Plessey is one of a very select few selling GaN-on-silicon LEDs in the global solid state lighting market - what Plessey has developed is a truly unique technology. The Solid State Lighting (SSL) market is developing very fast and becoming even more price sensitive as it moves into the consumer market where Plessey's manufacturing cost advantage is particularly strong."

Plessey previously announced that its GaN on silicon LEDs are produced using standard high-yield automated processing in contrast with current generations of LEDs which use expensive sapphire and other exotic materials requiring non-standard semiconductor manufacturing processes.

QuantumClean joins EICC`s tantalum programme

The company says it is the first and only semiconductor industry outsourced process tool parts cleaner to participate in the programme

QuantumClean has announced its inclusion in the Electronic Industry Citizenship Coalition's (EICC) Conflict-Free Smelter (CFS) programme for tantalum.

QuantumClean is a global provider of high-purity outsourced process tool parts for cleaning, surface treatment and refurbishment. The firm provides analytical and engineering services to the semiconductor, solar and LED industries,

The EICC, in partnership with the Global e-Sustainability Initiative (GeSI) launched "The Conflict-Free Sourcing Initiative" in 2010. This was to meet the need for downstream companies to demonstrate with reasonable certainty the origin and validate smelter procurement processes for four "conflict minerals". These materials include tantalum which is used by many semiconductor wafer fabs. In servicing these fabs, QuantumClean strips and recycles tantalum from many semiconductor process tool chamber parts.

"QuantumClean is committed to do its part in the elimination of unlawful and immoral activities, including unthinkable work conditions surrounding the trade and use of minerals mined in conflict-afflicted areas of the world and used in the semiconductor industry, which is why we elected to participate in the EICC's Conflict-Free Smelter Program for Tantalum," says David Zuck, Vice President and COO of Quantum Global Technologies.

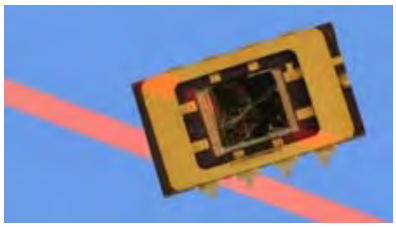
To achieve inclusion in the CFS program, QuantumClean demonstrated tantalum supply chain integrity and traceability at both its Fremont California and Hillsboro Oregon Advanced Technology Cleaning Centres through rigorous 3rd party audits.

QuantumClean says it is the first and only semiconductor industry outsourced process tool parts cleaner to participate in the CFS program.

"When we founded QuantumClean many years ago, we wrote six essential, governing policy statements, including an Environmental and Social Responsibility policy. Our inclusion in EICC's Conflict-Free Sourcing program is the latest affirmation of management's commitment to this policy," concludes Zuck.

Magic molybdenite creates solar cells and LEDs

Electronic components made up of a layer of molybdenite superposed on a layer of silicon can produce light due to the the special properties of molybdenite



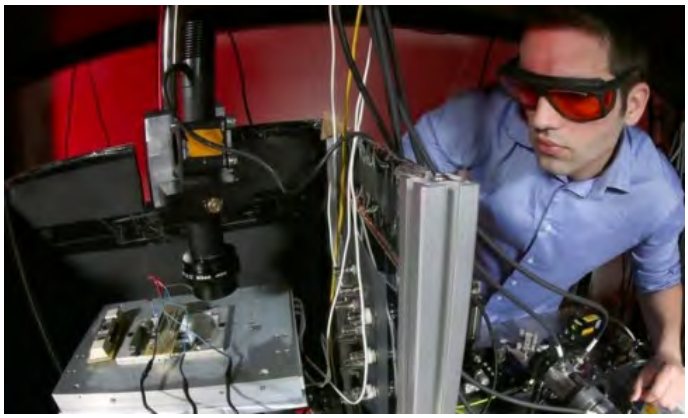
After using it to develop a computer chip, Flash memory device and photographic sensor, EPFL scientists have once again tapped into the electronic potential of molybdenite (MoS_2) by creating diodes that can emit light or absorb it to produce electricity.

Molybdenite has a few surprises still up its sleeve.

EPFL professor Andras Kis and his team in the Laboratory of Nanoscale Electronics and Structures (LANES) is continuing his study of this promising semiconductor. In research recently published in the journal *ACS Nano,* they have demonstrated

the possibility of creating ILEDs and solar cells.

The scientists built several prototypes of diodes - electronic components in which voltage flows in only one direction - made up of a layer of molybdenite superposed on a layer of silicon. At the interface, each electron emitted by the MoS2 combines with a “hole” - a space left vacant by an electron - in the silicon. The two elements lose their respective energies, which then transforms into photons. “This light production is caused by the specific properties of molybdenite,” explains Kis. “Other semiconductors would tend to transform this energy into heat.”



Working in tandem

Even better, by inversing the device, electricity can be produced from light. The principle is the same: when a photon reaches the molybdenite, it ejects an electron, thus creating a “hole” and generating voltage.

“The diode works like a solar cell,” says Kis. “Our tests showed an efficiency of more than 4 percent. Molybdenite and silicon are truly working in tandem here. The MoS2 is more efficient in the visible wavelengths of the spectrum, and silicon works more in the infrared range, thus the two working together cover the largest possible spectral range.”

The scientists want to study the possibility of building electroluminescent diodes and bulbs. This discovery could, above all, reduce the dissipation of energy in electronic devices such as microprocessors, by replacing copper wires used for transmitting data with light-emitters.

Some LEDs look on the brighter side of white

Tests have inicated that under halogen light and violet-pumped LED lights, the whiteness of cards (of varying whiteness) can be correctly assessed. On the other hand, the human eye cannot correctly differentiate whiteness when exposed to the most common type of modules used in LED lamps, blue pumped LEDs

For years, companies have been adding whiteners to laundry detergent, paints, plastics, paper and fabrics to make whites look “whiter than white.”

Now, with a switch away from incandescent and fluorescent lighting, different degrees of whites may all look the same, according to experts in lighting.

“Retailers have long been concerned with the colour-rendering qualities of their lighting, but less aware how light sources render white,” says Kevin W. Houser, professor of architectural engineering, Penn State.

Kevin Houser, Professor of Architectural Engineering at Penn State, sorts tiles in a light box in the departments illuminating engineering lab for observation under several light sources (Image: Patrick Mansell)

Not long ago, the only practical choices for home, office or commercial lighting were incandescent or fluorescent bulbs. More recently, compact fluorescent bulbs, which use less energy than incandescent bulbs, became popular, but compact fluorescents are not always accepted by consumers because of poor colour rendition, lack of dimability, slow warm-up to full output and because they contain mercury.

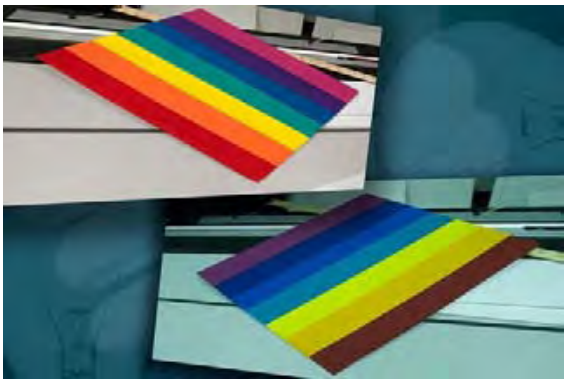
The most recent popular entry into home or commercial lighting are LED bulbs, which while currently expensive, are often even more energy-saving than compact fluorescents.

While some LED bulbs will make colours pop, the vast majority do not showcase or differentiate the appearance of white products, according to Houser, because all white light is not the same.

Different light sources contain different combinations of the wavelengths of light. A broad variety of wavelengths will create light that appears white to the human eye, but different mixtures of wavelengths will affect how colours are rendered. When it comes to seeing the colour white, the light source is very important because of how product manufacturers make white products appear white using whiteners.

Whiteners contain fluorescent materials that glow under violet and ultraviolet light. Sunlight, fluorescent light and incandescent light all produce some light in the violet and ultraviolet range. The whiteners used in consumer products work under those conditions, resulting in a bright white perception.

However, most current LED bulbs use blue LEDs to excite a phosphor that then glows white, but produces no violet or ultraviolet light.



A rainbow pattern as seen under a long-linear, fluorescent light source common for commercial interiors (top). And, the same rainbow pattern as it appears under a non-commercial, fluorescent light source (bottom). The colour differences result from the use of different phosphors in the lights glass tubing (Image: Patrick Mansell)

Houser, working with a Penn State student and researchers from Soraa of Fremont, California, asked thirty-nine participants to observe various combinations of light sources and white objects to see how light source affected perceptions of white. They report their results in a recent issue of *Leukos,*the *Journal of the Illuminating Engineering Society.*

The participants completed three tests - selection, forced choice and sorting - using five different light sources - a blue-pumped LED, filtered halogen lamp and three violet-pumped LEDs with differing levels of violet emissions.

In the sorting experiment, the researchers placed six calibrated whiteness cards of varying whiteness on a table in a booth enclosed on three sides. They asked participants to arrange the cards in order of whiteness under each of the five light sources.

Under the halogen light and violet-pumped LED lights with 7 and 11 percent violet emission, the order was correct. Two of the cards were flipped under violet-pumped LEDs with only three percent violet emissions.

“With the LED with only blue pumping the phosphors, the order became random,” says Houser. “People simply couldn’t tell the difference between the cards under the blue-pumped LED, which is notable because blue-pumped LEDs are by far the most common type for general lighting.”

In the forced choice test, two nominally identical cards were placed in each of two booths containing different light sources. Participants were asked to choose the card that was whiter under all of the permutations of each of the five light sources.

The same set of white cards as seen under a violet-pumped light emitting diode (LED) top, and under a blue-pumped LED below (Image: Patrick Mansell)

“The light sources with higher violet component permitted the best discrimination between the targets,” adds Houser.

In the selection test, researchers asked the participants to look at a reference card in one booth and rank the cards in a second booth as either as white or whiter than the reference card. Again the blue-pumped LEDs did not fare well.

The researchers note that “engineering of an LED source’s spectrum is necessary for an accurate rendering of whiteness.”

These results have been described in further detail in the paper, “ Whiteness Perception under LED Illumination,” by Kevin W. Houser *et al* in *LEUKOS: The Journal of the Illuminating Engineering Society of North America,* 10, (3), p165 - 80, 2014.

DOI: 10.1080/15502724.2014.902750

Soraa Inc. funded this study.

Everlight unveils ultra-thin 940nm IR LED

The compact III-nitride based device is suited to higher output intensity in space-constrained end products such as smartphones and tablets

Everlight Electronics is introducing the ultra-thin 940nm top-view infrared LED IR92-01C/L491/2R in a miniature MIDLED package.

This small SMD device has been developed for applications where high power output, narrow beam angle or available space is of concern.

Devices suited for incorporating Everlight's SMD top-view MIDLED package. IR92-01C/L491/2R module (inset)

The new 940nm IR topled comes in a small 2mm x 1.4mm MIDLED package with a thickness of ultra-low 0.7mm. This makes the module a perfect match for all kinds of space-constrained end products like tablets, smartphones and the like.

Along with a low forward voltage of 1.3 V at 20mA, a high output power of 25mW/sr at 70mA and a narrow viewing angle of 45° for even higher output intensity without lens, Everlight's IR92-01C Series is suited for IR data transmission applications of any kind.

These are remote controls, proximity and optical touch sensors, night-vision cameras or high-tech touch panels. Other applications include light curtains or barriers, turbidity sensors and coin counters.

Everlight's IR92-01C Series in a MIDLED package is lead-free, halogen-free and RoHS compliant.

A dedicated application-based marketing approach supports the idea that every application is to be paired with "The Right LED" to provide the best performance and quality. Every package design presents its own advantages in certain applications.

Samples are available upon request.

Lumileds takes its LED array efficacy to a new level

The new LUXEON CoB 1202 arrays for PAR38 equivalent lamps and spotlights, are claimed to deliver the highest efficacy at an affordable price

Philips Lumileds says its Chip on Board (CoB) arrays for PAR38 equivalent lamps achieve 10 percent or greater efficacy than competing solutions.

Also ideal for spotlights, LUXEON CoB 1202 has a typical efficacy of 115 lm/W, and it varies from 95 to 130 lm/W over a CCT range of 2700 to 5700K at CRI of 70, 80 or above 90. This depends on colour temperature and CRI of the array.

LUXEON CoB 1202 LED

"The high efficacy, combined with our line-up of compatible reflectors and drivers, enables the most affordable PAR38 and spotlight designs to date," says Eric Senders, Product Line Director, Philips Lumileds.

The LUXEON CoB 1202 completes the portfolio for PAR lamps. Together with the 1203, these 9 mm Light-Emitting Surface (LES) versions will be the best in price/performance for directional retrofit lamps.

Due to the LUXEON CoB 1202's mechanical and optical compatibility with the LUXEON CoB 1203, one is able to use the same ecosystem to create a high efficient and most cost effective solution.

Typical output for warm white (3000K, 80 CRI) is 800 lm when driven at 200mA. The warm white arrays can be driven at up to 400mA to achieve a flux of 1500 lumens. The high CRI (cover 90) versions deliver an R9 of above 80 for demanding applications such as retail downlights and spotlights.

Strategies Unlimited: HB LED market to top $26 billion

The global packaged LED industry grew from $1.2 billion in 2000 to $14.2 billion in 2013. Back in 2009, illumination accounted for $665 million in revenues and in 2013 the general lighting segment was worth $4.4 billion

Strategies Unlimited foresees revenue growth of 12.9 percent from 2013 to 2018 for the total market for packaged LEDs, bolstered by 27 percent CAGR in LEDs in lighting applications.

The company has released its annual market research report, "The Worldwide Market for LEDs: Market Review and Forecast 2014".

The report offers analysis and a forecast through 2018 for packaged LEDs used in display backlighting, mobile devices, automotive applications, signage, and general lighting.

The global packaged LED industry grew from $1.2 billion in 2000 to $14.2 billion in 2013. Back in 2009, illumination

accounted for $665 million in revenues and in 2013 the general lighting segment was worth $4.4 billion.

Strategies Unlimited analyst Katya Evstratyeva says, “We forecast the growth for LEDs in lighting to be 27 percent of CAGR from 2013 to 2018, driven mostly by an increased consumer confidence and continuously increasing sales of replacement lamps, downlights, industrial, commercial, and outdoor products.”

The top fifteen companies in the LED space account for about 81 percent of global revenues and the top twenty-five companies account for 93 percent of revenues. It is clear that quite a few manufacturers continue to struggle to find their identity in this fast-changing environment as the packaged LED industry is becoming more and more complex.

As a result, the market analyst anticipates consolidation of the market in the coming years.

Osram LEDs light up Ford pickup

The company has worked with Flex-N-Gate for what it says is the world’s first pickup with full LED front lighting

One of America’s pickup trucks, and said to be the biggest seller in the USA, is now blazing the pioneer trail in lighting thanks to Osram.

The German LED device manufacturer says the 2015 model of the Ford F-150 will be the world’s first pickup on the market with a complete LED forward lighting solution.

The new LED forward lighting solution from Osram gives the new Ford F-150 an unmistakable appearance (Picture: Ford Motor Company)

“We are proud to be supplying the complete LED module for the world’s first LED headlamps on the Ford F -150 as standard, once more underlining our leading position on the automotive lighting market,” says Hans-Joachim Schwabe, CEO of the Specialty Lighting, Division at Osram.

This lighting system comprises dipped beam and high beam, turn indicators, parking light and control module. In terms of its performance, life expectancy and design it is designed to catch the eye and make the Ford pickup stand out from its competitors.

The LED forward lighting solution meets all the requirements in terms of robustness and durability and are extremely resistant to shocks and vibrations - an important factor for a vehicle which is also used off-road.

What’s more, the LED headlamps consume far less energy than conventional lighting technologies and their light colour is very similar to that of natural daylight. Osram says the LEDs also compare very favourably with conventional halogen technology in terms of their light output.

In close cooperation with the US headlight manufacturer Flex-N-Gate, Osram has given the front of the vehicle a completely new look.

The LED front lights, in which LEDs from Osram’s subsidiary Osram Opto Semiconductors are installed, give the F-150 a unique and unmistakable appearance which blends perfectly with the styling of the whole vehicle. The complete LED lighting solution is assembled at Osram’s Hillsboro plant in New Hampshire (USA).

In addition to conventional technologies, automobile manufacturers are turning more and more to LED light sources as a means of differentiating their vehicles through individual front lighting design and of boosting their brand image.

Osram has gone one step further with its laser technology, which it has supplied for the new BMW i8 and other high-end models. Thanks to its high luminance, which is significantly greater than that of any other light source available today, headlamps can be made even smaller than they are already.

At the same time, high beam from a laser module offers the greatest beam range and therefore better visibility for the driver and greater road safety. This combination of design and functionality means the laser has enormous potential alongside the LED.

Obducat reveals mass production tool for LEDs and Optics

The second generation SINDRE system enables throughputs of up to sixty wafers per hour. It has been delivered and passed customer final approval in January

Obducat, a manufacturer of lithography solutions based on nanoimprint lithography (NIL), has launched its 2nd generation SINDRE.

With the improved performance it will represent a cost effective NIL production solution on the market. The system is based on Obducat’s patented SoftPress, IPS and STU technologies.

SINDRE 400 G2

The fully automated SINDRE system enables throughputs of up to sixty wafers per hour.

The new SINDRE integrates the latest advances in manufacturing technology which enables high throughput, high repeatability at a defectivity level which surpass industry requirements.

The first system has already been delivered and passed customer final approval in January this year and the next system will be delivered in third quarter this year.

The new SINDRE platform is a fully integrated NIL system which includes integrated fabrication of the Intermediate Polymer Stamp (IPS). This is a proven and reliable process which was also integrated in previous generation of SINDRE systems delivered by Obducat during the last five years.

Obducat's patented IPS technology covers the use of a transparent flexible stamp in any kind of imprint process. The use of the IPS technology ensures a long life time of the stampers which minimise the stamp related costs per imprint.

The patented SoftPress technology, applied in the system, ensures the necessary level of conformity between the stamp and substrate vital for establishing high imprint uniformity. This enables a large process window for downstream processes leading to a high yield and low Cost of Ownership. All this has been integrated into a very compact system having a small footprint.

The new SINDRE system also offers a wide flexibility which includes the possibility to use different resists and IPS materials to support customisation of the imprint process. In addition the system can run both UV as well as thermal based NIL processes, giving the capability to imprint structure sizes ranging from 20nm and upwards, on substrate sizes up to 200 mm in diameter.

"The versatility and superior performance of our patented key technologies has been extended further to safeguard Obducat's continued technological leadership in the NIL industry," says Babak Heidari, CTO of Obducat.

Example of components which are ideally produced with this system are optical, photonic, LEDs, fluidic and other biomedical components.

"Obducat again confirms its leading position with this launch. With more than 130 NIL systems delivered during the last decade and several of these being used for manufacturing purposes in LEDs, photonics and biomedical applications, we are breaking new barriers in terms of performance and cost efficiency" says Patrik Lundström, CEO of Obducat.

Marktech multichip emitters and LEDs pack a punch

The new line of III-nitride devices offer enhanced performance and are ideally suited for illumination purposes, emission and detection

Marktech has launched a new line of multichip LEDs.

As electronic products continue to evolve technologically and the push for miniaturisation continues, space constraints for electronics continue to be a concern for design engineers.

Marktech Multichip Emitters and LEDs

Marktech has concentrated on chip on board (COB) solutions where multiple LED die can be placed into a small amount of space offering many advantages to standard packaging.

In addition to using COB technology for illumination purposes, emission and detection functions of a sensor application can be enhanced. With the ability to pack more light emission or light detection chips into an area, performance of the circuit could be greatly increased.

The firm's multichip devices come in a variety of packages including TO-18, PLCC, TO-5 and surface mount.

These devices hold anywhere from two to seven die and are available in Marktech's selected standard die (UV through SWIR Short Wave Infrared) or can be modified to the customer's specification which includes power and wavelength sorting. The standard multichip LED product is available through Digi-key.

Osram LED turns smartphones and tablets into remote controls

The 940 nm flush-mountable infrared T-Midled is claimed to save on height but not on performance

Osram Opto Semiconductors is enabling remote control functionality to be incorporated in a low profile thanks to its first flush-mountable infrared LED.

The compact side looking T-shaped Midled offers high radiant intensity and protrudes only fractions of millimetres from the board.

An infrared transmitter can therefore now be integrated in extra-thin smartphones or tablet computers.

Osram Opto Semiconductors says it has, for the first time, succeeded in sinking a surface-mountable infrared LED in a pc board. The LED in question is the T-Midled SFH 4140.

Almost completely flush: the T-shaped SFH 4140 Midled protrudes 0.6 mm above and below the board, offering remote control functions in a very small space

“We want to enable our customers to install a powerful infrared transmitter even if there is very little height in the device to work with”, explains Bianka Schnabel, the person responsible for the product at Osram Opto Semiconductors.

“We have therefore developed a transmitter that disappears almost entirely into the board. Only 0.6 of a millimetre extends above and below the board. That saves plenty of height,” continues Schnabel.

The T-shaped transmitter takes up 4.6 mm2 of board space and emits a powerful focused plus point in terms of space requirements.

The SFH 4140 component size is 3.1 mm x 1.5 mm x 1.5 mm (height above and below a 0.3mm thick board: 0.6 mm). It produces 50 milliwatts per steradiant (mW/sr) as its typical radiant intensity from 100 mA so it achieves the ranges needed for remote control functions. The wavelength of 940 nm also suits the requirements of this application.

This component is Osram Opto Semiconductors’ contribution to the trend of turning smartphones and tablet computers into universal remote controls, particularly for home entertainment electronics. If the device is equipped with the appropriate infrared transmitter diode then the diode can be controlled with a suitable app.

Whereas classic remote controls traditionally use radial infrared LEDs, this option is not an attractive one for slim smartphones and tablets. These need a low-profile SMT solution which can nevertheless operate over the required distance. Up to now, manufacturers have been using transmitters such as Midled, Mini Midled and Chipled.

The powerful T-Midled SFH 4140 is Osram Opto Semiconductors’ latest addition to its portfolio of remote control transmitters, a no-compromise low profile solution for which there will almost always be sufficient space.

T-Midled SFH 4140 turns tablet computers and smartphones into remote controls without taking much space

Trifortune buys Aixtron tool for GaN LED growth

The 56 x 2 inch reactor will be used to grow gallium nitride on alternative substrates

Jiangsu Trifortune Electronic Technology, China, has ordered an AIX G5 HT system to develop GaN based high brightness LEDs.

The Aixtron system will be equipped to handle 56 x 2 inch wafers per run and will be installed at Trifortune’s R&D centre.

AIX G5 HT reactor

The developed process will be transferred to mass production in the Jiangsu area upon successful completion of the

research.

Hu, Technical Head of Trifortune, comments, "We are developing GaN processes to grow LEDs on substrates that offer some advantages compared to the well-established sapphire substrates. To compete in the HB-LED market, there is a real need to achieve the maximum yield in our manufacturing process, so that products with better performance in lumen per dollar can be established."

Hu adds, "The AIX G5 HT system is widely acknowledged as having the top yields in LED mass production, along with excellently repeatable performance at high growth rates."

Andreas Toennis, Aixtron Chief Technology Officer, continues, "We are very pleased to contribute to Trifortune's success and to share our comprehensive expertise in optimisation of epitaxy yields with them."

Trifortune Electronic Technology Co. Ltd, headquartered in Jintan City, China, was founded in May 2013. In phase one of its strategic business plan the company made an initial investment into a preproduction demo line located at Shahe, Beijing.

GaN discrete, IC and substrate market to soar to over $15 billion

The gallium nitride market will be dominated by power devices and draw most of its revenue from the communication infrastructure sector
MarketsandMarkets estimates that the GaN discrete, IC and substrate market will be worth $15607.85 million by 2022.

This is stated in the "Gallium Nitride (GaN) Semiconductor Devices and Substrate Wafer Market research report," which analyses the global market by market dynamics & trends. Key players are Fujitsu Limited, Toshiba Corporation, Koninklijke Philips N.V., Texas Instruments, Mitsubishi Chemical Corporation and Aixtron SE among others. The specific sub sector where GaN-based semiconductors and wafers have an edge over normal silicon-based counterparts are in Power Semiconductors & Electronics and in terms of end-user application sectors. The two major upcoming sectors facilitating the huge demand for GaN semiconductor devices are the Industrial & Power sector and Communication Infrastructure sector.

The Communication Infrastructure sector has found use for GaN power discretes, particularly for transistors in power amplification, rectification, and high-frequency switching. Gallium nitride, along with SiC devices have turned out to be the choice for most power semiconductor applications and are quickly replacing the existing silicon technology. GaN has a wider band gap, high break-down voltage, larger critical electric field, and higher thermal conductivity than silicon. This enables GaN devices to operate at higher voltages and high switching frequencies and handle higher power density. They also offer enhanced power efficiency compared to pure silicon devices. These properties allow GaN discretes such as Schottky diodes, FETs, HEMTs and other advanced transistors to operate efficiently at much higher voltage levels, exceeding the limits of their silicon counterparts. GaN power semiconductors also help in reducing the conduction and switching losses, thereby offering higher efficiency in electronic systems. Currently, the major application segments of GaN power semiconductors are inverters and converters, RF devices, power supply modules and motor drives which are being used across all the end user sectors.

The market of GaN power semiconductor devices is primarily growing due to penetration into the medium-voltage power electronics market and applications across all the major end-user verticals. It is obvious that most of the market revenue comes from the rising number of advanced power applications of industrial, power, solar and wind sector and the sector's developing globally. Gallium nitride power devices draw most of their revenue from the Communication Infrastructure sector. They have been solely focusing on replacing their silicon counterparts in various RF power devices, particularly in RF communication applications over the past few years. GaN devices are smaller, lighter but tougher and efficient compared to silicon semiconductor devices and serve as ideal replacements for silicon devices which have hit maturity. GaN devices and wafers also feature low sensitivity to ionising radiation, better stability in some radiation environments, They also have a future in solar cell arrays, satellites and high-end power appliances in the Military, Defence & Aerospace sector.

These devices also have huge revenue potential in the automotive and transportation sector, mainly in the electric vehicles & hybrid electric vehicles segment of the automotive sector. GaN power semiconductors possess the potential to operate at higher temperatures, higher power levels and voltages, high frequencies (microwave ranges). The number of applications is increasing day by day in various industries that include telecommunication, consumer electronics, automotive, industrial, power and clean-tech applications. The GaN market's total competitive landscape had only a handful of players at the beginning of the previous decade, but it quickly emerged into a significant network of key players for both power and opto-semiconductors. Currently, the overall GaN power semiconductors market accounts for less than 1 percent of the total power semiconductors market (currently at $34 billion including power discrete and power ICs), but over the next ten years, the entire base for power semiconductors & electronics players is expected to penetrate into this new value chain, thereby rapidly increasing the percentage share.

Today's world includes numerous suitable power applications for GaN in several application segments, such as power distribution systems, industrial systems, heavy electrical systems, turbines, heavy machinery, advanced industrial control systems, electro-mechanical computing systems, and so on. They also include several new power applications (clean-tech) such as High-Voltage Direct Current (HVDC), Smart Grid Power Systems, Wind Turbines, Wind Power Systems, Solar Power Systems, Electric & Hybrid Electric Vehicles. Another application sector is ICT, with several communication application segments such as RF, RADAR, and Satellite communication offering huge revenue potentials owing to the unbeatable ability of GaN to operate at high-frequency ranges, including microwave frequencies. The potential market

size of these massive applications is currently in trillions, making the total addressable market for the GaN power semiconductors worth billions.

Polarisation-free GaN shows promise for visible photonics

A new development at IBM culminates in a stress-free gallium nitride material ideally-suited for enabling polarisation-free visible light emitters

GaN-on-silicon LEDs promise to cut the cost of solid-state lighting and accelerate its adoption, but they suffer from a high dislocation density that stems from significant lattice and thermal mismatches between the substrates and epilayers.

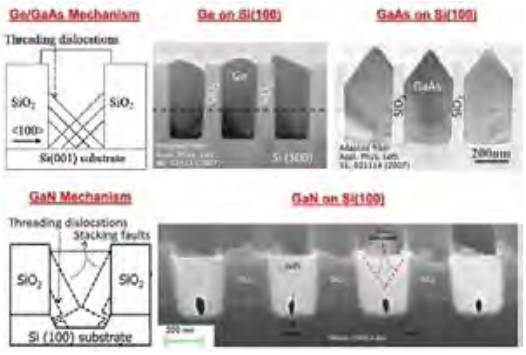
However, scientists at IBM have shown that these issues can be addressed by growing a unique nanopattern on a CMOS-compatible silicon substrate –a cubic phase of stress-free GaN can result in a dislocation density of less than 108 /cm2, which is three orders of magnitude below that of conventional GaN-on-silicon.

What's more, turning to the cubic phase can improve LED performance. Conventional GaN materials are grown on three- or six-fold base-symmetric substrates such as sapphire, SiC, and silicon (111).

As such, conventional GaN devices are hexagonal (wurtzite) phase structures that are plagued by very high polarisation fields along the common growth direction of < 0001 >.

These large polarisation fields produce shifts in wavelength and current, and are thus detrimental to the performance of both photonic and vertical transport electronic devices. So, if these polarisation fields could be eliminated, it is possible that the performance of GaN devices could hit a new high.

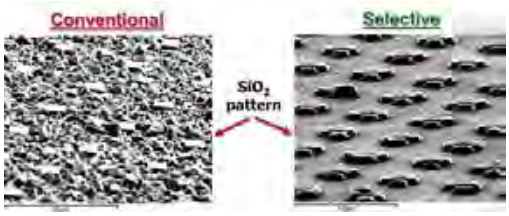
The GaN formed by Dr. Can Bayram and co-workers from IBM could enable this, because it is polarisation-free along the common < 001 > growth direction. However, until now, this phase was thermodynamically unstable and required low temperature deposition conditions and unconventional substrates, such as GaAs.



Schematic sketch and TEM images of Ge, GaAs, and GaN grown on patterned Si (100) substrates. The threading dislocations inside the materials are shown as black lines in the sketches. Very different growth and dislocation behaviour is observed for GaN with respect to gerrmanium and GaAs. In the GaN case, high quality (defect density < 108 /cm2), planar, and cubic phase material is enabled

In order to overcome this thermal instability, Bayram developed a novel nano-groove patterning and MOCVD-compatible maskless selective area epitaxy processes.

After the integration of thermodynamically-stable, stress-free, and low-dislocation density-GaN on CMOS-compatible on-axis silicon, InGaN/GaN multi-quantum-well structures were grown on top. The material showed strong room temperature luminescence in the visible spectrum - promising polarisation-free visible emitter applications for this technology.



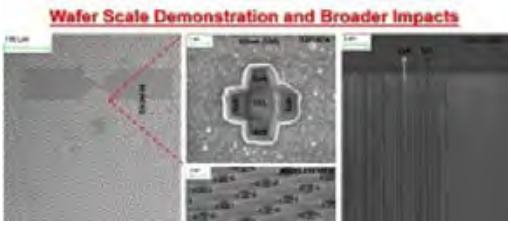
SEM images of (left) conventional and (right) selective MOCVD growth processes on the same groove structures

Furthermore, cubic phase GaN-on-silicon (100) has a cleavage plane suitable for mirror formation and shows promise for laser diodes.

Another strength of the IBM process is its compatibility with CMOS processing. Conventional GaN-on-silicon technologies employ silicon (111) substrates, a platform that renders them useless for co-integration with CMOS-devices.

That's because (111)- oriented silicon substrates have a similar three-fold crystal symmetry to that of six-fold GaN in the (0001) plane. However, it is essential to grow GaN-based devices on on-axis silicon (100) substrates to integrate GaN devices with already-established silicon-based CMOS technology.

The performance of GaN devices is ultimately determined by the quality of the GaN. For many applications it would be ideal if one could achieve low dislocation densities (< 106 /cm2) and stress-free GaN over wafer-sized areas. However, according to Bayram, no such material has been demonstrated on CMOS compatible on-axis silicon (100).



Broader growth demonstrations of selective GaN regrowth on Silicon (100) substrate. This approach could be useful for interconnects as well as novel device architectures. Oxide pattern can be used to locate GaN layers along the periphery

For example, GaN-on-silicon (111) suffers from dislocation

densities of greater than 1011/cm2 and wafer bow. Although single-crystal GaN can be epitaxially grown on off-cut on axis silicon (100) substrates, such substrates are not CMOS-compatible and GaN re-growth suffers from similar issues.

In comparison, the efforts at IBM have resulted in material growth compatible with conventional CMOS processes, and have provided a novel roadmap for making GaN-based visible emitters cost-competitive.

The work has been described in detail in the paper, "Cubic Phase GaN on Nano-grooved Si (100) via Maskless Selective Area Epitaxy," by Can Bayram *et al* in *Advanced Functional Materials, 2014.*

DOI: 10.1002/adfm.201304062

Think tiny to bridge the green LED gap

Using InN nanowires to make LEDs eliminates the lattice mismatch problem of layered devices, and can significantly improve LED efficiency

Nanostructures half the breadth of a DNA strand could improve the efficiency of LEDs, especially in the "green gap," a portion of the spectrum where LED efficiency plunges.

This has been suggested by simulations performed at the U.S. Department of Energy's National Energy Research Scientific Computing Centre (NERSC).

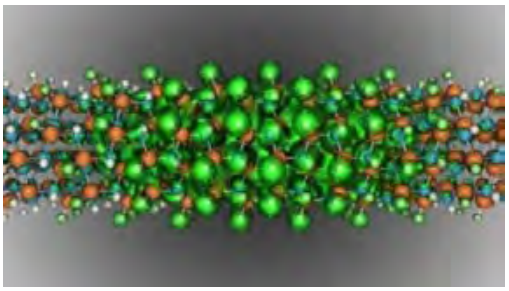
Using NERSC's Cray XC30 supercomputer "Edison," University of Michigan researchers Dylan Bayerl and Emmanouil Kioupakis found that InN, which typically emits infrared light, will emit green light if reduced to 1 nanometre-wide wires.

What's more, just by varying their sizes, these nanostructures could be tailored to emit different colours of light, which could lead to more natural-looking white lighting while avoiding some of the efficiency loss today's LEDs experience at high power.

"Our work suggests that InN at the few-nanometre size range offers a promising approach to engineering efficient, visible light emission at tailored wavelengths," says Kioupakis. Their results will be featured on the cover of the July issue of *Nano Letters*.

LEDs are semiconductor devices that emit light when an electrical current is applied. Today's LEDs are created as multilayered microchips. The outer layers are doped with elements that create an abundance of electrons on one layer and too few on the other. The missing electrons are called holes. When the chip is energised, the electrons and holes are pushed together, confined to the intermediate quantum-well layer where they are attracted to combine, shedding their excess energy (ideally) by emitting a photon of light.

At low power, nitride-based LEDs (most commonly used in white lighting) are very efficient, converting most of their energy into light. But turn the power up to levels that could light up a room and efficiency plummets, meaning a smaller fraction of electricity gets converted to light. This effect is especially pronounced in green LEDs, giving rise to the term "green gap."



Simulation of a 1nm wide InN wire shows the distribution of an electron around a positively charged 'hole.' Strong quantum confinement in these small nanostructures enables efficient light emission at visible wavelengths (Credit: Burlen Loring, Lawrence Berkeley National Laboratory)

Nanomaterials offer the tantalising prospect of LEDs that can be grown in arrays of nanowires, dots or crystals. The resulting LEDs could not only be thin, flexible and high-resolution, but very efficient, as well.

"If you reduce the dimensions of a material to be about as wide as the atoms that make it up, then you get quantum confinement. The electrons are squeezed into a small region of space, increasing the bandgap energy," Kioupakis explains. That means the photons emitted when electrons and holes combine are more energetic, producing shorter wavelengths of light.

The energy difference between an LED's electrons and holes, called the bandgap, determines the wavelength of the emitted light. The wider the bandgap, the shorter the wavelength of light.

The bandgap for bulk InN is quite narrow, only 0.6 electron volts (eV), so it produces infrared light. In Bayerl and Kioupakis' simulated InN nanostructures, the calculated bandgap increased, leading to the prediction that green light would be produced with an energy of 2.3eV.

"If we can get green light by squeezing the electrons in this wire down to a nanometre, then we can get other colours by tailoring the width of the wire," notes Kioupakis. A wider wire should yield yellow, orange or red. A narrower wire, indigo or violet.

That bodes well for creating more natural-looking light from LEDs. By mixing red, green and blue LEDs engineers can fine tune white light to warmer, more pleasing hues. This "direct" method isn't practical today because green LEDs are not as efficient as their blue and red counterparts.

Instead, most white lighting today comes from blue LED light passed through a phosphor, a solution similar to fluorescent lighting and not a lot more efficient. Direct LED lights would not only be more efficient, but the colour of light they produce could be dynamically tuned to suit the time of day or the task at hand.

Using pure InN, rather than layers of alloy nitride materials, would eliminate one factor that contributes to the inefficiency of green LEDs: nanoscale composition fluctuations in the alloys. These have been shown to significantly impact LED efficiency.

Also, using nanowires to make LEDs eliminates the "lattice mismatch" problem of layered devices. "When the two materials don't have the same spacing between their atoms and you grow one over the other, it strains the structure, which moves the holes and electrons further apart, making them less likely to recombine and emit light," explains Kioupakis, who discovered this effect in previous research that also drew on NERSC resources. "In a nanowire made of a single material, you don't have this mismatch and so you can get better efficiency," he says.

The researchers also suspect the nanowire's strong quantum confinement contributes to efficiency by squeezing the holes and electrons closer together, a subject for future research. "Bringing the electrons and holes closer together in the nanostructure increases their mutual attraction and increases the probability that they will recombine and emit light." Kioupakis continues.

While this result points the way towards a promising avenue of exploration, the researchers emphasize that such small nanowires are difficult to synthesise. However, they suspect their findings can be generalised to other types of nanostructures, such as embedded InN nanocrystals, which have already been successfully synthesised in the few-nanometres range.

NERSC's newest flagship supercomputer (named "Edison" in honour of American inventor Thomas Edison) was instrumental in their research, says Bayerl. The system's thousands of compute cores and high memory-per-node allowed Bayerl to perform massively parallel calculations with many terabytes of data stored in RAM, which made the InN nanowire simulation feasible.

According to Bayerl, "We also benefited greatly from the expert support of NERSC staff". Burlen Loring of NERSC's Analytics Group created visualisations for the study, including the journal's cover image. The researchers also used the open-source BerkeleyGW code, developed by NERSC's Jack Deslippe.

The results were published online in February in the paper, "Visible-Wavelength Polarized Light Emission with Small-Diametre InN Nanowires," by Dylan Bayerl *et al* in *Nano Lettters*

DOI: 10.1021/nl404414r

This work was supported as part of the Centre for Solar and Thermal Energy Conversion, an Energy Frontier Research Centre funded by the U.S. Department of Energy Office of Science.

DOE's Office of Science is the single largest supporter of basic research in the physical sciences in the United States, and is working to address some of the most pressing challenges of our time.

Polymer cools down LEDs at 200 degrees C

A novel thermal interface material could be used to draw heat away from high-brightness LEDs and other semiconductor devices

Polymer materials are usually thermal insulators.

But by harnessing an electropolymerisation process to produce aligned arrays of polymer nanofibres, researchers have developed a thermal interface material able to conduct heat twenty times better than the original polymer. The modified material can reliably operate at temperatures of up to 200 degrees Celsius.

The new thermal interface material could be used to draw heat away from electronic devices in servers, automobiles, high-brightness LEDs and certain mobile devices. The material is fabricated on heat sinks and heat spreaders and adheres well to devices, potentially avoiding the reliability challenges caused by differential expansion in other thermally-conducting materials.

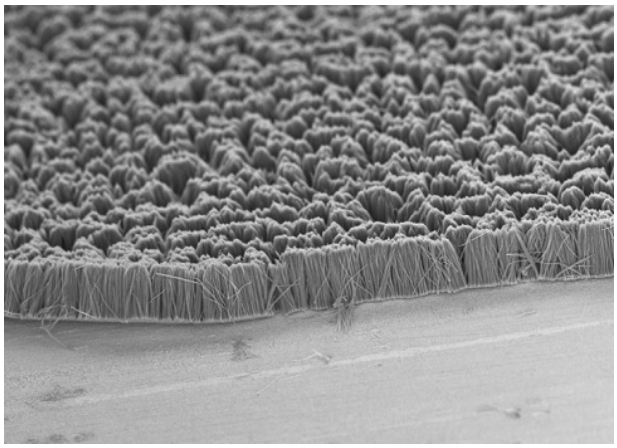
"Thermal management schemes can get more complicated as devices get smaller," notes Baratunde Cola, an assistant professor in the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology. "A material like this, which could also offer higher reliability, could be attractive for addressing thermal management issues. This material could ultimately allow us to design electronic systems in different ways."

The research was reported March 30th in the online publication *Nature Nanotechnology*. The project involved researchers from the Georgia Institute of Technology, University of Texas at Austin, and the Raytheon Company. Virendra Singh, a research scientist in the Woodruff School, and Thomas Bougher, a Ph.D. student in the Woodruff School, are the paper's co-first authors.

Amorphous polymer materials are poor thermal conductors because their disordered state limits the transfer of heat-conducting phonons. That transfer can be improved by creating aligned crystalline structures in the polymers, but those structures - formed through a fibre drawing processes - can leave the material brittle and easily fractured as devices expand and contract during heating and cooling cycles.

According to Cola, the new interface material is produced from a conjugated polymer, polythiophene, in which aligned polymer chains in nanofibres facilitate the transfer of phonons - but without the brittleness associated with crystalline structures. Formation of the nanofibres produces an amorphous material with thermal conductivity of up to 4.4 watts per metre Kelvin at room temperature.

The material has been tested up to 200 0C, a temperature that could make it useful for applications in vehicles. Solder materials have been used for thermal interfaces between chips and heat sinks, but may not be reliable when operated close to their reflow temperatures.

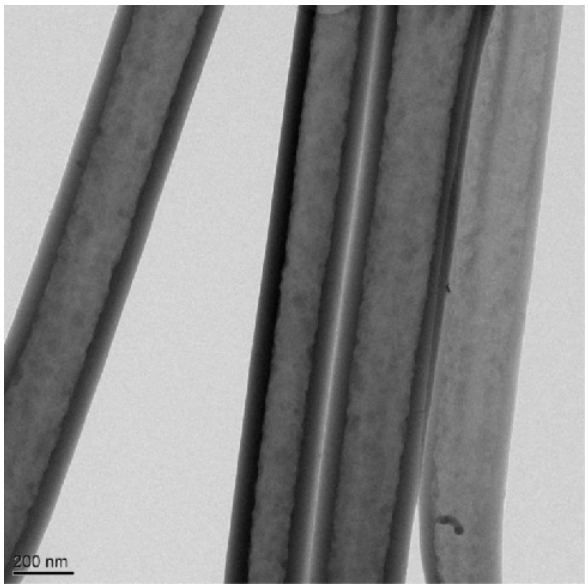


Scanning electron microscope image shows vertical polythiophene nanofibre arrays grown on a metal substrate. The arrays contained either solid fibres or hollow tubes, depending on the diameter of the pores used to grow them. (Credit: Virendra Singh)

"Polymers aren't typically thought of for these applications because they normally degrade at such a low temperature," Cola explains. "But these conjugated polymers are already used in solar cells and electronic devices, and can also work as thermal materials. We are taking advantage of the fact that they have a higher thermal stability because the bonding is stronger than in typical polymers."

The structures are grown in a multi-step process that begins with an alumina template containing tiny pores covered by an electrolyte containing monomer precursors. When an electrical potential is applied to the template, electrodes at the base of each pore attract the monomers and begin forming hollow nanofibres.

The amount of current applied and the growth time control the length of the fibres and the thickness of their walls, while the pore size controls the diameter. Fibre diameters range from 18 to 300 nm, depending on the pore template.



Transmission electron microscope image shows four polymer nanofibres with hollow structure. The thickness of the walls of the tubes ranged from 40 to 80 nm, depending on the amount of current applied and the growth time. (Credit: Ye Cai)

After formation of the monomer chains, the nanofibres are cross-linked with an electropolymerisation process, and the template removed. The resulting structure can be attached to electronic devices through the application of a liquid such as water or a solvent, which spreads the fibres and creates adhesion through capillary action and van der Waals forces.

"With the electrochemical polymerisation processing approach that we took, we were able to align the chains of the polymer, and the template appears to prevent the chains from folding into crystals so the material remained amorphous," Cola explains. "Even though our material is amorphous from a crystalline standpoint, the polymer chains are highly aligned - about 40 percent in some of our samples."

Though the technique still requires further development and is not fully understood theoretically, Cola believes it could be scaled up for manufacturing and commercialisation. The new material could allow reliable thermal interfaces as thin as three microns - compared to as much as 50 to 75 µm with conventional materials.

"There are some challenges with our solution, but the process is inherently scalable in a fashion similar to electroplating," he says. "This material is well known for its other applications, but ours is a different use."

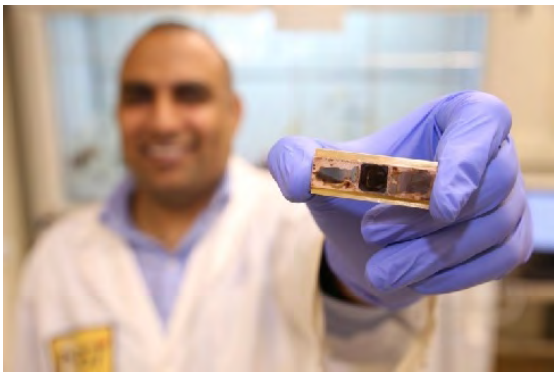
Engineers have been searching for an improved thermal interface material that could help remove heat from electronic devices. The problem of removing heat has worsened as devices have gotten both smaller and more powerful.

Rather than pursue materials because of their high thermal conductivity, Cola and his collaborators investigated materials that could provide higher levels of contact in the interface. That's because in some of the best thermal interface materials, less than one percent of the material was actually making contact.

"I stopped thinking so much about the thermal conductivity of the materials and started thinking about what kinds of materials make really good contact in an interface," Cola comments. He decided to pursue polythiophene materials after reading a paper describing a "gecko foot" application in which the material provided an estimated 80 percent contact.

Samples of the material have been tested to 200 0C through eighty thermal cycles without any detectable difference in performance. While further work will be necessary to understand the mechanism, Cola believes the robustness results from adhesion of the polymer rather than a bonding.

"We can have contact without a permanent bond being formed," he adds. "It's not permanent, so it has a built-in stress accommodation. It slides along and lets the stress from thermal cycling relax out."



Research scientist Virendra Singh holds a test sample used to measure thermal conductance and thermal cycle reliability in a new polymer material developed to remove heat from electronic devices. (Georgia Tech Photo: Candler Hobbs)

A patent application has been filed on the material. Cola has formed a startup company, Carbice Nanotechnologies, to commercialise thermal interface technologies. It is a member of Georgia Tech's VentureLab program.

The research has been described in the paper, "High thermal conductivity of chain-oriented amorphous polythiophene," by Virendra Singh, *et al*. in *Nature Nanotechnology, 2014*. doi:10.1038/nnano.2014.44

http://www.dx.doi.org/10.1038/nnano.2014.44

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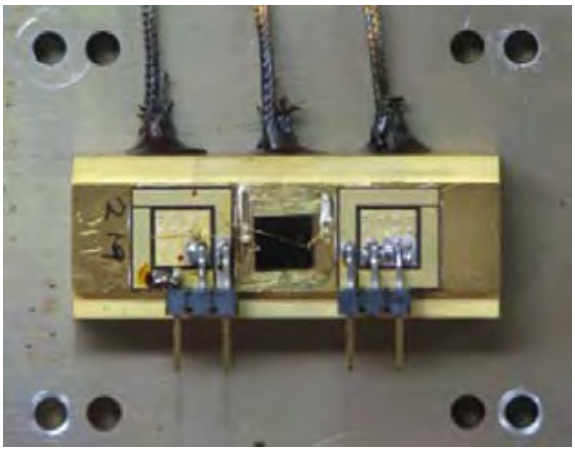


This image shows testing of a polythiophene nanofibre array grown on a copper heat sink and dried in contact with a SiC RF device simulator. (Credit: Daniel P. Resler)

Samco to distribute VPE`s MOCVD tools

Regions where Samco will distribute the reactors include the Far East and Europe. The systems are used in GaN and solar cell production

Valence Process Equipment (VPE) of Branchburg New Jersey has signed an agreement with Samco Inc., based in Kyoto, Japan, to distribute VPE's MOCVD equipment.

The agreement gives Samco exclusive distribution rights in Japan as well as non-exclusive rights to sell the products in a number of other countries including China, South Korea and Europe.

VPE is a technology company that has developed a novel MOCVD reactor for GaN based semiconductor devices including High Brightness LED's for Solid State Lighting.

The unique patented design of the VPE system is claimed to reduces consumption of expensive gases and metal-organic precursors by up to 40 percent in comparison with competing products. VPE's initial product was the GaN-500 reactor, announced in 2011, with a current capacity of 59 x 2" or 18 x 4" wafers. VPE has recently released the GaN-550 MOCVD reactor with a capacity of 72 x 2" or 20 x 4" wafers.

Valence GaN_500 Reactor

Samco is a provider of dry etch and plasma CVD systems to the global Compound Semiconductor Industry.

Recently, Samco has placed a focus on selling next-generation production equipment for GaN power devices that are a cornerstone of "green electronics" and have a large impact on energy efficiency. The addition of MOCVD strengthens Samco's product line-up as MOCVD, plasma-CVD, dry etching and surface treatment systems can be bundled to provide a "one stop solution" for customers involved in GaN semiconductor applications.

As part of the agreement Samco will purchase and install a GaN-550 MOCVD system in its facility in Kyoto for customer demonstrations. Installation is planned for July 2014 and the

system will be used to develop novel power device epitaxial structures on large diameter wafers in collaboration with a key customer.

VPE CEO and Founder, Frank Campanale, comments, "We are delighted to embark on this partnership with a highly respected and capable company like Samco. Our MOCVD system complements Samco's existing product range and creates a unique suite of products for the GaN semiconductor community".

Altatech wins CVD system order from U.S. university

The tool will be used in the production of advanced LEDs and solar cells and silicon based devices

Altatech, a subsidiary of Soitec, has received an order from the University of Washington in Seattle for an AltaCVD system.

The tool offers a combination of capabilities that allows users to develop new process materials with higher added value.

Altatech's CVD system will be installed at the University's Washington Nanofabrication Facility (WNF), where it will be used by both internal and external researchers in fabricating a broad range of semiconductor-based devices.

These will include advanced LEDs, solar cells, CMOS transistors, MEMS and ICs built with the latest in through-silicon-via (TSV) technology,

Altatech's pulsed CVD systems are currently used n R&D iand pilot production facilities throughout Europe. However, the University of Washington's order represents the first such system to be delivered to a North American university R&D and pilot production facility.

The university's acquisition of the AltaCVD system, along with recent installations of an advanced deep reactive ion etcher (DRIE) and a plasma-enhanced CVD (PECVD) tool, provides the capability to assemble an electroplated TSV fill process.

Commenting on the tool's capabilities, Michael Khbeis, acting director of the WNF, claims, "The AltaCVD system provides a unique capability that enables researchers to deposit conformal metal films for TSV applications as well as metal oxides and nitrides for high-k dielectrics and piezoelectric materials."

"The higher deposition rate enabled by pulsed CVD makes ALD (atomic layer deposition) films a tractable solution for scale-up paths toward high-volume manufacturing for our researchers and industrial clients. This ensures a viable pathway from academia to real economic impact in our region," he adds.

"Extending the use of our CVD systems into this acclaimed user facility in North America continues to demonstrate the widely recognised advantages of our pulsed deposition technology," says Jean-Luc Delcarri, general manager of Soitec's Altatech subsidiary. "We are very pleased to add the University of Washington to the growing list of our CVD equipment adopters."

Altatech will support its AltaCVD installation at the University of Washington from its U.S.-based business and service operation centre.

The AltaCVD system uses pulsed deposition technology to offer a unique combination of capabilities for developing new materials. It can perform ALD for exceptional 3D coverage at deposition rates matching those of more conventional CVD techniques.

This allows superior stoichiometry control while creating highly conformal thin and thick films, which cannot be achieved using many of today's existing technologies.
Altatech's system design combines a unique vaporiser technology, gas/liquid panel integration, dual-channel showerhead and chamber design. The combination of Altatech's proprietary reactor design and precursor introduction path with pulsed liquid injection and vaporisation enables nanoscale control of film thickness, uniformity, composition and stoichiometry in complex materials.

Osram exploits the diverse options of light

The Lightify product enables living rooms, workrooms, balconies and gardens to be bathed in a wide variety of light atmospheres using a smartphone or tablet

With Lightify, Osram has presented a lighting system at Light+Building 2014 that enables users to exploit a wide range of lighting possibilities using an app on a smartphone or tablet.

Lightify simply integrates into existing WLAN networks, and users are able to set a wide diversity of light atmospheres.

"Connected light is yet another important step for us towards the digital light era. With Lightify we have transformed an idea into an innovation that contains almost everything that light is able to do today," says Peter Laier, Osram's Chief Technology Officer and executive board member responsible for the company's general illumination business.

Lightify will be available from the start of the coming lighting season in Germany and other European markets.

Lightify contains almost everything that light is able to do today

Lightify enables living rooms and workrooms as well as balconies and gardens to be bathed in a wide variety of light atmospheres using a smartphone or tablet. The scenes can be freely configured and also controlled while on the move. In addition, the app also provides programmed light scenes such as a realistic sunrise for example, and selection can also be based on photos.

Lightify is not only able to design rooms in light differently each day, the light itself can also be useful for the sense of well-being. The right scene helps people to get out of bed better in the morning and to sleep more easily in the evening.

On vacations, users at home can flexibly create dynamic light profiles before or while away using the absence mode, which can offer greater protection from burglars when compared to standard time clocks.

Lightify can be simply integrated into the existing WLAN network and Lightify components interconnect automatically. The complete Lightify range of LED lamps and luminaires can be controlled independent of the location, whether this is for corridors or living rooms, terraces and gardens or professional lighting in offices.

Osram with its Lightify system is following an integrative approach and provides corresponding products from a single source. Installed lighting systems and products from other manufacturers that support the common ZigBee Light Link standard or Home Automation standard can also be simply integrated into the system. In addition, the Lightify system offers an interface for the so called DALI standard. DALI is widely used in professional applications in Europe.

Lightify should be available from the coming light season onwards in a version for end consumers and a second version for professional users, and the starter kit for end customers consists of the gateway and a lamp. The app is free and available from various app stores.

Lumileds creates LED for mass lighting market

The LUXEON 3020 emitter crosses the 1,000 lumens per dollar threshold

Philips Lumileds is launching the LUXEON 3020 emitter, which is aimed at driving a variety of commercial LED lighting fixtures into the mass market, including lamps and troffers.

"The LUXEON 3020 is the most affordable of all our mid-power LEDs, delivering over 1,000 lumens per dollar. This product will inspire the market with the next generation of high quality, efficient and attractively priced LED lamps," says Orson Lo, Product Manager, Philips Lumileds.

Like other offerings in the company's mid-power portfolio, the LUXEON 3020 also features hot colour targeting and a 1/9th micro colour binning structure. Philips Lumileds hot colour targeting ensures the colour temperature remains within ANSI specifications at operating conditions.

With the new binning option, customers have the ability to select portions of the bin structure that are within the ANSI, 5-step MacAdam Ellipse or 3-step MacAdam Ellipse regions, achieving the colour point needed for a particular application.

For designers of lamps, troffers, TLEDs, high bay and low bay luminaires, the LUXEON 3020 produces 90 lm at 6500K and 80 CRI when driven at the maximum drive current of 240 mA.

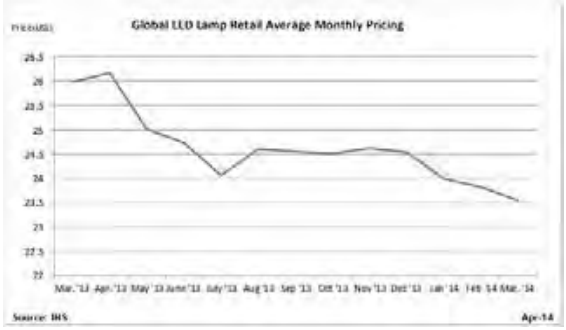
The LUXEON 3020 also features the use of epoxy molding compound (EMC) along with QFN packaging technology to deliver superior reliability and thermal properties. Typical efficacy of the LUXEON 3020 is 135 lm/W at 6500K at a CRI of 80 and drive current of 120 mA.

Global LED lamp retail price drops 9.4 percent

During the past 12 months the lumens per dollar ratio of LED lamps has increased by 17.5 percent to 30.2 lumens per dollar

The March 2014 release of the IHS Technology LED lamp Retail Price Tracker has found the global average LED lamp retail price was $23.5, indicating a fall of 1.2 percent in March 2014 over February 2014 and a 9.4 percent drop from the same time last year.

IHS has been tracking the LED lamp retail pricing trends for more than two years. Each month IHS analysts sample over 2,500 individual LED lamps sold in retailers across 15 countries globally.



Hamamatsu reveals high output 870nm LED

The III-V based LED is suited for optical fibre communications

Hamamatsu Photonics has launched a new 870nm LED, the L11368 to its range of high quality LEDs.

L11368 LED module

This new LED features a special microball lens that is bonded to the LED chip surface, with an additional mini-lens within the can package to make a very narrow emission beam.

This process allows for highly efficient input of the beam into an optical fibre. The new device features a cut-off frequency of 50Mhz and a high fibre end output of 65μW. The new LED is packaged in a high reliability TO can.

Hamamatsu says the high speed and output power make the L11368 an ideal and affordable solution for optical fibre communications.

Bridgelux extends COB LED light source warranty to 10 years

Built to reflect the lifespan of LED lighting, the announcement provides customers and end-users with a new level of confidence backed by the performance of Bridgelux Vero Series LED arrays

Bridgelux products will be backed with, what it says is, the world's first 10 year warranty for its Chip-on-Board (COB) products.

Bridgelux has over ten years of solid-state lighting innovation experience.

In 2010, the firm claimed it was the first company to introduce the five year warranty for COB products. The company is now introducing higher levels of quality and assurance with the new ten year warranty.

This new ten year warranty applies to Vero Series LED arrays shipped on or after April 16th, 2014.

Vero LED arrays

"The level of R&D, technology, product development focus and investment Bridgelux has made over the years is paying off. It is rewarding to be in a market leadership position to continuously add value to our products, solve customer specific problems and see an immediate return on investment," says David Connors, VP Product Marketing.

The announcement is made during this week's Light + Building exhibition in Frankfurt, Germany where Bridgelux has introduced the OLM Series integrated subsystem for outdoor applications and several new CCT and CRI combinations available for its Vero Series LED product line.

The Vero Series LED array portfolio gives manufacturers the flexibility to develop and manufacture high quality light solutions tailored for specific applications, delivering the light output and colour temperatures required for retail, hospitality, commercial, industrial, residential and outdoor lighting applications.

Vero Series LED arrays, for instance, can be employed to create fixtures that deliver ultra-white light for surgical theaters and healthcare facilities, or cool white, ultra-high CRI light combinations for television studios. Vero Series products can also be used to carefully tune colour temperatures for bakery, grocery, deli or textile displays.

In addition, Bridgelux is showcasing new Zhaga options for the Vero Series LED arrays this week at the conference, further enhancing its compatibility and flexibility with Zhaga-based luminaries around the globe.

Lextar to debut `White Chip` LED

The III-nitride based module is claimed to have an efficiency of 200 lumens per Watt

Lextar Electronics, a vertically integrated LED company, has announced the packaging-free 'White Chip' to demonstrate its new achievement in LED technology.

It is being demonstrated in various LED lamps, including the 50-watt halogen equivalent GU10 LED spot lamp, point-light candle lamp, and omni-directional LED tube.

Lextar's new White Chip technology involves substrate-free flip chip and phosphor molding process, and can be fabricated by current SMT equipment. These features can simplify the manufacturing process significantly.

Lextar White Chip LED

The firm's device is a chip scale die without packaging process, featuring high lumen densities, high lumen output, wide beam angle, and can be packaged closer therefore simplify optical lens design.

Lextar's White Chip can be applied to lighting products especially small sized lamps such as spot or candle lamps. It can also be applied to backlighting, helping reduce the thickness of direct-lit backlight modules.

When used in GU10 spot lamp, this White Chip can achieve high lumen output and high lumen intensity, reaching up to 2500cd at a 25 degree beam angle; with a CRI 90 performance, making it a replacement for a 50 Watt halogen lamp.

The White Chip also gives its point-light candle lamp identically glowing effects to the starlight indoors.

Moreover, the light tube equipped with White Chip and COG (Chip on Glass) technology, on the other hand, allows 3600 illumination reaching an efficiency of 200 lumens per Watt.

"Since LED companies have been eager to attempt simplified manufacturing process at reduced costs in these few years, flip chip and several packaging-free LED products are getting more popular," says Reg Tsai, Director of Technology R&D Division of Lextar.

Thanks to its vertical integration, Lextar provides products and services through different stages from upstream chip to finished lighting products.

The company expects to move this newly launched White Chip into market during Q2 this year.

Cree breaks 300 lumens-per-Watt barrier

The company's III-nitride on SiC LED technology is continuing to push the boundaries of LED performance

Cree has demonstrated 303 lumens per watt from a white, high-power LED. This result surpasses Cree's previous R&D record of 276 lumens per watt announced just over a year ago.

Cree's LEDs combine InGaN materials with proprietary G•SIC substrates to deliver high-intensity LEDs.

"This is truly an impressive accomplishment. Achieving this level of LED efficacy amplifies the potential for the solid-state-lighting industry to deliver smaller, lower-cost lighting solutions, and even larger-than-expected energy savings," says Steven DenBaars, professor and co-director, Solid State Lighting and Energy Centre, University of California, Santa Barbara.

Cree reports that the LED efficacy was measured at 303 lumens per watt, at a correlated colour temperature of 5150 K and 350 mA. Standard room temperature was used to achieve the results.

"Relentless innovation is a driving force at Cree as we continue the pursuit of 100-percent LED adoption," says John Edmond, Cree co-founder and director of advanced optoelectronics. "Pushing the boundaries of LED performance is critical to enhancing LED lighting designs, and this 303 lumens-per-watt result will enable more cost-effective lighting solutions."

Cree reveals industry's first 8000-lumen LED module

The LMH2 LED GaN module family enables the complete replacement of 150-watt ceramic metal halide lamps

Cree is introducing the new 8000-lumen LMH2 LED module, an easy-to-use solution for high-ceiling applications.

The 8000-lumen LMH2 is designed to replace 150-watt ceramic-metal-halide (CMH) lamps while using only 63 percent of the power and lasting three times as long. With the addition of the 8000-lumen LMH2, the Cree LMH2 LED module family offers a broad range of lumen output from a single form factor, making it possible to obsolete CMH technology.

Cree LMH2 8000-lumen LED Modules

"The new Cree 8000-lumen LMH2 LED Module allows us to effectively address high-ceiling, high-lumen applications without having to sacrifice colour quality or reliability," says Wesley Johnson, product manager, Hi-Lite Mfg. "We can now easily offer our customers better lighting solutions to replace 150-watt ceramic-metal-halide lamps in spaces such as convention centres, airports, auditoriums and shopping malls."

Cree's LMH2 LED module series provides an extensive range of light output (850 to 8000 lumens) from a single light source, enabling lighting manufacturers to quickly develop an entire product portfolio with just one set of tooling and optical design. Lighting designers can now utilise one light source and technology to illuminate an entire space and avoid problems such as colour inconsistency and re-lamping.

"Having an 8000-lumen option in the LMH2 LED module family gives us the flexibility to create an entire product family from a single form factor," says Chris Roemlein, president, Spectrum Lighting. "Cree's ability to increase the performance of the LMH2 Module allows us to address a wide range of ceiling heights with minimal design investment."

Cree will be at Light+Building 2014 at Hall 5.0, Stand C34, and will showcase the entire LMH2 LED module family.

Samples and production quantities are available with standard lead times from Cree distributors. Cree also offers a complete ecosystem of LED accessories to help lighting manufacturers speed their time to market.

Soraa to showcase new GaN-on-GaN lamps

The company will display its Simply Perfect PAR and AR111 lamps next week at Light + Building

Soraa has announced a full range of LED AR111, PAR30, and PAR38 lamps that will be available to ship in late Q2 2014.

All Soraa lamps feature 3-phosphor GaN-on-GaN LEDs with violet pump that enable benefits such as Point Source Optics for uniform beams of high intensity, Violet 3-Phosphor (VP) Natural White and VP Full-spectrum Vivid Colour, which reveal the magic of whiteness and colours in every environment.

Now, Soraa's Simply Perfect Light is available in a portfolio of larger form factors essential for retail, hospitality and residential applications.

Since its 2012 launch, the Soraa says its LED MR16 lamp has become synonymous with exceptional light quality and innovative design, which is continued in this portfolio expansion.

Soraa's signature elements of Simply Perfect Light, powered by its GaN on GaN LED technology, shift the landscape completely.

In addition, Soraa's SNAP System provides a lamp-accessory solution that delivers endless design and display possibilities and ANSI/IEC conforming form factors for worry-free fit and reliable operation in both enclosed and open fixtures.

"We eagerly anticipated Soraa's MR16 product becoming available on the market, and it met all our expectations. Its narrow, tight, and very bright beam projects an even field of natural light thanks to its full-spectrum colour rendering, and its clean single shadow," says Johan Sustrac, CEO of the prominent Paris-based lighting design firm Distylight.

The Distylight projects include Club Med Bahamas, the Kuznetsky Hotel in Moscow, the Pathé Gaumont cinemas in France and numerous hotels in Paris like Hotel Codet or Hotel Rebuplique.

"We love the smart SNAP System that provides us lighting designers with endless possibilities and huge flexibility to change the spread and colour temperature of our LED, without having to change our source. We are also looking forward to having Soraa's AR111 on the EU market, especially for its high power performance, its dimmable aspect and of course the

great flexibility of the SNAP System," continues Sustrac.

Soraa's large lamp portfolio of AR111, PAR30 Long Neck (LN), PAR30 Short Neck (SN) and PAR38 lamps achieve 1000 lumen output with VP Natural White and VP Vivid Colour technology, defined by full-visible-spectrum, high whiteness rendering, 95-CRI, and 95-R9. The family of large lamps will be available in 25°, 36°, and 60° beam angles, and in a wide range of colour temperatures.

The AR111 is an important lamp for object lighting, requiring narrow spots, crisp beam edges, and no glare. With a peak intensity of 27,500Cd, Soraa's 8° 95-CRI/95-R9 AR111 is the only LED product that matches halogen levels, 50 percent higher than the nearest 80-CRI competitor.

The PAR30LN and PAR30SN lamps offer a 8° narrow spot option on the market without active cooling, achieving a centre beam intensity of 28,250Cd, more than twice the level of the nearest 80-CRI competitor.

Samsung unveils versatile flip chip LED packages and modules

all line-up of LED component solutions

Samsung Electronics has introduced a new line-up of flip chip LED packages and modules offering enhanced design flexibility and a high degree of reliability.

The new offerings, for use in LED lighting such as LED bulbs, MR/PAR and downlights, will be available in the market during the second quarter of this year.

"By utilising an advanced flip chip technology, Samsung has made significant improvements to its LED packages and modules," says Bangwon Oh, senior vice president, LED strategic marketing team, Samsung Electronics. "Our new Samsung FC and FCOM solutions also strengthen our overall line-up of LED component solutions, further enhancing our market competitiveness."

Samsung's new flip chip (FC) LED package and flip chip on module (FCOM) solutions feature highly efficient and versatile LED structures, created by flipping over blue LED chips and adhering phosphor film to each of them. Unlike conventional LED packages that dispense phosphor and then place a plastic mold over each chip, Samsung's FC package technology can produce LED packages down to a chip-scale size without any mold, enabling more compact lighting fixture designs.

Samsung Flip Chip FCOM LED Lighting

Samsung's new FC and FCOM series can be driven at a current higher than that of conventional LED components, and have low thermal resistance. The low thermal resistance improves the reliability of the FC and FCOM solutions, resulting in higher flux, and a decrease in the number of packages needed, plus a reduction in the size of the circuit board.

Also, by attaching a cell film, each package gains uniform thickness and lower colour deviation. As a result, the FC and FCOM solutions provide a high level of colour consistency and ensure the chromaticity control of MacAdam 3-step ellipses.

The new FC and FCOM LED solutions include a middle power LED package (LM131A), a high power LED package (LH141A) and an LED downlight module, all featuring the new Samsung flip chip technology.

Flip chip middle power LED package (LM131A) and high power LED package (LH141A)

Samsung's LM131A and LH141A flip chip packages feature exceptionally compact form factors of 1.22x1.22 millimetres and 1.4 x 1.4mm, respectively. By excluding a plastic mold, the two packages can function at a high current level in a highly reliable manner, even after long hour of use. These advantages make them ideal for use in LED lighting applications requiring a small form factor with high light output, including LED bulbs and spotlight products such as MRs and PARs.

In addition, the use of a phosphor film assures colour quality that satisfies the MacAdam 3-step.

Flip chip on module (FCOM) for LED downlight fixtures

Samsung's new FCOM downlight products are distinguished by their high light output. Compared to a chip-on-board (COB) engine, which has a fixed wattage, the new FCOM permits simple adjustments in the number of FC LED packages to make the module compatible with a variety of electrical drivers of different wattages, in allowing greater design flexibility.

To create a downlight with 1000lm output and 100lm/W efficacy, Samsung FCOMs require a 1.7 x 1.7 centimetre circuit. Such a small form factor makes these FCOMs well-suited for size-sensitive LED lighting applications, which include LED bulbs, MR/PAR spotlights, downlights and even cove lighting.

Samsung's FCOMs satisfy the MacAdam 3-step and can support MacAdam 2-step depending on customer needs,

thanks to the superb color consistency of the chips and a rating of at least 80 on the colour rendering index (CRI). The new Samsung FCOMs also offer a range of correlated colour temperature (CCT) – from 2700K to 5000K.

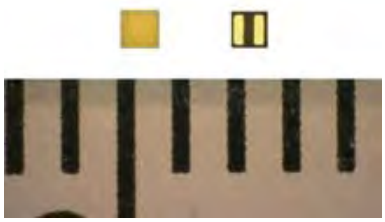
Toshiba reveals ultra-small chip white LEDs

The compact scale GaN-on-silicon package is claimed to reduce mounting area by 90 percent

Toshiba Corporation has announced the launch of ultra-small chip scale package white LEDs for lighting applications.

The company claims the device can reduce the mounting area by 90 percent compared to conventional 3.0 x 1.4 mm package products. This is according to a Toshiba survey.

The new TL1WK series will start sample shipment from April.



TL1WK LED

The new products utilise GaN-on-silicon process technology and a new process technology that fabricates the elements of a packaged LED on an 8-inch silicon wafer. The LEDs are claimed to be the industry's smallest in sub-watt class (1/4-1/2W) white LEDs as of a March 27th, 2014 Toshiba survey.

The package size is 0.65 x 0.65mm, and the LED achieves a luminous efficacy of 130lm/W during 60mA operation and superior heat dissipation. Using the new white LEDs makes it possible to achieve a narrow beam in small-size lighting equipments and can contribute to innovation in lighting design.

Applications of the LED includes light sources for general lighting, including straight tube lights, light bulbs and ceiling lights.

The colour temperature is 5000K, the colour rendering Index (Ra) is 80 (Min) while the forward current is 180mA (Max).

Colour variations under planning for 4000K, 3000K and 2700K.

IQE revenues up 44 percent thanks to wireless

The robust wireless business and diversification strategy drives strong rises in revenues, profit and earnings

IQE has announced its final results for the year ended 31st December 2013.

The firm achieved a new Group record of £126.8 million, up from £88.0 million in 2012.

This includes £30.9 million revenues from Kopin Wireless, acquired in January 2013. However, the company was affected by adverse H2 currency impact as sterling appreciated 3 percent against the US dollar.

H2 wireless sales were up 3 percent over H1 in constant currency and H2 photonic sales were up 12 percent over H1 (in constant currency). The adjusted PBT was up 51 percent to £13.0 million from £8.6 million (Reported PBT £5.2 million).

The adjusted fully diluted EPS increased 43 percent to 2.00p from 1.40p (Reported fully diluted EPS 0.89p). Cash inflow from operations before exceptional items was up 346 percent from £4.7 million to £16.2 million.

Cash conversion before exceptional items was 111 percent up from 51 percent. Net debt was £34.4 million (opening net debt £15.5 million increased primarily due to £25 million of debt to part fund the Kopin acquisition.

Drew Nelson, IQE Chief Executive, made the following statement:

"IQE's core wireless division has again delivered a robust performance, with continued growth despite a significant downstream inventory correction in the major chip companies due to softness in the high end smartphone market. As a direct result of our customer risk mitigation strategy, which we have executed over the last 18 months and completed with the acquisition of Kopin Wireless, we are much less sensitive to market share shifts between the major chip supply companies.

"Concerns in the UK over the last year that silicon CMOS would significantly damage the Compound Semiconductor industry have proved unfounded and are not reflected in our financial performance nor in our customers' expectation of future long term demand drivers.

"Wireless remains an attractive market for us over the coming years with demand continuing to be driven by the proliferation of wireless applications and the need for sophisticated GaAs chips to deal with the explosive growth in data traffic. Beyond this, the next waves of innovation which will drive handset replacement cycles are likely to include lasers and sensors using compound semiconductor technology, for gaming, 3D image capture, gesture recognition, and sensing for a variety of applications including healthcare monitoring devices.

"Our business diversification strategy also gained strong traction, and we achieved a number of significant technical and commercial milestones during 2013 which reflect the

strong progress made in our other key markets including photonic sensors and lasers, advanced solar (CPV), power semiconductors, infrared, LED and advanced electronics.

"Our integration remains firmly on track, and we expect to realise significant reductions in our financial overheads, whilst benefiting greatly from the operational and technical synergies we are delivering.

"IQE is at the forefront of the enabling technologies that are at the very heart of many of the twenty-first century trends and products. We are confident that the Group is well positioned for continued growth in earnings and cash flow in 2014 and beyond."

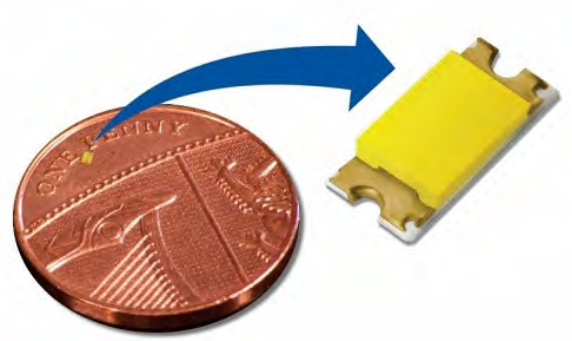
Plessey launches GaN-on-silicon LEDs for wearables

The gallium nitride on silicon dotLED is 0.2mm in height and designed for applications that demand low profile electronic components

Plessey has announced the launch of its smallest packaged MaGIC LED manufactured on a GaN-on-silicon I/C. aimed at the surging wearable electronics market.

The PLW138003 is a white LED in a 1005 SMT package designed specifically for the demand for ever smaller LED components producing highly collimated light.

Plessey's dotLEDs weighing 0.2 milligrams and a profile of 0.2mm are an option for any wearable application with LED content.



Plessey dotLED

The 1005-size of the PLW138003 (1.0mm x 0.5mm) is a standard electronic component size, handled by the common surface-mount machines used in high volume consumer electronics. The Plessey dotLED is 0.2mm in height and designed specifically for applications that demand low profile electronic components.

This first product in Plessey's dotLED family is the PLW138003, delivering up to 0.7lm of white light with a 1300 viewing angle from a 5mA drive current. A blue version, the PLB138003 is also available.

Further additions to the dotLED family will be colour variants and a series in the larger 1608 footprint. Plessey also provides a range of blue LED die for customers needing a further breakthrough in size: the PLB030003 ultra-thin die is just 200µm x 200µm x 7µm.

Plessey's LEDs are produced using its proprietary MaGIC technology. By using standard silicon semiconductor production techniques, Plessey is able to produce high-volume high-quality industry standard LEDs that are demanded in the consumer electronics market. The 1005-size dotLEDs are the latest product family to be released using this technology.

Jose Lopez, Plessey's Chief Commercial Officer, says, "Plessey is demonstrating its commitment to bringing to market a comprehensive range of LED products across all markets and applications. The dotLED family addresses the exacting optical, mechanical and cost requirements where small is beautiful."

For sample requests, you can visit the Plessey website, www.plesseysemiconductors.com or send an email to enquiries@plesseysemi.com.

Bridgelux to unveil advanced exterior LED sub-system

The LED based module is designed as a replacement for the high pressure sodium lamp

Bridgelux has unveiled the Outdoor Lighting Module (OLM); a new line of LED sub-systems which integrates optics, environmental protection and the LED source for roadways, parking garages and other outdoor and industrial applications.

Bridgelux Outdoor Lighting Module

OLM will allow manufacturers to rapidly expand their product lines while lowering costs.

Outdoor applications, including roadways, parking lots and flood lighting are some of the fastest growing segments in the industry. According to McKinsey & Company, LED based outdoor lighting solutions are expected to grow from six percent of the market ($10 billion USD) to 74 percent by 2020.

The new Bridgelux OLM Series incorporates a number of key technology advancements and features that will help luminaire manufacturers develop a broad range of differentiated outdoor lighting products with lower total costs, faster time to market, and industry leading energy efficacy.

The Bridgelux OLM Series is a platform that integrates a number of fundamental components for building solid-state luminaires into a single sub-system. OLM reduces product development time by three to six months, eliminating up to $100,000 in R&D expenses. Building solid-state fixtures with OLM can reduce manufacturing time by five to seven days.

When compared to conventional high pressure sodium systems, OLM can reduce the manufacturing cost of outdoor solid state lighting fixtures by 10 to 20 percent, and reduce maintenance costs while lowering power consumption by up to 65 percent.

Further more, OLM has been specifically designed to enable lighting manufacturers to reduce the overall bill of material cost of their luminaires and deliver a best-in-class cost to the market.

OLM's slim profile, impact resistant optics, and broad area lighting capabilities make it a platform for outdoor wall pack and flood light applications. Designed to be compliant with key light pattern standards (IESNA, EN13-201, NEMA), the OLM sub-system also has an Ingress Protection (IP) rating of 66; making it an ideal solution for harsh outdoor environments.

"Bridgelux continues to push the envelope in LED and SSL technology innovation, developing products that help light manufacturers and designers solve their biggest manufacturing problems and toughest challenges," says Brad Bullington, Bridgelux's chief executive officer. "We are now introducing the industry's most advanced and sophisticated LED sub-system for outdoor applications."

Bridgelux's proprietary integrated symmetric and asymmetric optics enable lighting manufacturers to design luminaires for targeted applications that spread light in more effective and efficient ways. OLM-based fixtures can also be designed into applications with specific lighting pattern requirements such as glare reduction and dark sky.

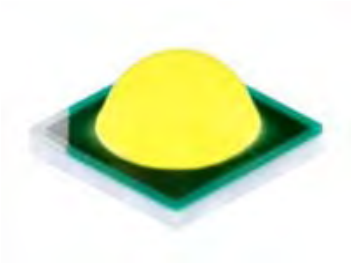
Bridgelux is initially launching six OLM subsystems ranging in power from 18 to 40 watts and estimated product lifetimes of 50,000 to 100,000 hours. The new OLM sub-system will be commercially available in June 2014 with pre-orders for this new product being accepted now.

Toshiba reveals two new series of GaN-on-silicon LEDs

The gallium nitride-on-silicon white LEDs are suited to general lighting applications. Mass production is expected to start at the end of March

Toshiba has revealed two new series of white LEDs.

These are the 3.5 x 3.5mm lens package 1W type TL1L2 series and the 3.0 x 3.0mm flat package 0.6W type TL3GB series.



Toshiba White LED: 3.5 x 3.5mm Lens Package 1W Type TL1L2 Series

Mass production of both will start from the end of March 2014.

Utilising GaN-on-silicon process technology, the new white LEDs are claimed to have a low forward voltage (VF) and low power consumption and can contribute to low power consumption and cost reductions.

The forward voltage (VF) is 2.85V at an IF of 350mA and the luminous efficacy is 135lm/W (5000K, Ra70) at 1W operation (IF = 350mA).

The TL3GB series has been designed for use in light sources for general lighting (including light bulbs, base lights, down lights and ceiling lights). The VF is 5.76V at an IF of 100mA and the luminous efficacy is 118lm/W (5000K, Ra80) at 0.6W operation (IF = 100mA).

The colour variation of both devices achieve 6 colour temperatures between 2700K and 6500K.

Seoul Semi launches new family of mid-power LEDs

The company has introduced the Acrich MJT 2525 series with high lumen density in a small footprint

Seoul Semiconductor has released a new generation of LEDs, the Acrich MJT 2525 series, with lumen density in the mid-power class.

The new mid-power product family series symmetrical package has dimensions of 2.5mm x 2.5mm and wide beam angles making these LEDs ideal for applications that require uniform illumination.

This new package is claimed to optimise light extraction from the package resulting in high luminous efficacies.

The Acrich MJT 2525 series high voltage mid-power package with a typical forward voltage of 22V. At 3000 Kelvin (K) and a CRI of 80 it achieves a brightness of 95 lumens (lm) and an efficacy of 105 lumens per watt (lm/W) at an operating current of 40 milliamps (mA) at 25°C.

With a lumen density of 15lm/mm2 this midpower package is suited to space constrained lighting applications. The wide viewing angle on these LEDs also helps implement the omni-directionality in replacement lamp designs.

The high voltage Acrich MJT 2525 series incorporates the Acrich- Multi-junction Technology with multiple junctions on a single monolithic chip eliminating the usage of multiple wire bonds between several die's to create the high voltage architecture.

This construction is said to improve the reliability of the LED package since it reduces the potential number of failure modes associated with wire bonds within the LED package. The high voltage architecture also enables the use of simpler, more cost-efficient drivers, compared to conventional LEDs.

The improved efficiency of the driver electronics also results in less heat generated and fewer electronic components used in the driver design allowing more space for thermal management within the luminare.

Seoul Semiconductor Executive Vice President of Lighting sales division, Jay Kim says that, "The new 2525 Series has unparalleled lumen density in the mid-power class of LEDs not only reducing the total system costs for designers but also enabling new possibilities in lighting design. To add to that the MJT 2525 series has higher cost efficiency than most mid-power packages and has already been adopted worldwide in a number of design by key customers".

MJT 2525	CCT	CRI	Size	Maximum Power Dissipation	Forward Current		Luminous Flux (lm)		Viewing Angle
	K	Ra	mm	W	Typ	Max	40mA	60mA	
	2600~3700	80	2.5x2.5	1.4	40	60	95	129	130

Martini Tech offers GaN MOCVD deposition for LEDs

The Tokyo based firm is offering gallium nitride MOCVD for deposition on sapphire substrates

Martini Tech has started to offer its customers a new GaN deposition service on sapphire substrates by MOCVD for LED applications.

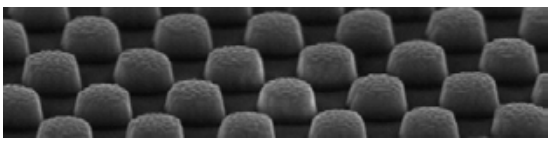


Image of GaN MOCVD on sapphire substrate

LEDs are becoming increasingly popular in various fields of the electronics industry: they can be used inside digital clocks, for street illumination applications, to send information and in large-size television screens and computer monitors.

LEDs are similar to incandescent light bulbs but they differ from them as they do not have a filament and therefore they do not get particularly hot and do not become unusable after a certain period of time due to filament burn out.

Different from incandescent light bulbs, LEDs are illuminated uniquely by the movement of the electrons in a semiconductor material.

Such important characteristics, coupled with electricity consumption which is lower than that of incandescent light bulbs make them viable as their potential replacement.

The widespread adoption of LEDs has so far being hindered by a series of factors, the main ones being the relatively high price and lower light output compared with traditional incandescent light bulbs.

GaN deposition is one of the most promising techniques to improve the light output of LEDs and involves the deposition of a thin GaN epitaxial layer on a patterned sapphire substrate (PSS).

The service offered includes the deposition by MOCVD of undoped GaN and of *n*- or *p*- doped GaN for high-quality highly-ordered crystalline layers up to 5μm of thickness.

Source: Newswire Today and LINK

SiO2 ded GaN for high-quality highly-ordered crystalline layers up to 5μm of thickness.Source: Newswire Today and LINK

EpiGaN wins Gazelle Ambassador Starter 2014 award

The specialist in GaN-on-silicon technology was awarded for its fast growth in revenue and employees in a three-year time span

EpiGaN nv, a provider of III-nitride epitaxial materials, was awarded the title of 'National Trends Gazelle Ambassador 2014' in the category 'Starter' by Trends, a financial-economics Belgian magazine.

The annual award recognises EpiGaN for its fast growth in revenue and employees in a three-year time span. It was further selected for its highly innovative products addressing a large international market, offering further growth perspective and local job creations.

The award was presented to EpiGaN by Flemish Minister President, Kris Peeters, in Brussels.

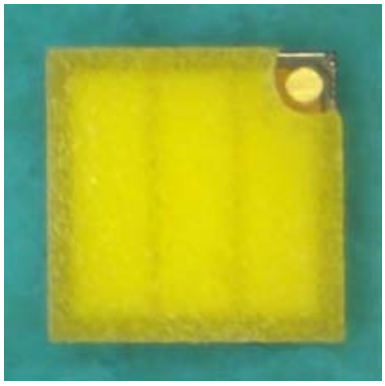
"We are thrilled and very proud with this title and recognition," said Marianne Germain, Co-Founder and CEO of EpiGaN. It is great to be awarded for the hard work of a very committed team and its constant efforts since the founding of the company in 2010. And this is just the beginning, as we are in the middle of expanding our production capacity to support volume growth driven by our worldwide customers."

Marianne Germain, Co-Founder and CEO of EpiGaN

SemiLEDs delivers high CCT uniformity to low profile packages

The new white III-nitride chip series implements a novel phosphor coating process

SemiLEDs has announced the sampling and volume availability of the EV-W series of white LED chips.



SemiLEDs ReadyWhite Technology EV-W LED

This is aimed at providing LED packagers with a vastly increased range of capabilities while lowering production costs. The new EV-W chips incorporate SemiLEDs' proprietary ReadyWhite phosphor technology, which delivers a highly uniform phosphor coating across the emitter surface, greatly increasing colour precision and uniformity.

The availability of high-output, high-consistency unpackaged white chips offers LED packaging and luminaire manufacturers a wide variety of new COB and package options by eliminating the phosphor application from the packaging process. Innovative package-level implementations can include variable-CCT single-package solutions, and greatly simplified RGBW, WWRA, WWWR or WWGR solutions to provide enhanced CRI and higher efficiency red/amber/green augmentation.

EV-W LEDs, based upon SemiLEDs EV product line, are available in high-power 40-, 45-, and 53-mil low-profile vertical chips and can deliver up to 140 lumens with efficacies of 130 lm/watt at 350 milliamps, depending upon the chip bin and chosen packaging approach. Standard CCT/CRI options range from 6500K/70CRI to 2700K/80CRI, and include distributions as tight as ¼ of a standard ANSI bin.

Additional customisation, including specialised phosphor options is also available.

Mark Tuttle, General Manager for SemiLEDs Optoelectronics Co., Ltd., comments, "A traditional barrier to the availability of creative new LED packages, especially lower-profile implementations, has been the issue of phosphor application within the packaging process."

He adds," The additional capital requirements, expertise, processing time, overspray and wastage issues have all either limited packaging options or unnecessarily driven up costs. By combining our rugged vertical-metal EV-blue chips, and the proprietary ReadyWhite phosphor coating technology, SemiLEDs' EV-W eliminates blue-leakage while delivering an impressive level of colour uniformity and tight binning options for low-profile and multi-colour white packaged LEDs."

Historically, manufacturers who assemble LED chips into low profile packages have been faced with a substantial challenge when it comes to uniformity and cost issues. While the industry has developed effective techniques to evenly cover the blue chip in a cavity-based package, current dispensing and spray-coating techniques tend to deliver a domed distribution rather than a flat, uniform coating.

While moving to a vertical-metal chip solves the problem of blue leakage that would typically emanate from the sapphire substrate with a dispense-coated or spray-coated horizontal chip, SemiLEDs ReadyWhite technology also addresses the equally important issue of uniformity.

The SemiLEDs' EV-W chip series is designed for manufacturability and rugged longevity and is available with an option of gold/tin (AuSn) metallisation to support eutectic bonding to further enhance thermal characteristics. The SemiLEDs EV-W series is RoHS compliant with production quantities available now.

deployment in the latest smartphones. It appears that devices based on CMOS will gain market share, but GaAs will dominate the market for many years to come.

A more detailed report of the presentations at CS International Conference will appear in the April /May edition of *Compound Semiconductor* magazine. This issue will also contain details of the winners of the coveted CS Industry Awards.

For more information about CS International Conference, and opportunities available for the 2015 event, contact Stephen Whitehurst: stephen.whitehurst@angelbc.com Tel 0044 (0)2476 718 970. www.cs-international.net

Compound Semiconductor conference hits a new high

35 presentations equipped delegates with a comprehensive overview of the compound semiconductor industry

Around 300 delegates and over 30 sponsors descended on Frankfurt for the fourth CS International Conference, which was held at the Sheraton Airport Hotel this week.

This must-attend event for the leaders of the compound semiconductor industry set a new standard for its number of presentations.

The conference covered all aspects of the industry, with presentations grouped into six key themes:

Power Electronics
LEDs
Integration of CMOS and III-Vs
Wide Bandgap RF Devices
Front-ends for Mobile Devices
Lasers, PICs & PV

Presentations on these topics highlighted the growing penetration of compound semiconductors into the silicon industry, and the use of silicon in the making of III-V chips. Leading developers of next-generation CMOS, such as IBM and Imec, are pioneering approaches to integrate high-mobility materials, for example InGaAs, into the channels of transistors in microprocessors, while silicon substrates are viewed as a low-cost platform for making LEDs, as well also power and RF electronics based on GaN.

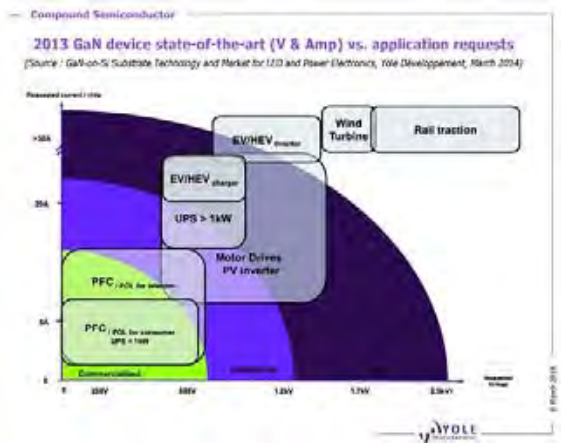
Meanwhile, power amplifiers that are based on silicon are starting to go head-to-head with those made from GaAs for

Yole: Power has the strength over LEDs for GaN-on-Silicon

The market analysts believe that the LED market will stick to GaN-on-sapphire

Yole Développement is releasing, this week, the “GaN-on-Si Substrate Technology and Market for LED and Power Electronics” report.

Yole analysts Hong Lin and Eric Virey give an overview of the GaN-on-silicon epiwafer playground. The report also provides an analysis of GaN-on-silicon technology for LED and power electronic applications, including technology and cost aspects.



GaN-on-silicon LEDs are already adopted by some LED manufacturers, but could it become the industry standard?

Today, GaN-on-sapphire is the main stream technology for LED manufacturing. GaN-on-silicon technology appeared naturally as an alternative to sapphire to reduce cost.

Yole’s cost simulation indicates that the differential in silicon substrate cost is not enough to justify the transition to GaN-on-silicon technology. The main driver is the ability to manufacture in existing, depreciated CMOS fabs in 6” or 8”.

“Despite potential cost benefits for LEDs, the mass adoption of GaN-on-silicon technology for LED applications remains unclear. Opinions regarding the chance of success for LED-

on-silicon vary widely in the LED industry from unconditional enthusiasm to unjustified skepticism. Virtually all major LED makers are researching GaN-on-LED, but few have made it the core of their strategy and technology roadmap. Among the proponents, only Lattice Power, Plessey and Toshiba have moved to production and are offering commercial LED-on-silicon," explains Hong Lin.

GaN-on-silicon enables GaN power electronics, will LED transition as well?

Yole Développement, analysts believe that although significant improvements have been achieved, there are still some technology hurdles (performance, yields, CMOS compatibility).

They consider that if the technology hurdles are cleared, GaN-on-silicon LEDs will be adopted by some LED manufacturers, but will not become the industry standard. Yole analysts expects that silicon will capture less than 5 percent of LED manufacturing by 2020.

But GaN-on-silicon technology will be widely adopted by power electronics applications.

The power electronics market addresses applications such as AC to DC or DC to AC conversion, which is always associated with substantial energy losses that increase with higher power and operating frequencies.

Incumbent silicon based technology is reaching its limit and it is difficult to meet higher requirements.

GaN based power electronics have the potential to significantly improve efficiency at both high power and frequencies while reducing device complexity and weight. Power GaN are therefore emerging as a substitution to the silicon based technology. Today, Power GaN remains at its early stage and presents only a tiny part of the power electronics market.

"We are quite optimistic about the adoption of GaN-on-silicon technology for Power GaN devices. GaN-on-silicon technology have brought to market the first GaN devices. Contrary to the LED industry, where GaN-on-sapphire technology is main stream and presents a challenging target, GaN-on-silicon will dominate the GaN based power electronics market because of its lower cost and CMOS compatibility," says Eric Virey.

"Although GaN based devices remain more expensive than silicon based devices today, the overall cost of GaN devices for some applications are expected to be lower than silicon devices three years from now, according to some manufacturers. In our nominal case, GaN based devices could reach more than 7 percent of the overall power device market by 2020," he adds.

Yole believes GaN-on-silicon wafers are expected to capture more than 1.5 percent of the overall power substrate volume, representing more than 50 percent of the overall GaN-on-silicon wafer volume, subjecting to the hypothesis that the 600V devices would take off in 2014 to 2015.

GaN- on-silicon epiwafer: buy it or make it?

Which business will be dominated?

To adopt the GaN-on- silicon technology, device makers have the choice between buying epiwafers or templates on the open market, or buying MOCVD reactors and making epiwafer by themselves.

Today, there is a limited number of players selling either epiwafers or templates or both on the open market. These players comes from Japan, US and Europe. Yole has not observed an absolute dominance from one region.

As perceived by device markers, each business model has its pros & cons in terms of IP, technology dependence, R&D investments, and time.

According to Yole reports, analysts do not expect to see a significant template/epiwafer business emerge for LEDs and consider that LEDs makers would prefer making their epiwafers internally for mass production.

For the power electronics industry, the opinion is divided. Yole considers that buying epiwafers could work as long as the price of the epiwafer on the open market keeps decreasing.

Shedding new light on quantum physics for LEDs

Superconductivity and LED technology could provide a new approach to quantum devices

A team of University of Toronto physicists led by Alex Hayat has proposed a novel and efficient way to leverage the quantum physics phenomenon known as entanglement.

The approach would involve combining LEDs with a superconductor to generate entangled photons and could open up a rich spectrum of new physics as well as devices for quantum technologies. These could include quantum computers and quantum communication.

Entanglement occurs when particles become correlated in pairs to predictably interact with each other regardless of how far apart they are. Measure the properties of one member of the entangled pair and you instantly know the properties of the other. It is one of the most perplexing aspects of quantum mechanics, leading Einstein to call it "spooky action at a distance."

Working with LEDs and superconductors to generate entangled

photons (photo courtesy NSERC)

"A usual light source such as an LED emits photons randomly without any correlations," explains Hayat, who is also a Global Scholar at the Canadian Institute for Advanced Research. "We've proved that generating entanglement between photons emitted from an LED can be achieved by adding another peculiar physical effect of superconductivity - a resistance-free electrical current in certain materials at low temperatures."

This effect occurs when electrons are entangled in Cooper pairs-a phenomenon in which when one electron spins one way, the other will spin in the opposite direction.

When a layer of such superconducting material is placed in close contact with a semiconductor LED structure, Cooper pairs are injected into the LED, so that pairs of entangled electrons create entangled pairs of photons. The effect, however, turns out to work only in LEDs which use nanometre-thick active regions-quantum wells.

"Typically quantum properties show up on very small scales-an electron or an atom. Superconductivity allows quantum effects to show up on large scales-an electrical component or a whole circuit. This quantum behaviour can significantly enhance light emission in general, and entangled photon emission in particular," Hayat says.
The research was published in *Physical Review B* on March 10th.

http://journals.aps.org/prb/pdf/10.1103/PhysRevB.89.094508

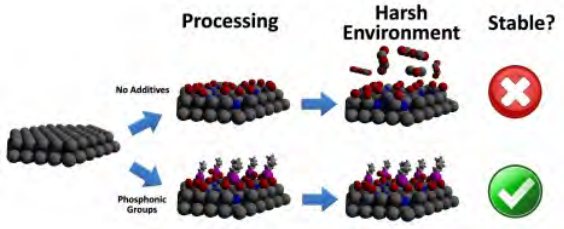
Brightening and strengthening GaN LEDs

Scientists have reported that adding phosphonic groups increases luminescence and enhances the stability of the gallium nitride based devices

Researchers from North Carolina State University have developed a new processing technique that makes LEDs brighter and more resilient by coating GaN with a layer of phosphorus-derived acid.

"By coating polar GaN with a self-assembling layer of phosphonic groups, we were able to increase luminescence without increasing energy input," says Stewart Wilkins, a Ph.D. student at NC State and lead author of a paper describing the work. "The phosphonic groups also improve stability, making the GaN less likely to degrade in solution."

"Making the GaN more stable is important," Wilkins adds, "because that makes it more viable for use in biomedical applications, such as implantable sensors."



By coating polar GaN with phosphonic groups, the researchers increased luminescence without increasing energy input. (Image: Stewart Wilkins)

The researchers started with polar GaN, composed of alternating layers of gallium and nitrogen. To increase luminescence, they etched the surface of the material with phosphoric acid.

At the same time, they added phosphonic groups - organic molecules containing phosphorus - that self-assembled into a monolayer on the surface of the material. This layer further increased luminescence and improved the stability of the GaN by making it less likely to react chemically with its environment.

The work has been described in the paper, "In Situ Chemical Functionalization of Gallium Nitride with Phosphonic Acid Derivatives during Etching," by Stewart J. Wilkins *et al* in Langmuir, 2014, 30 (8), pp 2038–2046. DOI: 10.1021/la404511b

The research was supported in part by the National Science Foundation under grant EEC 1156762.

Osram's compact LEDs conquer compact spotlights

The firm says its latest III-nitride based CoB LEDs offer twice the light from half the surface

For the first time, Osram is offering a chip-on-board LED.

The Soleriq P 9 is suitable for compact powerful spotlights like the ones used in retail outlets and museums.

The latest member of the Osram Soleriq family produces 2000 lumen from a surface with a diameter of nine millimetres. Compared with the existing Soleriq S 13, that is twice as much light from an area half the size. This high brightness is made possible by the surface-emitting chips used.

The Soleriq P 9

Osram says just one of the new LEDs is enough to replace a 35 W HID lamp for spotlighting.

The P 9 has a light emitting surface of 64 mm² and produces 2000 lm and has a luminous efficacy of 100 lm/W (at a temperature of 85°C and 3000 K).

Even at very high packing densities they can produce high luminous flux with above-average efficiency. The small light-emitting surface means that extremely compact and therefore lightweight optics can be fitted for highly compact spotlights.

The spotlights can therefore be less cumbersome and more cost-effective, while still providing the same luminous intensity.

The Soleriq P 9 has been designed for use in spotlights for directional indoor lighting and in particular for shop and museum lighting

"The Soleriq P 9 is just the start of a series of LEDs with enormous brightness and efficiency, generated from a light-emitting surface of only a few millimetres in diameter. Over the next few months we will be unveiling more products in the Soleriq P family, taking the benefits of the P series into different form factors and areas of application,"explains Andreas Vogler, responsible for the P 9 in the SSL division at Osram Opto Semiconductors.

The new Soleriq is being tested and measured at a temperature of 85°C to simulate the thermal conditions in actual applications as closely as possible. Customers will therefore be able to directly plan the use of the LED in their applications and will not have to carry out time-consuming appraisals based on data sheet values.

The P 9 is the first member of the new Soleriq P series; following the existing E and S series. All Soleriq versions are CoB LEDs (Chip-on-Board) and offer a high brightness. They are ideal for indoor spotlight applications and are easy to install. The Osram partner network "LED Light for you" offers accessories such as holders, optics and drivers tailored to the Soleriq families.

Rubicon announces pricing of public offering of common stock

The provider of sapphire substrates and products to the LED, semiconductor and optical markets will sell stockholders at a price to the public of $13.00 per share

Rubicon Technology, Inc. has announced the pricing of an underwritten public offering of 2,500,000 shares of its common stock.

The offering is expected to close on March 24th, 2014, subject to satisfaction of customary closing conditions. In addition, Rubicon has granted the underwriters a thirty day option to purchase up to an additional 375,000 shares of its common stock to cover over-allotments, if any.

Canaccord Genuity Inc. is acting as sole book-running manager for the offering and D.A. Davidson & Co. is acting as co-manager for the offering. Rubicon will not receive any proceeds from the sale of common stock by selling stockholders.

The offering is being made pursuant to an effective shelf registration statement previously filed with the Securities and Exchange Commission (SEC). A prospectus supplement and accompanying prospectus describing the terms of the offering will be filed with the SEC.

Silicon carbide goes quantum

Carbon anti-site vacancy pairs in SiC are sufficiently bright to allow detection at the single-photon level enabling the generation of single photons at a high repetition rate, This makes them potentially useful qubits for quantum information processing and applications in photonics

Silicon carbide is a semiconductor that is now widely used in a variety of micro-electromechanical systems (MEMS), LEDs and high-power electronics.

Its technological appeal stems from the fact that it is amenable to mature, robust nanofabrication methodologies and possesses both a high Young's modulus and excellent thermal conductivity.

To many, silicon carbide (SiC) is a material that offers few surprises. Nevertheless, the increasing need for novel materials for implementing quantum technologies and nanophotonic integrated circuits is forcing scientists to revisit several traditional materials - SiC is one of them.

The crucial step in manipulating a material in the quantum regime is the ability to modify and probe individual quantum states, which can be employed as qubits.

Until recently, only diamond has offered a solid-state platform for optically stable, room-temperature single quantum emitters.

The game has changed now, say scientists Stefania Castelletto and Hannes Kraus and their colleagues. who have isolated single emitters and identified microwave spin qubits in SiC.

The results were reported in the journal *Nature Materials*. The researchers, including those at the University of Sydney, identified individual defects, known as carbon anti-site vacancy pairs, in SiC that are sufficiently bright to allow detection at the single-photon level.

These emitters can generate single photons at a high repetition rate, which makes them potentially useful qubits for quantum information processing and applications in photonics. The defects have the practical benefit that they are optically active at room temperature.

Another notable advantage is their natural abundance in the host matrix. Consequently, there is no need for external ion implantation, as in the case of diamond, or for the epitaxial growth typical of III-V semiconductors.

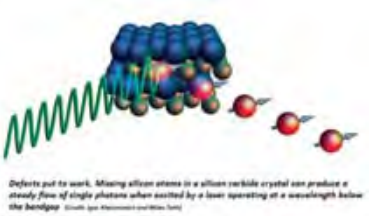
Electron irradiation and annealing provide the material restructuring needed to optically activate the defects. It is thought that the defects are clusters comprising carbon atoms that reside in silicon sites adjacent to carbon vacancies.

In a parallel report in *Nature Physics*, Kraus and his colleagues describe optically induced population inversion of the spin states of another type of single defect in SiC - a silicon vacancy. This result could pave the way to SiC solid-state masers and extremely sensitive travelling-microwave amplifiers.

What's more, by exploiting the double radio optical resonance technique, the team proved that the silicon vacancy has a spin-3/2 ground state - a topic that has been under debate for many years. They are therefore able to detect an optical magnetic-resonance signature from a silicon-vacancy defect at room temperature.

The ability to focus exclusively on a known defect at room temperature in a forest of paramagnetic centres is crucial for practical and scalable engineering of sensors and solid-state devices for quantum information processing.

Missing silicon atoms in a SiC crystal can produce a steady flow of single photons when excited by a laser operating at a wavelength below the bandgap. This is shown in the figure below.



Defects put to work. Missing silicon atoms in a silicon carbide crystal can produce a steady flow of single photons when excited by a laser operating at a wavelength below the bandgap

So, despite many years of intense research on SiC and its spectroscopic characterisation, why have single-photon emission and unambiguous identification of paramagnetic defects not been previously observed?

The answer to this question is rather simple. In traditional semiconductor physics, most spectroscopy is performed using above-bandgap laser excitation that predominantly excites near-gap emissions.

However, this approach cannot address deep-level states. Instead, individual defect states that reside within the forbidden energy gap must be optically accessed using sub-bandgap excitation. This is a critical issue for wide-bandgap semiconductors.

Indeed, this is the case for the infamous negatively charged nitrogen-vacancy centre in diamond, which is visible on green excitation but inaccessible by ultraviolet excitation.

SiC, not surprisingly, shows similar behaviour. Red and infrared excitation, as was used by Castelletto, Kraus and their colleagues, is not sufficiently energetic to promote electrons into the conduction band, but provides an excellent way to identify new quantum systems at room temperature.

Both works highlight the urgent need to revisit other wide-bandgap materials, including zinc oxide and AlN. Hopefully, it will not be long before more robust room-temperature quantum systems are unveiled.

The pivotal observation of single-photon sources and stimulated microwave emission from SiC complements the recent discovery of novel fluorescent SiC nanostructures (tetrapods) and ushers in a new era for this technologically important material.

Integration of single defects into nanomechanical systems will hopefully pave the way to the burgeoning field of optomechanics and enable unprecedented applications in sensing, quantum information processing and magnetometry.

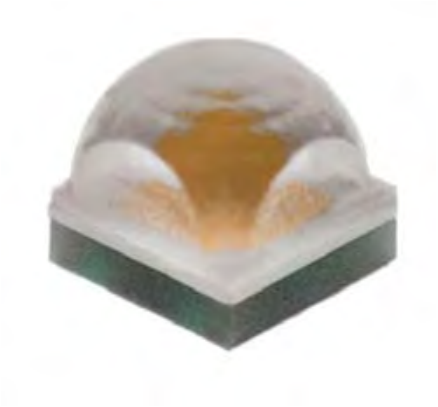
At last, we may have a convincing candidate for scalable quantum devices at our fingertips.

Cree high-density discrete LED ups the stakes

The compact XLamp XB-H III-nitride based LED is claimed to deliver excellent lumen density and optical control

Cree is introducing the XLamp XB-H LED, the brightest discrete in Cree's high-density (HD) class of LEDs.

The company says it delivers a breakthrough combination of lumen output and efficacy in a small package. The XB-H LED brings the lighting-class performance of the XP-G2 LED into a package that is 50 percent smaller.



XB-H LED device

Delivering more than 500 lumens at 1.5 A, 25º C in a 2.45 x 2.45-mm package, the Cree XB-H LED can enable luminaires that use the same-size-footprint XB-D LED to triple their light output at the same efficacy.

XLamp XB-H LEDThe XB-H joins the XQ-E in the family of HD-class discrete LEDs that offer the industry's highest optical control factor (OCF), a measurement of how LED size and performance benefit directional lighting applications.

High-OCF LEDs enable lighting manufacturers to improve the performance of any lighting design, create smaller and less-expensive systems, and develop new lighting solutions that were previously not possible.

"Cree is the first LED manufacturer to bring this level of performance to such a small size," says Roger Suen, supply chain management director, Light Engine Ltd. "With a high optical control factor, the XB-H LEDs enable new levels of brightness and optical control to improve design flexibility, increase performance and lower system cost without sacrificing reliability."

Utilising Cree's ceramic-package technology, the new XB-H LED delivers long L70 lifetimes at both high temperature and current. In addition, the XB-H offers compatibility with most optics designed for the Cree XP family of LEDs, allowing lighting manufacturers to leverage the optics of existing lighting designs and improve time-to-market.

"We are excited to offer our breakthrough high-density performance to manufacturers who prefer to work with discrete LEDs," says Dave Emerson, vice president and general manager for Cree LEDs. "Delivering up to 175 lumens-per-watt efficacy at 1 W, 25° C in its small package, the XB-H LED sets a new performance standard for high-power LEDs. Our new HD class of discrete LEDs demonstrates Cree's commitment to offering customers the best options for their applications."

To improve time-to-market, lighting manufacturers seeking ENERGY STAR qualification can take advantage of the XB-H LED's successor status to the XP-G2 LED-meaning that ENERGY STAR qualification can be achieved using just 3,000 hours of LM-80 data, instead of the normal 6,000 hours.

The XLamp XB-H LED is available in colour temperatures ranging from 2700 K to 8300 K and CRI options of 70, 80, 85 and 90. Binned at 700 mA, 85° C, the XB-H LED delivers up to 499 lumens at 5 W, 85° C.

Product samples are available now and production quantities are available with standard lead times.

Plessey to expand GaN on silicon distribution into Iberia

The firm's LEDs will be distributed by Matrix

Plessey Semiconductors has entered into a distribution agreement with Matrix Electrónica S.L. for the Iberian market for Plessey's GaN on silicon LED products,

Matrix is an electronics distributor and provider of complete advanced electronic solutions.

Plessey's GaN on silicon LEDs are produced using standard silicon-based semiconductor manufacturing processes in contrast with existing LEDs which use expensive sapphire and other exotic materials. Plessey's ambition is to drive global uptake of its patented MAGIC (Manufactured on GaN-on-Si I/C) technology as a cost-effective alternative to existing SSL LED technologies.

Jose María Vilallonga Presas, President and CEO of Matrix, says, "We are very excited about partnering with Plessey. I am confident that the combination of Plessey's innovative products and our extensive knowledge of the market will be very successful. The GaN-on-silicon technology is going to be a revolution in the solid state lighting market and Matrix will be a pioneer in introducing the new technology in Spain and Portugal."

David Owen, Regional Sales Director for Plessey, adds, "Plessey are very pleased to work with a distributor who has been focusing on the solid state lighting market for a considerable number of years. Matrix has a dedicated team working in the lighting segment and therefore considerable knowledge of the lighting industry and customer base in the region."

QMC moving closer to mass production of QDs

The firm's tetrapod quantum dots could be integrated into LANL's 'Thick-Shell' technology. The aim is to develop a line of devices for displays and lighting units to enhance performance and life expectancy

Quantum Materials Corporation (QMC) has placed purchase orders for the equipment necessary to increase production of inorganic quantum dots.

The tools are scheduled for delivery and deployment in the third quarter of 2014.

Recently. QMC announced that it will obtain equipment funding

and said that the Los Alamos National Laboratory's (LANL) Thick-Shell technology will be integrated with a variety of QMC's composite tetrapod quantum dots to develop a line of advanced high performance quantum dots.
QMC has now teamed up with LANL and they have jointly written and submitted a proposal for funding to the recent DOE EERE Funding Opportunity for Solid-State Lighting Advanced Technology R&D.

The venture aims to increase performance and market readiness of efficient LED lights incorporating improved quantum dots.

David Doderer, Vice President of Research and Development, comments, "Very meaningful quantum dot research is being conducted globally, and in particular at our national labs. We are glad to be able to adapt the thick-shell 'giant' QD technology developed by Los Alamos into an industrial process to provide the end consumer with a much better product. New electronics in displays and lighting continue to amaze, and while quantum dots might not be headliners, it is exciting for us to see great materials allow designs that seem to make the impossible a reality."

With the benefit of the scaled and controlled production, and enhanced quantum dot structure, QMC's goal is to resolve volume-manufacturing problems that date back to the discovery of quantum dots over twenty years ago. The high cost of manual production, the lack of batch uniformity, and the inability to ensure a reliable supply for industrial production have, until this point, restricted the broad commercialisation of consumer products that are enhanced by quantum dots.

QMC says its combination of thick-shell technology and tetrapod quantum dots is expected to deliver unsurpassed optoelectric brightness and colour purity leading to higher resolution and colour vitality, and as integrated into the manufacture of displays and lighting units, will enhance performance life expectancy.

For photovoltaics including solar cells, thermovoltaics, near infrared, MEMS, cameras, strain gauges and other sensor applications, the increased photon absorption by thick-shell tetrapod semiconductor nanocrystals correspond to increased sensitivity, nd higher efficiencies due to suppressing recombination.

QMC has initiated designs for even higher capacity equipment for future production, details of which the Company expects to announce later this year.

QMC aims to roll out both cadmium-core and cadmium-free non-heavy metal quantum dots and out new composite or hybrid quantum dots as they are developed.

ITRI and TNSC unite to enhance GaN LED growth

The firms aim to develop a new UVA LED technology and promote GaN on GaN growth

TNSC, a manufacturer of MOCVD systems, has signed a technical agreement with ITRI in Taiwan which focuses on optoelectronic devices.

The objective of the agreement is to develop UVA LEDs on GaN substrates with TNSC's AP (atmospheric pressure) MOCVD in order to demonstrate the potential of AP-MOCVD, which is a proprietary technology of Taiyo Nippon Sanso.

ITRI says that TNSC's AP-MOCVD system has numerous advantages in growing UVA material. This, ITRI believes, include the high growth rate of low carbon GaN, high luminescence efficiency of low Indium content InGaN and GaN, constant pressure and continuous growth of the InGaN and AlGaN interface and high doping efficiency of AlGaN due to high quality.

Potentially, ITRI and TNSC believe they could develop a higher performance UVA LED on a native GaN substrate at a comparable price to one grown on a conventional sapphire substrate. This, they say, is because it is possible to inject more current into an LED grown on a native GaN substrate due to low dislocation density and easy current spreading.

An almost ideal point light source will improve utilisation efficiency of UV light by simple optics. ITRI and TNSC hope that their partnership will contribute to a new UVA LED technology standard as well as GaN on GaN application promotion.

More research endorses the benefits of WSe2 for LEDs

By making diodes using tungsten diselenide, researchers have shown it is possible to produce photodetectors, photovoltaic cells, and LEDs

A team of MIT researchers has used a novel material that's just a few atoms thick to create devices that can harness or emit light.

This could lead to ultrathin, lightweight, and flexible photovoltaic cells, LEDs and other optoelectronic devices, they say.

Their report is one of three papers by different groups describing similar results with this material, published in the March 9th issue of *Nature Nanotechnology*.

The MIT research was carried out by Pablo Jarillo-Herrero, the Mitsui Career Development Associate Professor of Physics, graduate students Britton Baugher and Yafang Yang, and postdoc Hugh Churchill.

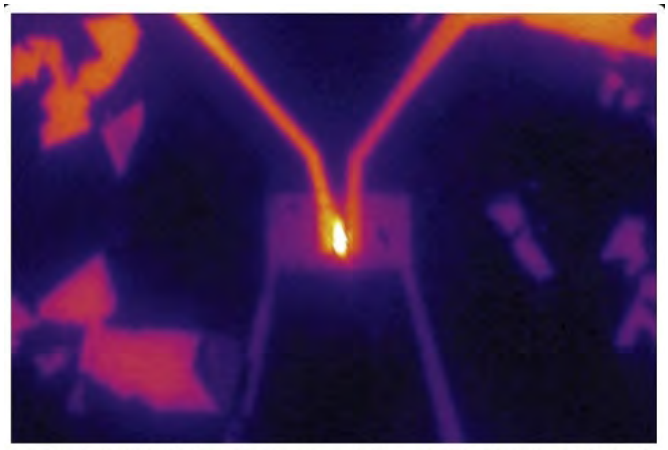
The material they used, tungsten diselenide (WSe2), is part of a class of single-molecule-thick materials under investigation for possible use in new optoelectronic devices - ones that can manipulate the interactions of light and electricity. In these experiments, the MIT researchers were able to use the material to produce diodes, the basic building block of modern electronics.

Typically, diodes (which allow electrons to flow in only one direction) are made by doping, a process of injecting other atoms into the crystal structure of a host material. By using different materials for this irreversible process, it is possible to make either of the two basic kinds of semiconducting materials, *p*-type or*n*-type.

But with the new material, either *p*-type or*n*-type functions can be obtained just by bringing the vanishingly thin film into very close proximity with an adjacent metal electrode, and tuning the voltage in this electrode from positive to negative. That means the material can easily and instantly be switched from one type to the other, which is rarely the case with conventional semiconductors.

In their experiments, the MIT team produced a device with a sheet of WSe2 material that was electrically doped half *n*-type and half *p*-type, creating a working diode that has properties "very close to the ideal," Jarillo-Herrero says.

By making diodes, it is possible to produce all three basic optoelectronic devices - photodetectors, photovoltaic cells, and LEDs; the MIT team has demonstrated all three, Jarillo-Herrero says. While these are proof-of-concept devices, and not designed for scaling up, the successful demonstration could point the way toward a wide range of potential uses, he says.



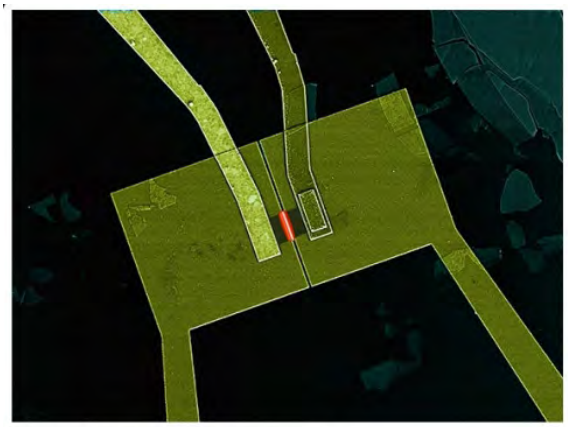
In the team's experimental setup, electricity was supplied to a tiny piece of tungsten selenide (small rectangle at center) through two gold wires (from top left and right), causing it to emit light (bright area at center), demonstrating its potential as an LED material.
IMAGE COURTESY OF BRITT BAUGHER AND HUGH CHURCHILL

"It's known how to make very large-area materials" of this type, Churchill says. While further work will be required, he says, "there's no reason you wouldn't be able to do it on an industrial scale."

In principle, Jarillo-Herrero says, because this material can be engineered to produce different values of a key property called bandgap, it should be possible to make LEDs that produce any colour - something that is difficult to do with conventional materials. And because the material is so thin, transparent, and lightweight, devices such as solar cells or displays could potentially be built into building or vehicle windows, or even incorporated into clothing, he says.

While selenium is not as abundant as silicon or other promising materials for electronics, the thinness of these sheets is a big advantage, Churchill points out, "It's thousands or tens of thousands of times thinner" than conventional diode materials, "so you'd use thousands of times less material" to make devices of a given size.

In addition to the diodes the team has produced, the team has also used the same methods to make p-type and n-type transistors and other electronic components, Jarillo-Herrero says. Such transistors could have a significant advantage in speed and power consumption because they are so thin, he says.



Microscope image shows the teams experimental setup.
IMAGE COURTESY OF HUGH CHURCHILL AND FELICE FRANKEL

Kirill Bolotin, an assistant professor of physics and electrical engineering at Vanderbilt University, says, "The field of two-dimensional materials is still at its infancy, and because of this, any potential devices with well-defined applications are highly desired. Perhaps the most surprising aspect of this study is that all of these devices are efficient. ... It is possible that devices of this kind can transform the way we think about applications where small optoelectronic elements are needed."

The research was supported by the U.S. Office of Naval Research, by a Packard fellowship, and by a Pappalardo fellowship, and made use of National Science Foundation-supported facilities.

Philips SlimStyle LED bulb comes in at $9.97

A new design and accessible price on dimmable 60-W EQ bulb offers consumers slimmer utility bills without compromising light quality

Philips has released a 60-watt LED equivalent bulb in its SlimStyle product.

It has a brand new shape that offers the high quality, omni-directional light of an incandescent, while eliminating the bulky heat sink commonly found on current LED offerings. The new value-priced 60-watt bulb is now available for purchase in store at The Home Depot, a partner in innovation, for $9.97.

Like other Philips LED bulbs, SlimStyle is also designed to meet or exceed ENERGY STAR specifications, reducing energy consumption by 85 percent, and lasting 25 times longer with an estimated $136 savings in electricity costs during its

25,000 hour lifespan, as compared to the traditional 60-watt incandescent. The bulb is dimmable and has already been submitted for ENERGY STAR testing.

Using mid-power LUXEON LEDs developed at the Philips Lumileds facility in San Jose, California, SlimStyle uses 10.5 watts of power, while putting out more than 800 lumens.

This latest generation Philips bulb has a flat surface to conduct heat away from the LEDs, eliminating the need for the heavy aluminium heat sinks currently associated with LED bulbs. This innovation helps to reduce the cost and weight of the bulb, while still delivering the omni-directional lighting consumers expect from a traditional 60-watt bulb.

“Philips was the first and only company to create a light bulb that could meet the exacting L Prize specifications and we have continued to revolutionise the 60-watt LED equivalent with SlimStyle,” says Bruno Biasiotta, CEO and president, Philips Lighting Americas.

“With this latest generation, we have demonstrated that the LED bulb can break with traditional design and that a value-priced offering can still deliver the innovation and light quality that consumers have come to expect from a Philips product. Leveraging innovations in LED technology and utility rebate programs, we continue to drive down the price and fuel mass adoption. With SlimStyle, we have slimmed the bulb and your utility bill, but not your wallet,” he adds.

Philips is at the forefront of LED lighting technology and SlimStyle joins a portfolio which includes Philips hue, the company’s “personal wireless lighting” offering that empowers users to create and control LED light using their smartphone or tablet.

Tungsten diselenide all the rage in LED technology

More researchers have explored WSe2 and claim the material can make LEDs stronger and more energy efficient

Most modern electronics, from flat-screen TVs and smartphones to wearable technologies and computer monitors, use tiny LEDs.

These LEDs are based on semiconductors that emit light with the movement of electrons. As devices get smaller and faster, there is more demand for such semiconductors that are tinier, stronger and more energy efficient.

Now researchers from the University of Washington (UW) say they have built the thinnest-known LED that can be used as a source of light energy in electronics. Thy say the LED is based on two-dimensional, flexible semiconductors, making it possible to stack or use in much smaller and more diverse applications than current technology allows.

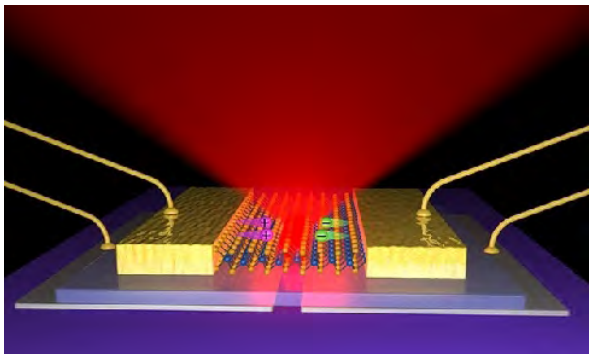
“We are able to make the thinnest-possible LEDs, only three atoms thick yet mechanically strong. Such thin and foldable LEDs are critical for future portable and integrated electronic devices,” says Xiaodong Xu, a UW assistant professor in materials science and engineering and in physics.

Xu along with Jason Ross, a UW materials science and engineering graduate student, co-authored a paper about this technology that appeared online on March 9th in *Nature Nanotechnology*.

Most consumer electronics use three-dimensional LEDs, but these are claimed to be ten to twenty times thicker than the LEDs being developed by the UW.

“These are 10,000 times smaller than the thickness of a human hair, yet the light they emit can be seen by standard measurement equipment,” Ross says. “This is a huge leap of miniaturisation of technology, and because it’s a semiconductor, you can do almost everything with it that is possible with existing, three-dimensional silicon technologies.”

The UW’s LED is made from flat sheets of the molecular semiconductor WSe2, a member of a group of two-dimensional materials that have been recently identified as the thinnest-known semiconductors.



This graphical representation shows the layers of the 2-D LED and how it emits light (Credit University of Washington)

Researchers use regular adhesive tape to extract a single sheet of this material from thick, layered pieces in a method inspired by the 2010 Nobel Prize in Physics awarded to the University of Manchester for isolating one-atom-thick flakes of graphene, from a piece of graphite.

In addition to light-emitting applications, this technology could open doors for using light as interconnects to run nano-scale computer chips instead of standard devices that operate off the movement of electrons, or electricity. The latter process creates a lot of heat and wastes power, whereas sending light through a chip to achieve the same purpose would be highly efficient.

“A promising solution is to replace the electrical interconnect with optical ones, which will maintain the high bandwidth but consume less energy,” says Xu. “Our work makes it possible to make highly integrated and energy-efficient devices in areas such as lighting, optical communication and nano lasers.”

The research team is working on more efficient ways to create these thin LEDs and looking at what happens when two-dimensional materials are stacked in different ways. Additionally, these materials have been shown to react with polarised light in new ways that no other materials can, and

researchers also will continue to pursue those applications.

This work has been detailed in the paper, "Electrically tunable excitonic light-emitting diodes based on monolayer WSe2 *p–n* junctions," by Jason S. Ross *et al* in *Nature Nanotechnology,* (2014). doi:10.1038/nnano.2014.26

The research is funded by the U.S. Department of Energy, Office of Science, the Research Grant Council of Hong Kong, the University Grant Committee of Hong Kong and the Croucher Foundation. Ross is supported by a National Science Foundation graduate fellowship.

IHS: China LED production to achieve double digit growth

In 2014, China's LED die production revenues are anticipated to grow 36.6 percent and packaged LEDs will grow 14.8 percent

Following the boom in expansion of the Chinese LED market in 2011, many industry insiders and analysts speculated on whether the Chinese would be able to sustain the growth, or if many companies simply ordered an excessive amount of MOCVD reactors just to benefit from government subsidies.

The failure of many of the companies was widely predicted. So, what's happening in the China LED industry after three years?

According to a new IHS report on the Chinese LED market, China's LED die production revenues will grow 36.6 percent to reach $1,475 million and packaged LEDs will grow 14.8 percent to reach $4,812 million in 2014.

Sanan, the largest Chinese LED company with a more than 30 percent share of die production in China, is actually expanding capacity. Its second phase project in Wuhu is still going ahead this year, leading to the addition of new tools.

Epistar, its largest rival will be directly competing this year to see who will be the world leader for total wafer capacity.

MLS was estimated to be the largest Chinese packaged LED company in 2013 with slightly more than 9 percent market share among thousands of other Chinese competitors.

Lighting is the major driving force for the China LED market growth from 2013 to 2014 and is forecast to exceed 50 percent share of all applications in 2014. The acceptance of LED replacement T-lamps, the falling cost of LED lamps generally, the continued economic growth, and the phasing out of incandescent A-lamps are all factors that are increasing the penetration rate of LED lamps in China.

The backlight market also grew significantly from 2012 to 2013 - by 74 percent in LED die. High growth is expected to continue in 2014 due to Chinese companies' technology improvements to replace imported products from Taiwan and Korea.

Although the Chinese domestic market is huge, international sales of most Chinese LED companies remain fairly low. However, they are catching up quickly. Larger companies are developing their own brands and IHS expects these suppliers to increase their presence in international markets in the near future.

Yole: Apple and GTAT investing over $1 billion in sapphire

The market analyst says that sapphire substrates will retain over 90 percent of the LED market through 2020, far higher than alternatives GaN and silicon

The sapphire industry recently ended an eighteen month period of depressed pricing and achieved US$936 million in revenue for wafer products.

Recovery was helped by an increase in LED demand due to growing adoption in general lighting and a resilient LCD backlight market.

This is according to the "Sapphire Applications and Market: From LED to Consumer Electronics" report from Yole Développement.

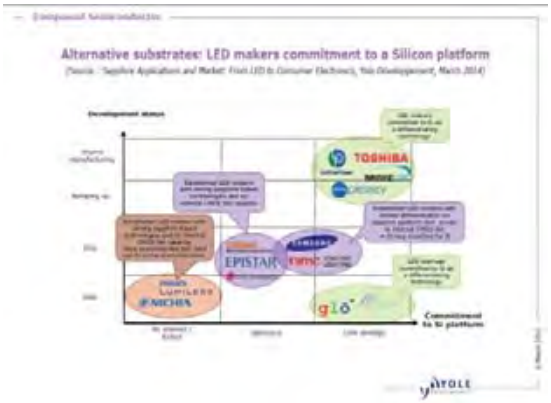
"But the saving grace was new consumer electronic (CE) applications: camera lens and fingerprint reader covers, mostly driven by Apple in 2013" explains Eric Virey, Senior Analyst at Yole Développement.

Overall, the growth in wafer demand will be enough to justify a capacity increase toward the end of 2014. For the longer term, Yole analysed opportunities of alternative LED substrates (GaN and silicon) but concluded that sapphire will retain over 90 percent of the market through 2020.

Yole says Apple and GTAT are investing more than US$1 billion in sapphire manufacturing.

After almost two years of losses, core prices increased by more than 50 percent in 2013; tier-1 sapphire vendors are finally selling at prices close to breakeven costs.

After a short pause, Yole expects the uptrend to resume through Q2 and Q3. But leading vendors' interests are not to increase prices above levels that would allow tier-2 competitors to generate a profit as well.



"We therefore expect prices to stabilise by the end of the year. Due to strong competition, finishing companies didn't pass the higher material costs on to their customers. Wafer prices remained stable in 2013 but will go up slightly in Q2-2014. For PSS, which now dominates with 85 percent penetration rate, prices could increase faster as supply currently falls short of demand in Taiwan", says Virey.

This,Yole estimates, will continue until leading suppliers increase capacity and emerging players in China ramp up and enter the supply chain later in 2014. Overall, sapphire prices should stabilise by the end of 2014 and start decreasing again in late 2015 as the industry keeps improving its cost structure.

And Apple could completely transform the industry in 2014.

Sapphire has been used for years in various luxury cell phones.

In 2013 Yole indicated that adoption in more accessible models could start in 2014. This just happened with the introduction by Gionee of the first 'non-luxury' (less than $1000) smartphone to feature a sapphire display cover. If adopted by leading cell phone OEMs for their flagship models, total sapphire demand could double by the end of 2014 and by twenty times by the end of the decade.

On November 4th 2013, GTAT and Apple announced a partnership to set up a large sapphire manufacturing plant in Mesa, Arizona. Yole Développement thoroughly analysed the deal and reached the conclusion that exiting 2014, the plant could reach a capacity equivalent of more than twice the current worldwide capacity.

What for?

Demand for home buttons and camera lens covers are expected to increase in 2014 and 2015, but even with aggressive forecasts for smart watches (and assuming that Apple uses sapphire for its own model which Yole Développement's analysts don't believe it will), the company could still tap into the existing supply chain to procure the sapphire it needs.

It's therefore difficult to justify this US$1 billion investment unless new applications requiring a lot of sapphire are coming to market. From our analysis, Yole considers cell phone display covers to be the most likely outlet for this capacity.

Yole modelled the Mesa operations and believe that the plant will make sapphire slabs that will then be sliced and polished by Apple subcontractors in China. The simulated slab cost of $6.40 per part would enable a US$17 cost per finished display cover, with a path for less than $13 ASP in the midterm. The plant could deliver an equivalent of forty-two million display covers in 2014 and more than eighty-five million in 2015.

QD Vision develops 'first' 30 nm FWHM quantum dots

The firm's CdSe-CdS emitters are suited to applications such as electronic displays and solid-state lighting

QD Vision has announced the commercial availability of what it says is the industry's first green quantum dots (QD) at 30 nm Full-Width Half-Maximum (FWHM).

QD Vision claims its new 30 nm green QDs and enable display manufacturers to benefit from increased performance when developing high-brightness, full-gamut colour displays.

The firm's LCD products, where blue LED's are used together with red and green QDs emit spectrally narrow red, green and blue colours to obtain full-gamut colour at a good efficiency.

By controlling the FWHM of the QD emission through manufacturing processes, QD Vision says its green and red QDs deliver the necessary colour saturation to achieve 100 percent overlap of any major colour gamut standard. These new 30 nm FWHM 'Color IQ' optics will further improve the colour performance in LCD applications, such as TVs, monitors and all-in-one computers.

"QD Vision continues to keep quantum dots on the leading edge of display technology," says John Ritter, Executive Vice President of Product Development, QD Vision. "Our solutions offer the best down-conversion material on the market today, and we continue to develop even narrower FWHM products to produce the most saturated colours at the highest efficiencies

for our customers, both now and in the future."

QDs are semiconductor nanocrystals that possess unique light emitting optical properties. The emission wavelength spectrum of QD light can be tuned to create almost any colour of the visible spectrum as defined by the CIE 1931 colour space.

FWHM, is a simple and well-defined specification used to measure the narrowness (spectral purity) of the emission from light emitting materials, such as QDs. In short, a narrower QD emission produces a wider colour gamut, resulting in higher colour fidelity and improved backlight performance.

When used in an LCD product, the backlight emission passes through a colour filter. Some colour filters allow light leakage from one colour channel to another, resulting in de-saturated colours.

Unlike conventional phosphors with much broader light emission (e.g. FWHM ~ 60-100 nm), QDs have a narrower emission spectra, which helps to reduce the crosstalk between the colour channels and improve system efficiency. Also unlike phosphors, the individual emission spectrum of QDs can be fine-tuned to match the peak wavelength of a given colour filter to achieve the maximum gamut possible.

IQE initiative to boost regional supply chains

The new programme is aimed at establishing partnerships to support the development of a broad range of key enabling technologies

IQE plc, a supplier of semiconductor wafer products and services, has launched its Open Innovation programme "openiqe".

The first major project under the new programme is the IQE Open Technology Challenge.

The aim of the challenge is to engage with small and medium enterprises, larger businesses and academic institutes, initially focusing primarily on the Welsh region, to develop new and enhance existing supply chains.

The project will focus on technology areas termed the Three Grand Challenges identified in the Science for Wales strategy and other major International programs, including the EU Horizon2020 Program. The three areas are life sciences and health; low carbon, energy and environment; and advanced engineering and materials.

Technology will play an increasingly important role in addressing a range of societal challenges. IQE's Open Technology Challenge is aimed at establishing partnerships along an end-to-end supply chain to develop and commercialise products that will meet real needs within the areas defined by the Three Grand Challenges.

Drew Nelson, IQE President and CEO, comments, "IQE has more than twenty-five years' experience of working closely with partners and customers worldwide to meet demanding technical specifications. We are delighted to be contributing our experience of collaborative innovation in the form of our new Open Innovation programme."

"We are confident that the Open Technology Challenge has the potential to become a key stepping stone towards the establishment of a major technology cluster in the region, as well as building stronger links to the global technology community."

IQE's Open Innovation programme is being supported by the Welsh Government.

Cree chooses Plextek RF as European design resource

The arrangement with Plextek RFI will give Cree's European customers access to Plextek RFI's design capabilities to develop their own custom GaN MMICs

Plextek RF Integration has been selected by Cree as a preferred design resource to provide third party design services to Cree's European foundry customers.

Plextek RF Integration is a UK based design house specialising in microwave and millimetre-wave IC design,

The commercial availability of GaN transistors has provided a big change in achievable performance for Solid-State Power Amplifiers (SSPAs).

Cree manufactures discrete transistors, microwave monolithic integrated circuits (MMIC), and GaN foundry services that allow customers to design their own transistors and MMICs for fabrication on Cree's processes.

In addition to providing design and layout services, Plextek RFI has in-house test facilities that allow evaluation of MMICs both in bare die form (directly on wafer) and as packaged parts.

"We see huge growth potential for GaN in Europe. Plextek RFI's experienced design and development team will provide a significant advantage to our European customers. We look forward to working with Plextek RFI to grow this market," says Jeff Barner, Cree foundry services program manager.

"We're delighted to have forged this relationship with a world leader in GaN technology such as Cree," comments Liam Devlin, CEO of Plextek RFI. "We have been seeing a steady increase in the amount of GaN MMIC design work we are taking on, and being able to provide our clients with access to one of the world's best foundry processes will significantly enhance the service we are able to offer."

GaN LED performance moves forward with drivers

By 2020 it is predicted that LEDs will have captured between 88 and 90 percent of the lighting market. Applied to a smaller surface capable with GaN, it is possible to make switching cheaper
LED lamps use less energy and provide more light than Incandescent light bulbs which are now banned in the EU, while energy-saving lamps remain a bone of contention.

In 2016, it will be lights out for halogen bulbs over 10 watts as well. LEDs therefore have the best chance of becoming the light source of the future.

Experts reckon that LED retrofit lamps for use in standard bulb fittings will overtake traditional energy-saving bulbs for the first time from 2015.

GaN transistors enable the compact design of this 2090 lumen retrofit LED lamp (exploded diagram for purpose of illustration) (Credit: Fraunhofer IAF)

The tiny diodes offer a whole host of advantages as the most environmentally friendly source of light - they contain no harmful substances, consume less energy and, with a lifetime of between 15,000 and 30,000 hours, last longer than conventional light sources. They also work at full brightness as soon as you flick the switch.

Coping with higher temperatures

LEDs do have one weakness, though - they are extremely sensitive to variations and spikes in power. To function properly, they need a driver that ensures a constant supply of power at all times.

This driver, which takes the alternating current from the grid and converts it into direct current with a reduced voltage, has a profound influence on the light yield and lifetime of the LED lamp as a whole.

The demands placed on the driver electronics are correspondingly high. This has prompted researchers at the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg to focus their attention on voltage transformers featuring GaN transistors.

During practical testing, the scientists found that the drivers developed using this new semiconductor material were extremely robust. Components made of GaN can operate at higher currents, voltages and temperatures than standard silicon transistors.

“Heat plays a role both in the brightness and the service life of LED lamps,” says Michael Kunzer, group manager at Fraunhofer IAF.

GaN transistors can also switch at high frequencies. The switching speed has a significant impact on the size of the coils and condensers built into the drivers for energy storage. In a GaN-based driver, the switch speed can be made as much as a factor of 10 faster than that of its silicon equivalent.

“Applied to a smaller surface, this means it is possible to make switching cheaper. The whole LED lamp can be made lighter and more compact while delivering the same or even improved illumination,” explains Kunzer. Since the energy storage component plays a decisive role in manufacturing costs, this could have an extremely positive effect on the end price.

Thanks to GaN’s properties, Kunzer and his team have been able to boost the efficiency of the GaN driver to 86 percent - between one and four percentage points better than its silicon equivalent.

When compared with the silicon transistor LED lamps available on the market, the scientists were able to increase the light output: while the luminous flux of commercial LED retrofit lamps featuring silicon components is around 1000 lumen (the unit used to measure the light produced), researchers from the IAF have been successful in increasing this to 2090 lumen.

“20 percent of energy consumption worldwide can be attributed to lighting, so it’s an area where savings are particularly worthwhile. One shouldn’t underestimate the role played by the efficiency of LED drivers, as this is key to saving energy. In principle, the higher the light yield and efficiency, the lower energy consumption is. If you think that by 2020 LEDs will have carved out a market share of almost 90 percent, then it is obvious that they play a significant role in protecting our environment,” says Kunzer.

Telecoms

Lightwave Logic boosts electro-optical effect in photonic devices

The new material system, 'Perkinamine Malachite', is based on the company's new proprietary multi-chromophore approach. It is claimed to increase thermal stability and durability in high speed fibre-optic telecom and optical computing devices

Lightwave Logic has integrated its proprietary Perkinamine chromophore technology, with other chromophores based in part on aspects of proprietary, in-licensed technologies.

This has resulted in, what the firm claims, is a powerful and durable nonlinear organic electro-optical (EO) material that will be used in photonic device development. It is based on the company's new multi-chromophore approach that allows two or more chromophores to work in concert.

Starting with the fundamental underpinnings of Lightwave's proprietary Perkinamine technology, the Lightwave Logic research scientists have found that by combining various Perkinamine chemical compounds with certain aspects of in-licensed chromophore portfolios, the total chromophore concentration in a host polymer system can be dramatically improved.

The company intends to further validate this performance in prototype photonic devices. Key results will be shared with interested industrial partners.

Lou Bintz, Vice President of Product Development states, "This multi-chromophore system has achieved a 50 percent increase in chromophore concentration, leading to higher electro-optical activity when compared to an equivalent single chromophore system. It does not cause the high chromophore density loading issues such as reduced effective electro-optic activity due to a non-uniform concentration of chromophore in the polymer host."

He adds, " For the past several months we have consistently witnessed amazing durability and poling stability (chromophore alignment) in thin film measurement tests in our new Longmont, Colorado device fabrication and testing facility. Repeated, multi-point measurements show twice the electro-optic effect of Lithium Niobate with excellent durability."

Tom Zelibor, Chairman and Chief Executive Officer of Lightwave Logic continues, "Since developing this new capability, our corporate focus has been to expand our portfolio of EO materials, not to replace our core Perkinamine family of chromophores, but to work with them adjunctively. These results are vitally important to our commercialisation efforts and validate our scientific approach. This creates a myriad of market opportunities due to almost infinite potential combinations of molecules and parts of molecules with unique properties to address distinct market opportunities. We will soon put the material into proprietary, advanced design photonic devices together with the Guided Wave Optics Laboratory in the University of Colorado."

"Malachite is undoubtedly the most durable nonlinear organic material system we have ever synthesised that also possesses high electro-optic efficiency, and the ability to work in ambient conditions. It is designed to enable a data communications transceiver to function inside the data centre. We intend to satisfy the enormous and as yet unfulfilled demand for 100gb/s data rates inside these massive and complex facilities. We are already working on a next generation Malachite material system to target a different application," finishes Zelibor.

Probing the sound of a GaAs quantum dot

New research has suggested that using interactions between sound waves and electrons reveal information about the environment of the electron. This discovery could have potential applications in quantum computing technology

Physicists at the University of Sydney have discovered a method of using microwaves to probe the sounds of a GaAs quantum dot, a promising platform for building a quantum computer.

The findings have been published *in Nature Communications*.

A quantum dot consists of a small number of electrons trapped in zero dimensions inside a solid. The quantum mechanical properties of these electrons can be used to store and manipulate quantum data for revolutionary applications in computing, communication, sensing and bio-medical diagnostic applications.

James Colless and Xanthe Croot from the University's School of Physics, discovered a way to study what happens when electrons in GaAs quantum dots interact with sound waves of the solid they are trapped in.

"The possibility of computing using quantum logic, rather than the classical logic on which today's machines are based, has changed the boundary between hard and easy problems. Previously it was thought that certain tasks - exactly modelling a complex molecule to construct new medicines or computing certain mathematical functions - were simply too hard for any computer, no matter how big," says David Reilly, from the Centre of Excellence for Engineered Quantum Systems (EQuS) and the University's School of Physics.

"The rules of the game have now changed. We now know that quantum mechanics allows certain interesting problems to be computed with ease, so long as you can build a machine that operates according to quantum mechanics - a daunting task!"

"Our work is a further step towards understanding the issues that enable or disable quantum machines. Sound waves in solids are a key mechanism that can lead to quantum devices interacting with their environment," Reilly explains.

These sounds waves are called phonons, and are similar to the

waves one can make in a stretched slinky. The 'slinky chain', in this case, is formed by the atoms which make up the solid. It turns out that interactions between sound waves and electrons reveal information about the environment of the electron - akin to detecting the size and shape of a room by listening to a singer's voice in that room.

The absence of inversion symmetry in the zinc-blende crystal structure of GaAs, results in a strong piezoelectric interaction between lattice acoustic phonons and qubit states with an electric dipole, a potential source of decoherence during charge-sensitive operations. To combat this, the scientists generated phonons in a GaAs double quantum dot, configured as a single- or two-electron charge qubit, and driven by the application of microwaves via surface gates.

The interaction between quantum dots and the solids in which they form is a double-edged sword for the purpose of quantum computing. On one hand, sound vibrations have been used to 'shuttle' electrons from place to place in quantum circuits - almost like a wave might pick up a surfer and take them into the beach.

"However, there are other contexts where sound interacting with electrons can cause huge problems: in particular, when you are performing a quantum algorithm and only want the electron to interact with certain parameters that the experimenter controls," explains Xanthe Croot.

Unwanted sound can significantly limit the time you have to perform the algorithm before the electron loses all the information it was storing. Understanding how the size and geometry of the quantum circuit affects these interactions is therefore extremely important.

In quantum computing, different configurations of electrons within the dot represent something similar to the 0 and 1 (or on and off) states in classical computing. The 1 and the 0 states have different energies: if you apply microwaves with exactly this energy difference you can change the state from 0 to 1 and vice versa.

"We found that if you apply microwaves with energy slightly higher than the electron energy difference, the system creates sound of a very specific frequency. It is almost like the electron saying, if you hit me too hard I'll scream," says Croot.

"Changing the microwave energy will change the frequency of the sound that the system creates in the solid. The results show that some frequencies of sound interact very strongly with the system, while others less so. There are hints in the data that the geometry of the quantum dot plays a key role in determining which frequencies will interact strongly."

This collaboration brought together experimentalists and theorists at the EQuS, University of Sydney, University of Queensland and materials scientists

The research is described in detail in the paper, "Raman phonon emission in a driven double quantum dot," by J.I. Colless *et al* in *Nature Communications,* 5, Article number: 3716. doi:10.1038/ncomms4716

GigOptix producing GaAs E-band radio chipsets in volume

The gallium arsenide based devices are designed for the point-to-point wireless backhaul market. The company has also taken on ex RFMD veteran Sushil Kumar as Senior Director of IC Development to lead engineering efforts for the wireless product line

GigOptix, a firm that focuses on optical and wireless communications networks, has announced it has a leadership position in point-to-point (PtP) wireless backhaul with production volume delivery and continuous revenue growth of E-Band radio chipsets.

The company has also appointed industry veteran Sushil Kumar to the newly created role of Senior Director of IC Development for the Wireless Product Line. Kumar's appointment is already effective.

GigOptix's Wireless Product line was launched in June 2012 when the firm augmented its internal GaAs power amplifier program with the license of the SiGe millimetre wave technology from IBM for E-band chipsets, for both 71 to 76GHz and 81 to 86GHz frequency bands.

"Today we are proud to announce that we have received a substantial purchase order of $1.5 million of our leading E-Band devices from one Tier 1 customer. In comparison, the total fiscal 2013 revenue from the Wireless Product Line was $1.7 million," says Raluca Dinu, Vice President and General Manager of the High-Speed Communications division at GigOptix, Inc.

"With the strong demand that we have seen so far this year, and considering our current GaAs power amplifier backlog, the Wireless Product Line is in an excellent position to about double the revenue of E-Band devices in 2014 compared to the previous year," Dinu adds.

GigOptix EXP7602-DNT and EXP8603-DNT devices were claimed to be the first GaAs E-band high performance power amplifiers with general availability - since September 2013 - and include integrated power detectors specifically designed to meet ANSI and ETSI requirements.

The amplifiers are said to have exceptionally good linearity, OIP3's better than 31dBm, and typical power dissipation lower than 2.2W.

"This is an exciting time at GigOptix for the wireless product team with such positive acceptance of our products in these early stages of the market. With increasing shipments of RF chipsets we have great momentum to continue to lead the market with best in class differentiated products. The Wireless Product Line is following a visionary path demonstrating GigOptix' relentless roadmap innovation," says Dinu.

"GigOptix's roadmap continues to lead the industry with improved performance, lower costs, and higher levels of integration. Customers can expect to receive samples of the new integrated SiGe transceiver chipset in Q3 fiscal 2014."

The E-Band radio market, still in its early stages only two years ago, is entering its maturity stage with significant volume deployment. Market estimates are that approximately 3,000 E-Band radios per month are currently being shipped and, based on strong demand from Tier 1 customers, the number of deployed radios is expected to grow to 6,000 per month with total shipments in 2014 in excess of 50,000 radios.

The demand for E-Band radios in the first few months of 2014 has been very strong, driven by the deployment of LTE cellular infrastructure in support of the ever growing demand for mobile data for smartphones.

If the current trend continues it is expected that in 2015 the E-Band radio will become one of the most deployed solutions for wireless back-hauling with volumes in the range of 200,000 radios in 2015 and doubling in 2017.

The deployment of small cells will be part of the second wave of LTE deployment with volume installation to start in 2015 and it will be addressed by V-Band devices, 60GHz band. With small cell density expected to be one order of magnitude greater than regular cells in urban areas, the demand for V-band radios is expected to boom in the next two years with volumes at much higher than E-Band.

According to EJL Wireless Research's 9th Edition (May 2013) of the Global Digital PTP Radio Market Analysis and Forecast, 2013-2017 report, a shift towards high capacity radios will continue to drive more value added products in the market, based on 4G networks launched in 2010 and continuing deployments through 2015.

The market report accounts for the impact of microcells, as well as the demand for new sites and capacity upgrades within the mobile infrastructure market.

At 60 GHz Gigabit Ethernet unit shipments are forecasted to grow from 20,000 in 2014 to 200,000 in 2017. At 70 / 80GHz Gigabit Ethernet unit shipments are forecasted to grow from 18,000 in 2014 to 120,000 in 2017. Gigabit Ethernet is expected to dominate the 60GHz and 70 / 80GHz frequency bands in the forecast period.

With this rapid business growth and customer demand, GigOptix has appointed industry veteran Sushil Kumar to the newly created role of Senior Director of IC Development for the Wireless Product Line. Kumar, who will be based at GigOptix's headquarters in San Jose, will be leading the engineering teams for the Wireless Product Line.

"Now that significant GigOptix product shipments have started to ramp, we hired Mr. Sushil Kumar to take the next generation of the E-Band and other wireless band products to the next level. I am happy to welcome Sushil to the GigOptix team. Sushil has more than twenty-five years of high speed RFIC and MMIC transceiver development experience to benefit GigOptix," says Andrea Betti-Berutto, Senior Vice President and Chief Technical Officer at GigOptix, Inc.

"Sushil will lead our advanced RF and E-Band initiatives and will help us accelerate our development of the next-generation millimetre wave IC transceivers."

Prior to joining GigOptix Kumar held Director of Engineering role at RFMD. At RFMD Kumar led GaN and GaAs MMIC development in the San Jose design centre. Sushil Kumar's experience includes participation in more than 100 MMIC designs with frequencies from near base band up to E-Band.

He also worked in various engineering and research roles for more than twenty years, including Senior RFIC/MMIC Design Engineer at Avago Technologies in San Jose, Senior RFIC/MMIC Design Engineer at Agilent Technologies in San Jose, Design Engineer at Hewlett Packard in Santa Clara, and a Senior Scientist at the Defence Research and Development Organisation in India.

Kumar has published numerous RF papers, has been awarded three patents, and is actively involved in activities of the IEEE and International Microwave Symposium. He begins his role at GigOptix immediately.

Antimonides surf the invisible wave

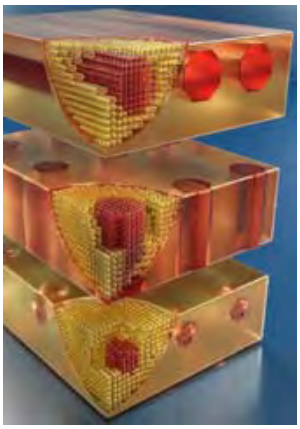
Researchers have created a semiconductor incorporating erbium antinonide, that manipulates light in the invisible infrared/terahertz range, paving the way for new and enhanced applications

Promising to address an array of applications, from energy efficiency to telecommunications to enhanced imaging, researchers at UC Santa Barbara say they have created a compound semiconductor of nearly perfect quality.

The material comprises embedded nanostructures containing ordered lines of atoms that can manipulate light energy in the mid-infrared range.

More efficient solar cells, less risky and higher resolution biological imaging, and the ability to transmit massive amounts of data at higher speeds are only a few applications that this unique semiconductor will be able to support.

"This is a new and exciting field," says Hong Lu, researcher in UCSB's Department of Materials and Department of Electrical and Computer Engineering, and lead author of a study that appears as a cover story of the March issue in the journal *Nano Letters*, a publication of the American Chemical Society.



Artist's concept of nanometre-size metallic wires and metallic

particles embedded in semiconductors, as grown by Hong Lu (Credit: Peter Allen, UCSB}

Key to this technology is the use of erbium, a rare earth metal that has the ability to absorb light in the visible as well as infrared wavelength - which is longer and lower frequency wavelength to which the human eye is accustomed - and has been used for years to enhance the performance of silicon in the production of fibre optics.

Pairing erbium with the element antimony, the researchers embedded the resulting compound - erbium antimonide (ErSb) - as semi-metallic nanostructures within the semiconducting matrix of gallium antimonide (GaSb).

ErSb, according to Lu, is an ideal material to match with GaSb because of its structural compatibility with its surrounding material, allowed the researchers to embed the nanostructures without interrupting the atomic lattice structure of the semiconducting matrix. The less flawed the crystal lattice structure of a semiconductor is, the more reliable and better performing the device in which it is used will be.

“The nanostructures are coherently embedded, without introducing noticeable defects, through the growth process by molecular beam epitaxy,” notes Lu. “Secondly, we can control the size, the shape and the orientation of the nanostructures.”

Epitaxy is a process where layers of material are deposited atom by atom, or molecule by molecule, one on top of the other with a specific orientation.

“It’s really a new kind of heterostructure,” says Arthur Gossard, professor in the Materials Department and in the Department of Electrical and Computer Engineering.

Semiconductors incorporating different materials have been studied for years. But a technology UCSB professor and Nobel laureate Herbert Kroemer pioneered was a single crystal heterostructured semiconductor/metal which was rather different.

The nanostructures allow the compound semiconductor to absorb a wider spectrum of light due to a phenomenon called surface plasmon resonance, explains Lu, and that the effect has potential applications in broad research fields, such as solar cells, medical applications to fight cancer, and in the new field of plasmonics.

Optics and electronics operate on vastly different scales, with electron confinement being possible in spaces far smaller than light waves. Therefore, it has been an ongoing challenge for engineers to create a circuit that can take advantage of the speed and data capacity of photons and the compactness of electronics for information processing.

The highly sought bridge between optics and electronics may be found with this compound semiconductor using surface plasmons, electron oscillations at the surface of a metal excited by light.

When light (in this case, infrared) hits the surface of this semiconductor, electrons in the nanostructures begin to resonate. This means that they move away from their equilibrium positions and oscillate at the same frequency as the infrared light .

This preserves the optical information but shrinks it to a scale that would be compatible with electronic devices.

In the realm of imaging, embedded nanowires of ErSb offer a strong broadband polarisation effect, according to Lu, filtering and defining images with infrared and even longer-wavelength terahertz light signatures.

This effect can be used to image a variety of materials, including the human body, without the risk posed by the higher energies that emanate from X-rays, for instance.

Chemicals such as those found in explosives and some illegal narcotics have unique absorption features in this spectrum region. The researchers have already applied for a patent for these embedded nanowires as a broadband light polariser.

“For infrared imaging, if you can do it with controllable polarisations, there’s information there,” says Gossard.

While infrared and terahertz wavelengths offer much in the way of the kind of information they can provide, the development of instruments that can take full advantage of their range of frequencies is still an emerging field.

Lu credits this latest breakthrough to the collaborative nature of the research on the UCSB campus, which allowed her to merge her materials expertise with the skills of researchers who specialise in infrared and terahertz technology.

“It’s amazing here,” she says. “We basically collaborated and discovered all these interesting features and properties of the material together.”

“One of the most exciting things about this for me is that this was a ‘grassroots’ collaboration,” says Mark Sherwin, professor of physics, director of the Institute for Terahertz Science and Technology at UCSB, and one of the paper’s co-authors.

The idea for the direction of the research came from the junior researchers in the group, he continues, grad students and undergrads from different laboratories and research groups working on different aspects of the project, all of whom decided to combine their efforts and their expertise into one study. “I think what’s really special about UCSB is that we can have an environment like that.”

Since the paper was written, the researchers have gone into industry, into companies such as Intel and Agilent, or pursued careers in academia.

Researchers on campus are also exploring the possibilities of this technology in the field of thermoelectrics, which studies how temperature differences of a material can create electric voltage or how differences in electric voltages in a material can create temperature differences.

UCSB researchers John Bowers (solid state photonics) and Christopher Palmstrom (heteroepitaxial growth of novel materials) are investigating the potential of this new semiconductor.

The research has been described in detail in the publication, "Self-Assembled ErSb Nanostructures with Optical Applications in Infrared and Terahertz," by Hong Lu *et al* in *Nano Letters*, 2014, 14 (3), pp 1107–1112. DOI: 10.1021/nl402436g

Thorlabs penetrates high-speed optoelectronics market

The firm is expanding its horizons and will develop products for up to 100 GHz deployment. Many similar products currently on the market utilise indium phosphide (InP) technology

Thorlabs has announced a greenfield initiative to start a new business unit, Thorlabs Ultrafast Optoelectronics (Thorlabs-UFO).

The team will focus on addressing the need for high-speed optoelectronic products with bandwidths as high as 100 GHz for deployment in applications outside of the traditional telecommunications market.

These new products will range from basic components to instrumentation consistent with Thorlabs' catalogue of Photonic Tools. Dedicated to establishing R&D facilities distributed geographically, Thorlabs made the decision to locate the new venture in the heart of Michigan's vibrant photonics community in Ann Arbor.

Thorlabs-UFO will look to design, develop, and manufacture leading-edge photonics and optoelectronics products and systems, guided by key insights from customers in the marketplace. The team aims to leverage the technical expertise that it possesses within the organisation's optomechanical, semiconductor, ultrafast laser, and imaging system product development areas.

Together, this combined knowledge and feedback loop should contribute to a high-speed product line aimed at meeting the specific needs of the market, expanding Thorlabs' catalogue offering, and supporting R&D initiatives within other Thorlabs' business units.

"Our initial efforts will be in the area of ultrafast optoelectronic components such as lasers, modulators, and subsystems," comments Janis Valdmanis, General Manager of the Michigan operation. "Ultimately, our research and development efforts here at Thorlabs Ultrafast Optoelectronics will also serve to complement and advance Thorlabs' other initiatives in ultrafast and high-power lasers, optical & fibre optic instrumentation, and life science products."

"There is a long tradition of successful photonics-related research activity going on right here at the University of Michigan and other Michigan-based industrial and educational institutions," notes Valdmanis. "We hope to promote a strong interaction with that research community and attract strong talent from those channels in the coming years, contributing to Michigan's overall job growth."

Michigan is also home to a new state-sponsored Photonics Cluster comprised of thirty companies and educational institutions called Mi-Light. This cohesive effort to enhance the Photonics industry in Michigan in conjunction with national photonics initiatives provides an ideal backdrop for Thorlabs' new venture.

MACOM awards TowerJazz for supplier excellence

The foundry was recognised for continued support, partnership commitment and delivery performance

TowerJazz has received the 2013 Supplier Excellence Award from M/A-COM Technology Holdings Solutions Inc. (MACOM).

MACOM is a provider of high performance analogue semiconductor solutions for use in wireless and wireline applications across the radio frequency (RF), microwave and millimetre wave spectrum.

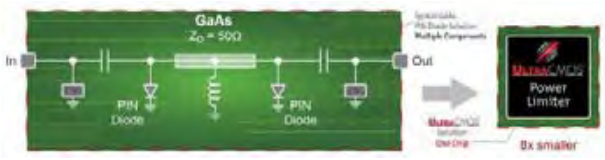
In 2013, MACOM acquired Mindspeed Technologies, a supplier of semiconductor solutions for communications infrastructure applications, which has been a TowerJazz customer for over ten years. This award recognises the foundry's continued support, partnership commitment and delivery performance to Mindspeed and now MACOM.

MACOM utilises a broad range of TowerJazz's specialty process offerings such as SiGe BiCMOS, and silicon CMOS offerings, and including SBC18H2 and SBC18H3 advanced nodes, to develop a variety of products such as cross point switches, TIAs, laser drivers, CDRs, PAs and equalisers.

"Mindspeed has been a long time customer of TowerJazz and we are extremely pleased to continue addressing it and MACOM's next-generation technology needs year after year to manufacture their leading-edge devices," says Todd Mahlen, TowerJazz Vice President of North American Sales. "This award demonstrates our commitment to partnering with our customers and providing leading edge technology to enable their new products and consistently support their on-time delivery needs. In addition, this is confirmation of our worldwide manufacturing excellence while providing the best technical and design solutions for our customers' specific needs."

GaAs competes with Peregrine SOI products for RF

The firm says incumbent gallium arsenide-based RF solutions do not rise to the challenge of new complexity in the telecoms market



Peregrine Semiconductor, a pioneer of SOI and advanced RF solutions, is debuting its new line of UltraCMOS based RF power limiters, including PE45140 and PE45450 slated for release in May.

Peregrine's Silicon on Insulator (SOI) power limiters represent turnkey, monolithic solutions to provide an alternative to discrete, PIN-diode limiters based on GaAs.

The firm says its UltraCMOS power limiters deliver simple, repeatable and reliable protection ideal for test-and-measurement, land-mobile-radio (LMR), wireless-infrastructure, military and radar systems.

"Peregrine makes best-in-class RF products, and we are pleased to extend that heritage into the new category of power limiters announced at EDI CON today," says Duncan Pilgrim, director of marketing at Peregrine. "Our customers continuously find that incumbent GaAs-based RF solutions do not rise to the challenge of new complexity in the market, and they are investing in Peregrine's SOI technology as fast as we can develop new options like this."

Turnkey Monolithic Architecture Delivers Benefits

On a chip claimed to be eight times smaller than the board space required by discrete, PIN-diode solutions, Peregrine's new power limiters are claimed to provide a ten to one hundred times improvement in response and recovery time. The company also says they deliver greater than 40 dB improvement in linearity (IP3) and offer a twenty times improvement in ESD (electrostatic discharge) protection.

Of particular interest to RF designers, Peregrine's power limiters can save PCB space with a small form factor, reduce BoM (bill of materials) by eliminating the need for extra components and improve time to market by reducing in-design time and costs.

Peregrine also says they beat existing solutions in RF performance, including higher linearity to eliminate signal distortion, high ESD to ensure high reliability, wide bandwidth to enable design flexibility and fast response and recovery times to ensure robust protection of power-sensitive components.

Finally, because Peregrine's power limiters are based on UltraCMOS instead of GaAs, they can be closely integrated with other UltraCMOS RF components.

The table below illustrates how Peregrine's new UltraCMOS power limiters compare to GaAs-based PIN-diodes.

Attributes	UltraCMOS Power Limiter	GaAs PIN Diode Power Limiters
Small form factor	Yes	No
Requires no external components	Yes	No
Superior ESD rating	Yes	No
Adjustable limiting threshold	Yes	No
Power reflection mode	Yes	No
Protection in unpowered conditions	Yes	Yes
Excellent linearity	Yes	No
Sub-nanosecond response time	Yes	No
Wide bandwidth support	Yes	No
High power handling	Yes	Yes
Low insertion loss	Yes	Yes

Peregrine's UltraCMOS power limiters can protect:

RF ports in test-and-measurement equipment

RF front ends and low-noise amplifiers (LNAs) in LMRs

RF receivers in wireless-infrastructure equipment

Tactical radio receivers from intentional jammers in military warfare

Transceiver (TRX) modules in radar systems

In order to achieve repeatable and reliable power protection, customers currently face challenges because it takes so long to design and validate PIN-diode power-limiter circuits and the multiple external components this architecture requires.

With Peregrine's new, all-in-one architecture, customers should be able to significantly reduce time to market and cost.

Availability

On display at EDI CON Booth #512, Peregrine plans to release the first two of its UltraCMOS power limiters in May 2014:

The PE45140 is a 20 MHz - 2GHz, 50 W power limiter designed for professional portable and mobile radios, such as tactical radios and LMRs, as well as HF, VHF, UHF, L-band radar transceivers.

The PE45450 is a 9KHz - 6GHz, 50 W power limiter designed for test-and-measurement systems, L/S/C-band radar transceivers, counter-measure receivers and wireless receivers.
Both power limiters feature an adjustable limiting threshold, unbiased power limiting and operation in two modes - power limiting or power reflecting.

New consortium to pioneer 100G CLR4 adoption

Silicon based manufacturers, Intel and Arista spearheaded the creation,

The 100G CLR4 Alliance was organised by a group of industry leaders, major data centre providers, networking companies and optical vendors who are in support of a transceiver based upon 100G CWDM (Coarse Division Multiplexing) LR4 (4 wavelengths) in the 1310nm window and 20nm spacing, hence "CLR4."

Although many of the 100G CLR4 Alliance members manufacture silicon based products, III-V experts are also members; these include Oclaro, Neophotonics, Fujitsu and MACOM.

Alliance partners believe that this approach will enable the rapid development and adoption of this market segment. Conversely, the lack of low-cost, 100G transceivers may become an impediment to the adoption of advanced CPUs, Flash, SSDs and switching silicon to build the next generation systems for cloud, HPC and enterprise data centres. This alliance may evolve into an MSA over time.

Infonetics Research: Infinera top of optical transport vendors

Service providers said Infinera did well in technology innovation, ease of operation, high reliability and leading services and support

Infonetics Research, an international market research and consulting firm serving the communications industry since 1990, has ranked Infinera as the top optical vendor in its latest scorecard.

In the report, Infonetics said, “Infinera is #1 this year as a result of very high ratings among customers for technology innovation, reliability, and service and support.”

Infonetics’ 2014 Optical Network Hardware Vendor Scorecard profiles, analyses and ranks the ten largest global vendors of optical transport equipment. Vendors were evaluated based on seven metrics including market share, market share momentum, financial stability, packet-optical intensity, technology innovation, product reliability, and service and support. In the report, Infinera emerges as the number one ranking optical transport equipment provider worldwide.

“The market for optical transport equipment is $12 billion annually, nearly as large as and growing faster than the market for service provider routers and switches. Infinera emerged as the highest scoring company in our optical vendor leadership scorecard,” stated Andrew Schmitt, Principal Analyst, Optical, Infonetics Research. “When we ask service providers what Infinera does well they mention technology innovation, ease of operation, high reliability and leading services and support.”

“The Infonetics optical vendor scorecard shows that Infinera’s focus on building Intelligent Transport Networks is resonating with global network operators,” added Tom Fallon, Infinera CEO. “In 2013, we grew our market share by enabling service providers to use time as a competitive weapon to deliver services faster while simultaneously scaling their multi-terabit networks and lowering costs. We believe we are at the beginning of a once-in-a-decade transition to 100G and beyond and we are honoured to see our focus on technology innovation and helping our customers win in their markets reflected in the outstanding results for Infinera in the Infonetics scorecard.”

Infinera`s 500G intelligent transport network deployed in South Africa

Internet Solutions is the first company to deploy the firm’s indium phosphide (InP) based super-channels in South Africa

Infinera has announced the deployment of the Infinera DTN-X platform across the company’s South African long distance network.

The Infinera Intelligent Transport Network solution, featuring the DTN-X packet optical transport networking platform, enables Internet Solutions to differentiate its services, and manage costs as they scale their network.

Internet Solutions, a division of Dimension Data and part of the NTT group, provides telecommunications services to public and private sector companies across South Africa and serves more than 80 percent of companies listed on the Johannesburg Stock Exchange.

Using the Infinera Intelligent Transport Network solution, Internet Solutions can now offer 10, 40 and 100 Gigabit Ethernet services to its clients across the long distance fibres it manages across South Africa with short lead times, leading prices and excellent reliability.

Internet Solutions’ clients will benefit from its newly enhanced transport network through faster provisioning of bandwidth, as well as quicker fault resolution timeframes, as a result of Internet Solutions now having complete control of the network, end to end. This networking solution delivers the industry’s only commercially available 500 gigabit per second (Gb/s) FlexCoherent super-channels based on Infinera’s widely deployed photonic integrated circuits and is a first for South Africa and the African continent.

The Infinera Intelligent Transport Network solution provides Internet Solutions with a system integrating dense wavelength division multiplexing optical transmission and five terabit per second non-blocking OTN switching in a single platform.

Infinera’s intelligent software combined with this converged platform automates manual operations to lower operational costs and enable faster service delivery. The Infinera DTN-X is designed to scale without compromise to enable future upgrades to terabit super-channels and Terabit Ethernet.

“The Infinera Intelligent Transport Network solution provides us with a cutting edge optical transport solution, allowing us to offer the highest lit capacity in a South African backbone,” says Prenesh Padayachee, CTO at Internet Solutions. “Internet Solutions is at the forefront of utilising the latest technology that will ensure reliable and rapid service delivery to our clients and it is critical that our vendors are able to deliver the latest and most cutting edge technology. Infinera has delivered this through their intelligent transport network system.”

“Internet Solutions’ selection of an Infinera Intelligent Transport Network solution underscores the value of the Intelligent Transport Network for service providers around the world,”

adds Chris Champion, senior vice president, EMEA sales. "Deploying the first 500 Gb/s super-channels across South Africa with Internet Solutions significantly increases the capacity available to business and consumers in the region."

Custom MMIC unveils GaAs driver amplifier for telecoms

The gallium arsenide device operates from DC to 20 GHz

Custom MMIC is adding a new driver amplifier, the CMD192C5, to its product library.

The CMD192C5 is the packaged version of the CMD192 amplifier that until now had only been available in die form.

The CMD192C5 is a wideband GaAs MMIC distributed amplifier that operates from DC to 20 GHz and has a positive gain slope versus frequency and low noise figure.

This design feature allows for the cascading of multiple amplifiers without the need for extra gain compensation circuitry. The amplifier delivers greater than 19 dB of gain with a corresponding output of 1dB compression point of +25 dBm, and has a low noise figure of 1.9 dB at 10 GHz. The CMD192C5 is a 50 Ohm matched design, housed in a Pb-free, RoHs-compliant, 5 x 5 mm SMT package.

Ideal applications for the CMD192C5 are microwave radio and VSAT, telecom infrastructure, test instrumentation, military and space, and fibre optics.

Samsung selects Anadigics` WiFi InGaP chips for GALAXY Tab Pro

The 802.11ac wireless connectivity in the tab is enabled by Anadigics' indium gallium phosphide technology

Anadigics has announced that the company's AWL9293 and AWL9581 802.11ac front-end integrated circuits (FEICs) are enabling WiFi connectivity in the new GALAXY Tab Pro by Samsung Electronics.

This feature-rich tablet includes a 10.1-inch WQXGA resolution display, Exynos 5 Octa processor, 8 megapixel camera and Android 4.4 KitKat operating system. The new GALAXY Tab Pro offers a virtual keyboard that mimics a physical keyboard, leveraging haptic feedback and hotkeys to offer users a more accurate and familiar typing experience.

"We are very pleased to power both the 2.4 and 5 GHz 802.11ac WiFi bands in the new GALAXY Tab Pro," says Jonathan Griffith, vice president of WiFi Products at Anadigics. "Our FEICs deliver differentiated performance and integration to help reduce time-to-market, extend battery life and increase data rates. By collaborating with Samsung, we continue to leverage these advantages in the latest generation of tablets to deliver an enhanced user experience."

Anadigics' AWL9293 2.4 GHz and AWL9581 5 GHz FEICs use the company's patented InGaP-Plus technology and uniquely designed architectures to combine a high-performance power amplifier (PA), low-noise amplifier (LNA) with bypass option, and RF switch on a single die.

This level of integration greatly improves manufacturability and reliability, while reducing PCB space requirements. These FEICs also deliver exceptionally low current consumption, significantly extending battery-life in mobile applications. The complete family of 802.11ac FEICs provides outstanding error vector magnitude (EVM) and noise figure performance, which enables ultra-high data throughput.

The devices come in a 2.5 mm x 2.5 mm x 0.4 mm QFN package with a high-accuracy, integrated power detector, and RF ports internally matched to 50 Ohms to reduce PCB space requirements.

Infinera customers deploy over one petabit/s transmission

The firm's long-haul super-channel technology utilise indium

phosphide PIC technology

Infinera, provider of Intelligent Transport Networks, has announced that its customers have deployed more than one petabit per second of super-channel transmission capacity in live networks globally.

Infinera says it was the first to ship 500 gigabit per second (Gb/s) long-haul super-channels commercially as the foundation of the Intelligent Transport Network architecture in 2012. Today, nearly two years later, the firm says it remains the only company in the industry delivering volume shipments of super-channels into production networks.

The Infinera Intelligent Transport Network features the Infinera DTN-X packet-optical transport networking platform, delivering 500 Gb/s super-channels based on the commercially deployed large scale Photonic Integrated Circuits (PICs). The platform features InP PICs.

In 2013, Infinera announced the second generation of super-channels enhanced with Soft Decision Forward Error Correction (SD-FEC) to increase transmission range. Recently Infinera announced its third generation super-channel line cards that support flexible grid operation based on the new ITU-T G.694.1 frequency grid.

The optical performance of these super-channels offers service providers long-haul transmission technology that delivers scalable, capacity without compromising on optical reach. Infinera's super-channels deliver long haul reach of up to 4,500 km. They use Polarisation Multiplexed (PM) QPSK modulation that supports up to 9.5Tb/s on a single pair of fibres.

For ultra-long haul and submarine reach, Infinera's FlexCoherent modulation capability allows the line card to be switched into PM-BPSK mode, where spans of over 9,500 km are deployed in production today.

The operational scalability of super-channels was demonstrated last year when a team from Infinera and DANTE, operator of the GÉANT pan-European Research and Education network backbone, achieved an official Guinness World Record for the fastest provisioning of 8 Tb/s of capacity on production route between Hamburg and Amsterdam based on Infinera super-channels.

Infinera is continuing to enhance its super-channel technology with new solutions simplifying operations via multi-layer automation of Intelligent Transport Networks.

The firm recently announced enhancements that include the super-channel CDC FlexROADM (colourless, directionless and contentionless reconfigurable optical add drop multiplexer) and the unified Layer 1 and Layer 0 control plane, including support for the emerging IETF standard for Spectrum Switched Optical Networks extensions to Generalised MPLS.

"From its introduction of the DTN-X, Infinera recognised the opportunity to offer an economically disruptive product just as the mass market for 100G transport took off," says Rick Talbot, Principal Analyst, Optical Infrastructure at Current Analysis.

"The milestone achievement not only validates the vendor's plans to play a leading role in that market, with sales to operators of all sizes, including Tier 1s, but it also confirms the market's appetite for long haul super-channels, whose economics depended on the implementation of the 500G Photonic Integrated Circuit," he adds.

"Infinera continues to lead through innovation in the optical transport industry," says David Welch, President, Infinera. "Our customers have now deployed more than a petabit per second of Infinera's super-channels in production, demonstrating that our PIC-based, single card 500Gb/s super-channel solution is preferred by service providers globally to scale their networks while minimising operations costs."

IQE revenues up 44 percent thanks to wireless

The robust wireless business and diversification strategy drives strong rises in revenues, profit and earnings

IQE has announced its final results for the year ended 31st December 2013.

The firm achieved a new Group record of £126.8 million, up from £88.0 million in 2012.

This includes £30.9 million revenues from Kopin Wireless, acquired in January 2013. However, the company was affected by adverse H2 currency impact as sterling appreciated 3 percent against the US dollar.

H2 wireless sales were up 3 percent over H1 in constant currency and H2 photonic sales were up 12 percent over H1 (in constant currency). The adjusted PBT was up 51 percent to £13.0 million from £8.6 million (Reported PBT £5.2 million).

The adjusted fully diluted EPS increased 43 percent to 2.00p from 1.40p (Reported fully diluted EPS 0.89p). Cash inflow from operations before exceptional items was up 346 percent from £4.7 million to £16.2 million.

Cash conversion before exceptional items was 111 percent up from 51 percent. Net debt was £34.4 million (opening net debt £15.5 million increased primarily due to £25 million of debt to part fund the Kopin acquisition.

Drew Nelson, IQE Chief Executive, made the following statement:

"IQE's core wireless division has again delivered a robust performance, with continued growth despite a significant downstream inventory correction in the major chip companies due to softness in the high end smartphone market. As a direct result of our customer risk mitigation strategy, which we have executed over the last 18 months and completed with the acquisition of Kopin Wireless, we are much less sensitive to market share shifts between the major chip supply companies.

"Concerns in the UK over the last year that silicon CMOS would significantly damage the Compound Semiconductor industry have proved unfounded and are not reflected in our financial performance nor in our customers' expectation of future long

term demand drivers.

“Wireless remains an attractive market for us over the coming years with demand continuing to be driven by the proliferation of wireless applications and the need for sophisticated GaAs chips to deal with the explosive growth in data traffic. Beyond this, the next waves of innovation which will drive handset replacement cycles are likely to include lasers and sensors using compound semiconductor technology, for gaming, 3D image capture, gesture recognition, and sensing for a variety of applications including healthcare monitoring devices.

“Our business diversification strategy also gained strong traction, and we achieved a number of significant technical and commercial milestones during 2013 which reflect the strong progress made in our other key markets including photonic sensors and lasers, advanced solar (CPV), power semiconductors, infrared, LED and advanced electronics.

“Our integration remains firmly on track, and we expect to realise significant reductions in our financial overheads, whilst benefiting greatly from the operational and technical synergies we are delivering.

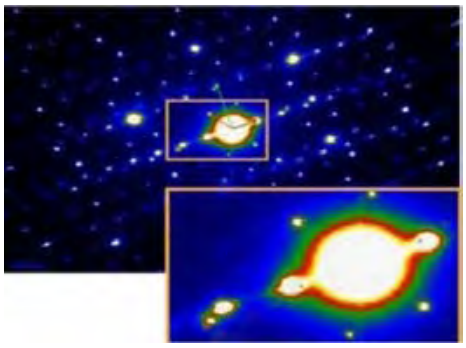
“IQE is at the forefront of the enabling technologies that are at the very heart of many of the twenty-first century trends and products. We are confident that the Group is well positioned for continued growth in earnings and cash flow in 2014 and beyond.”

Rhenium disulphide may hold promise for 2D electronics

Rhenium atoms have a relatively large atomic weight, which means electron spin-orbit interactions are significant

From super-lubricants, to solar cells, to the fledgling technology of valleytronics, many could be excited about the discovery of new two-dimensional semiconductor, rhenium disulphide, by researchers at Berkeley Lab’s Molecular Foundry.

Rhenium disulphide (ReS2), unlike molybdenum disulphide and other dichalcogenides, behaves electronically as if it were a 2D monolayer even as a 3D bulk material.
This not only opens the door to 2D electronic applications with a 3D material, it also makes it possible to study 2D physics with easy-to-make 3D crystals.

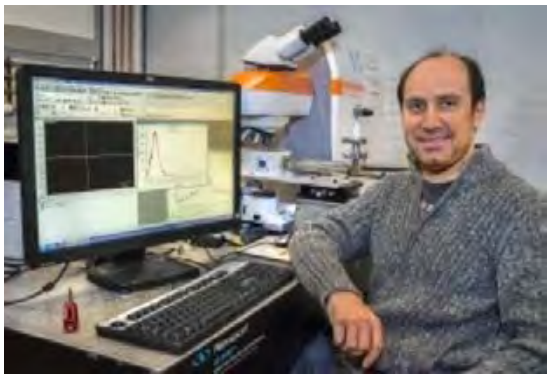


Nano-beam electron diffraction pattern of ReS2with a zoom-in insert image reveals a quasi-hexagonal reflection pattern

“Rhenium disulphide remains a direct-bandgap semiconductor, its photoluminescence intensity increases while its Raman spectrum remains unchanged, even with the addition of increasing numbers of layers,” says Junqiao Wu, a physicist with Berkeley Lab’s Materials Sciences Division who led this discovery.

“This makes bulk crystals of rhenium disulphide an ideal platform for probing 2D excitonic and lattice physics, circumventing the challenge of preparing large-area, single-crystal monolayers.”

Wu, who is also a professor with the University of California-Berkeley’s Department of Materials Science and Engineering, headed a large international team of collaborators who used the facilities at the Molecular Foundry, a U.S Department of Energy (DOE) national nanoscience centre, to prepare and characterize individual monolayers of ReS2.
Through a variety of spectroscopy techniques, they studied these monolayers both as stacked multilayers and as bulk materials. Their study revealed that the uniqueness of rhenium disulphide stems from a disruption in its crystal lattice symmetry called a Peierls distortion.



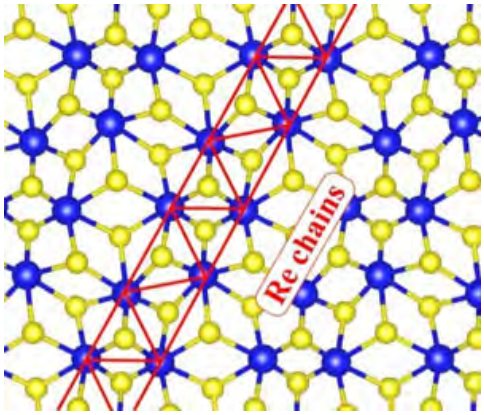
Sefaattin Tongay was the lead author of a Nature Communications paper announcing the discovery of rhenium disulphide, a new 2D semiconductor material. (Photo by Roy Kaltschmidt)

“Semiconducting transition metal dichalcogenides consist of monolayers held together by weak forces,” says Sefaattin Tongay, lead author of a paper describing this research in Nature Communications for which Wu was the corresponding author. The paper was titled “Monolayer behaviour in bulk ReS2 due to electronic and vibrational decoupling.”
“Typically the monolayers in a semiconducting transition metal

dichalcogenides, such as molybdenum disulphide, are relatively strongly coupled, but isolated monolayers show large changes in electronic structure and lattice vibration energies," Tongay says. "The result is that in bulk these materials are indirect gap semiconductors and in the monolayer they are direct gap."

What Tongay, Wu and their collaborators found in their characterisation studies was that rhenium disulphide contains seven valence electrons as opposed to the six valence electrons of molybdenum disulphide and other transition metal dichalcogenides. This extra valence electron prevents strong interlayer coupling between multiple monolayers of rhenium disulphide.

"The extra electron is eventually shared between two rhenium atoms, which causes the atoms to move closer to one another other, forming quasi-one-dimensional chains within each layer and creating the Peierls distortion in the lattice," Tongay says. "Once the Peierls distortion takes place, interlayer registry is largely lost, resulting in weak interlayer coupling and monolayer behaviour in the bulk."



Atomic structure of a monolayer of rhenium disulphide shows the dimerisation of the rhenium atoms as a result of the Peierls, forming a rhenium chain denoted by the red zigzag line

Rhenium disulphide's weak interlayer coupling should make this material highly useful in tribology and other low-friction applications.

Since rhenium disulphide also exhibits strong interactions between light and matter that are typical of monolayer semiconductors, and since the bulk rhenium disulphide behaves as if it were a monolayer, the new material should also be valuable for solar cell applications. It might also be a less expensive alternative to diamond for valleytronics.

In valleytronics, the wave quantum number of the electron in a crystalline material is used to encode information. This number is derived from the spin and momentum of an electron moving through a crystal lattice as a wave with energy peaks and valleys.

Encoding information when the electrons reside in these minimum energy valleys offers a highly promising potential new route to quantum computing and ultrafast data-processing. "Rhenium atoms have a relatively large atomic weight, which means electron spin-orbit interactions are significant," Tongay says. "This could make rhenium disulphide an ideal material for valleytronics applications."

The collaboration is now looking at ways to tune the properties of rhenium disulphide in both monolayer and bulk crystals through engineered defects in the lattice and selective doping. They are also looking to alloy rhenium disulphide with other members of the dichalcogenide family.

The work has been detailed in the paper, "Monolayer behaviour in bulk ReS2 due to electronic and vibrational decoupling".

This research was primarily supported by the DOE Office of Science.

Compound Semiconductor conference hits a new high

35 presentations equipped delegates with a comprehensive overview of the compound semiconductor industry

Around 300 delegates and over 30 sponsors descended on Frankfurt for the fourth CS International Conference, which was held at the Sheraton Airport Hotel this week.

This must-attend event for the leaders of the compound semiconductor industry set a new standard for its number of presentations.

The conference covered all aspects of the industry, with presentations grouped into six key themes:

Power Electronics
LEDs
Integration of CMOS and III-Vs
Wide Bandgap RF Devices
Front-ends for Mobile Devices
Lasers, PICs & PV

Presentations on these topics highlighted the growing penetration of compound semiconductors into the silicon industry, and the use of silicon in the making of III-V chips. Leading developers of next-generation CMOS, such as IBM and Imec, are pioneering approaches to integrate high-mobility materials, for example InGaAs, into the channels of transistors in microprocessors, while silicon substrates are viewed as a low-cost platform for making LEDs, as well also power and RF electronics based on GaN.

Meanwhile, power amplifiers that are based on silicon are starting to go head-to-head with those made from GaAs for

deployment in the latest smartphones. It appears that devices based on CMOS will gain market share, but GaAs will dominate the market for many years to come.

A more detailed report of the presentations at CS International Conference will appear in the April /May edition of *Compound Semiconductor* magazine. This issue will also contain details of the winners of the coveted CS Industry Awards.

For more information about CS International Conference, and opportunities available for the 2015 event, contact Stephen Whitehurst: stephen.whitehurst@angelbc.com Tel 0044 (0)2476 718 970. www.cs-international.net

EpiWorks to boost MOCVD production capacity

The manufacturer of compound semiconductor epitaxial wafers is increasing the ability to produce high volumes of 4-inch and 6-inch wafers for VCSELs, edge-emitting lasers, detectors and photovoltaics

EpiWorks is majorly expanding with a multi-faceted expansion of its production capacity.

The company makes wafers used in applications such as optical components, wireless devices and high-speed communication systems.

“A clear migration toward applications that require significantly higher volumes, particularly in the area of optical materials and photonics is underway. The markets include consumer electronics, sensors and displays, digital projection, and data communications. As the leader in the manufacture and development of high performance compound semiconductor products, we are pleased to announce a major increase in capacity. This is part of an aggressive, long-term production capacity roadmap to satisfy increasing demand from photonic and RF customers,” says Nick Kolarich, Director of Sales and Marketing at EpiWorks.

The expansion increases the ability to produce high volumes of 4-inch and 6-inch wafers for VCSELs, edge-emitting lasers, detectors and photovoltaics with a better cost structure. The new capacity includes upgrades to existing tools and the latest Aixtron 2800 G4 MOCVD technology. This allows EpiWorks to quickly and seamlessly satisfy customer demand while providing greater flexibility for new product development.

“For many years EpiWorks has been the leading US-based manufacturing and development partner for novel and advanced photonic and optical devices. Our customers have leveraged our development expertise to commercialise numerous complex advanced technologies from the lab into next generation photonic products. We are excited to now see our high-volume manufacturing expertise enabling proliferation of these products under stringent specifications and at low cost,” explains Quesnell Hartmann, EpiWorks CEO.

IQE delivers first 150mm VCSEL epiwafers

The high volume production of the wafers will be used in a variety of applications. These will include the mobile, defence and military, computing and medical sectors

IQE says it has delivered the world’s first 150mm (6”) VCSEL epi wafer process for high volume, low cost applications.

Markets for VCSELs are proliferating rapidly as this advanced laser is becoming the device of choice for many high volume applications including:

• *Gesture recognition, for gaming and non-contact navigation (e.g TV, smartphone, tablet)*

• *Depth imaging for 3D vision , driving next wave of handset innovation for must have new phones*

• *Low energy optical storage and fast switching in high capacity data centres, servers and ultra-high speed computing*

• *High speed datacomms, including Active Optical Cables (AOC)*

• *UltraHigh Density magnetic Storage using Heat Assisted Magnetic Recording (HAMR)*

• *Illumination for IR cameras for security, safety, night vision*

• *Industrial heating including paint curing and commercial print shops*

• *Cosmetics and healthcare including hair removal, antiwrinkle, blemish reduction*

A number of these applications require multi-element array configurations which use greater surface areas and therefore more epiwafer material. They also offer higher optical power output compared with discrete devices.

Many of these markets are price elastic, and by moving to 150mm wafer sizes, compatible with existing well established, state of the art 150mm RF GaAs wafer processing lines, high performance VCSELs can be manufactured in large volume using fabrication and testing techniques similar to that of LEDs.

This combination will provide a high volume manufacturing technology and capability to help drive down the cost of VCSEL based photonics products for deployment in mass market, consumer applications.

The improved cost structure will allow designers to utilise the operational and performance advantages of laser devices to further develop advanced sensing applications which are expected to drive the next wave of innovation in consumer products such as cell phones, tablets and other handheld devices.

Initial engineering evaluation and product qualification wafers have already been delivered and initial performances have replicated those of existing smaller wafer sizes. Production is

expected to ramp over the coming year.

Drew Nelson, IQE CEO, says, “VCSEL enabled products such as gesture recognition and ‘time of flight’ sensing are expected to ramp significantly over the coming period as they become incorporated into next generation handset and mobile communication devices, as well as a myriad of other high volume applications.”

“By introducing our new 150mm VCSEL epiwafer process, which is compatible with existing high volume RF GaAs chip processing lines, we are enabling a new low cost manufacturing route for high performance laser devices.IQE has built a powerful technology platform for VCSELs, and recent announcements on record low power consumption VCSELs for data centres and record high speed data transmission with IBM for datacentres, servers and supercomputers are testament to the strength and depth of this platform,” he adds.

RFMD and TriQuint merger to pip Skyworks at the post

The combination will increase defence market opportunities for the joint firm

The Strategy Analytics Advanced Defence Systems (ADS) service report, “TriQuint-RFMD Merger Solidifies Semiconductor Market Share Lead in Defense Sector,” provides analysis on this deal and outlines the market share that the new company will command.

On February 24th, RFMD and TriQuint announced a definitive merger agreement under which the companies will combine in an all-stock transaction.

Designed to be a merger of equals, the new company (NewCo) will have a new name and shared leadership team.

Both companies have an extensive portfolio of capabilities in the areas of advanced semiconductor process technologies such as GaAs and GaN.

The combination will collate these complementary capabilities and enable the new company to successfully pursue defence market opportunities.

“In the area of Defence, TriQuint has been a leading supplier of semiconductor technologies, for example, military radar systems used on fast-jets including the F-15, F-22 and F-35. The company also holds US DoD Trusted Source accreditation,” notes Eric Higham, North American Director for ADS. “RFMD has ongoing activity in the aerospace and defence sectors with products targeting radar, communications and electronic warfare applications.”

“The combined infrastructure and defense unit can achieve potential revenues of around $500 million. Strategy Analytics’ own estimates indicate that the new company’s defence revenues will account for up to 25 percent of this unit revenue,” notes Asif Anwar, Director of the ADS service.

He adds, “As a GaAs and GaN semiconductor technologies supplier, we believe TriQuint holds the number one position in the defence space, and the combined TriQuint-RFMD entity will cement this position extending a lead over contemporaries in this area such as Cree, Hittite and MACOM Technologies.”

TriQuint Ka-band GaN amplifiers set to fly

The firm’s latest gallium nitride ‘Spatium’ devices can be used for airborne wireless and defence applications

TriQuint Semiconductor announced at Satellite 2014 that its Spatium technology achieves unprecedented levels of Ka-Band solid state power, bandwidth and efficiency, which provides greater broadband capacity and opens up new satellite possibilities.

TriQuint’s patented Spatium technology enables satellite communications for commercial and defence use of the recently deployed Ka-band spectrum.

Its high frequency broadband connectivity can be used for media-rich and high-bandwidth communications such as airborne wireless access, defence communications; and video for unmanned aerial vehicles or systems.

Spatium combines multiple GaN monolithic microwave integrated circuits (MMICs) enabling cost effective and reliable solid state broadband power amplification (SSPA).

Spatium solid state power amplifiers

“With Spatium, TriQuint is advancing the use of GaN technology in a broad range of radar, electronic warfare and communication applications,” says Vice President James Klein, TriQuint Infrastructure and Defence Products. “Notably, TriQuint’s Spatium technology has eclipsed historical industry

performance levels by a significant margin, providing exactly what the rapidly growing Ka-band satellite market needs."

Spatium produces an average saturated power of more than 130 watts over the entire 27-31 GHz band. It also produces linear output power of 60 watts with more than 15 percent efficiency, operating at only 20 volts.

TriQuint says Spatium's ease of integration, small form factor and integral parallel redundancy ensure that its SSPA is a reliable alternative to travelling wave tube amplifiers (TWTA). Spatium's high power and bandwidth capability provide the industry with a solid state alternative to TWTAs, which operate at high voltage and require complex and expensive external optimisation networks to improve efficiency and linearity.

Spatium amplifiers are available in a wide variety of off the shelf and custom configurations operating at frequencies up to 40 GHz and power levels up to multiple kilowatts.

Windstream to use Infinera`s 100G InP long-haul express network

Windstream operates a nationwide fibre and IP network covering 118,000 miles of fibre and twenty-seven data centre locations

Infinera is deploying its DTN-X platform, featuring 500 Gigabit per second (Gb/s) super-channels across Windstream's long-haul express network.

The Infinera Intelligent Transport Network should enable Windstream to differentiate its services, protect its investment and lower operational expense as it scales its network.

As a cloud solutions provider, Windstream serves businesses with a wide range of cloud communication needs, in addition to offering an advanced data, voice and video network that provides customers low latency and reliable 100 Gigabit Ethernet services.

Windstream benefits from an Infinera Intelligent Transport Network featuring commercially available single-card 500 Gb/s FlexCoherent super-channels based on Infinera's InP photonic integrated circuits.

This provides Windstream with a solution integrating DWDM optical transmission and five terabit per second non-blocking OTN switching in a single platform. According to Infinera, its intelligent software combined with this converged platform automates manual operations to lower operational costs and enable faster service delivery. The Infinera DTN-X is designed with 1 terabit per slot, enabling it to scale without compromise to single-card terabit super-channels and Terabit Ethernet in the future.

"By deploying the Infinera Intelligent Transport Network, Windstream will significantly increase the capacity of our network infrastructure to meet the needs of our customers," says Randy Nicklas, executive vice president of engineering and chief technology officer for Windstream. "The DTN-X platform enables us to offer services that result in lower latency for mission critical applications while providing a network that is even more reliable and enables rapid provisioning of services."

"Windstream's selection of the DTN-X reinforces the value of the Infinera Intelligent Transport Network architecture," says Tom Fallon, Infinera CEO. "It's clear that in addition to the need for scale and efficiency, network operators value the ability to turn time into a competitive weapon by delivering the high capacity services their customers want, quickly and more reliably than their competitors."

"As the proliferation of content rich and low latency applications place greater demands for ultra-high bandwidth speeds, coupled with advances in optical technologies driving more efficient and cost-effective network infrastructure solutions, carriers deploying state-of-the-art, 100G upgrades are well positioned to meet the increasing network capacity requirements and to capitalise on the expected growth in 100GigE services," notes Roopashree (Roopa) Honnachari, Program Manager for Business Services at Frost & Sullivan.

"According to Frost & Sullivan's latest report on the U.S. Wavelength Services market, the total revenues (wholesale and retail) for 100GigE services is projected to grow at a compound annual growth rate of 165 percent between 2013 and 2017, reaching nearly $120 million by 2017," concludes Honnachari.

Northrop Grumman to highlight GaN MMIC technology

The company will showcase its gallium nitride devices used in commercial, military and scientific missions

Northrop Grumman Corporation will highlight its specialised space capabilities at SATELLITE 2014 for products ranging from secure military satellite communications to antenna technologies that will help NASA monitor California's ongoing drought.

Northrop Grumman will showcase products that incorporate technologies the company developed for the U.S. Air Force's protected satellites currently on orbit but adapted for future architectures.

These will include GaN Monolithic Microwave Integrated Circuits (GaN MMICs). The company has developed a line of GaN MMICs for military and commercial uses based on its high-frequency GaN process that achieved top-level performance and quality under military contracts received beginning in 2002. Target customers are in the defence and commercial ground satellite communication terminal markets and the commercial wireless infrastructure market.

Scientific missions will be another focus of Northrop Grumman's activities at SATELLITE 2014. Astro Aerospace, a Northrop Grumman strategic business unit, is providing a

deployable satellite reflector and boom assembly for NASA's Soil Moisture Active/Passive (SMAP) mission. The agency says SMAP will advance its ability to monitor droughts like the evolving one in California, and predict floods and mitigate their related impacts on people's lives.

Optical interconnects propelled by InP based VCSELs

Furukawa, OFS And Corning say they have increased reach and distance to benefit mega data centres

Furukawa Electric has developed a VCSEL that operates at 25 Gbps and realised transmission of up to 500 metres over prototype multimode fibres developed by OFS and Corning Incorporated.

«This is a significant accomplishment for data communications as both longer reaches and higher speeds are required for warehouse-scale data centres. Our customers are raising expectations as they implement next-generation data centres and we are pleased to be innovating the technology to meet and exceed those expectations,» says Haruki Ogoshi, senior fellow of Furukawa.

The rapid growth of cloud computing and expansion of ‹big data› is causing a dramatic increase in the volume of data handled in data centres. This has generated demand for greater throughput in servers, switches and routers in data centres. Increasing the serial speed of transmission of lasers and photo detectors is one approach to that end.

Also, there is a need to increase transmission distances between devices as data centres become larger. In mega data centres, for example, transmission distances of 300 m or longer can be required. At present, VCSELs at a wavelength of 850 nm are widely used for lowest cost optical interconnect.

However, many say that when the transmission speed is changed from 10 Gbps to higher-speed 25 Gbps, the transmission distance is limited to less than 200 m due to the influence of chromatic dispersion in multimode fibres.

In order to solve these issues, Furukawa has developed a VCSEL with a wavelength of 1060 nm that operates at 25 Gbps.

«Increasing the VCSEL wavelength from 850 to 1060 nm reduces chromatic dispersion of fibres by approximately two thirds,» says Durgesh Vaidya, Senior Manager Research and Development for OFS.

«Accordingly, use of a multimode fibre with the modal dispersion minimized at 1060 nm reduces transmission impairments and allows transmission distances to be extended. It is widely expected that it will be easier to increase VCSEL speeds in the future beyond 25 Gbps by moving from 850 to higher wavelengths.»

Furukawa created a prototype optical module integrating the newly developed 1060 nm VCSEL in a small package with a driver integrated circuit and then conducted a transmission experiment close to actual operating conditions. When a multimode fibre from OFS or Corning was used with the modal dispersion optimised for a wavelength of 1060 nm, a long-reach of 300 m was achieved.

In a joint experiment, a short length of modal dispersion-compensating fibre developed by Corning was used in conjunction with standard OM4 multimode fibre, and a transmission distance of 500 m was achieved.

These results were obtained without the use of electrical compensation technologies such as a clock data recovery or an error correction.

In this way, FEC›s new VCSEL technology can allow for an increase in speed and distance without complicating future systems.

«This collaboration shows that long wavelength VCSEL technology can meet the demands of next generation data centres when combined with new, wavelength optimised fibre, or even standard OM4 fibre with new modal dispersion compensation fibre,» says Alan F. Evans, research director, Optical Physics and Transmission Technology, Corning.

Optelian makes GaAs wafer supply agreement with CST

Under this foundry agreement, CST will supply to Versawave fully processed GaAs wafers with an optical coating, as designed and specified by Versawave

Optelian and Compound Semiconductor Technologies (CST) will supply GaAs wafers to Optelian's Versawave Division as a key component of Versawave's high-speed optical modulator technology.

"We are delighted to be working with a world-class partner like Compound Semiconductor Technologies," states David Weymouth, Optelian's CEO. "Their Class 50 clean room environment, combined with full ISO compliance, enables Optelian to maintain our exceptionally high manufacturing standards."

In conjunction with this agreement, Optelian has also ramped up Versawave facilities at its corporate and manufacturing headquarters in Ottawa. The wafers supplied by CST will be integrated into Versawave opto-electrical modules by Optelian's manufacturing team.

"Quality is a core aspect of the culture here at Optelian," says Dennis Isotti, Vice President of Operations. Optelian is TL-9000 certified, which is a catalyst that helps create an environment of continuous improvement for the organisation. We are proud of our North American manufacturing capabilities and have the expertise to ramp up production of Versawave modules to orders of magnitude above the current production capacity."

Versawave module production will be transferred into a newly built custom clean room space where process and operations will be fully integrated into Optelian's production and quality control systems. Manufacturing is capable of 24/7 production, resulting in shorter lead times while ensuring on-time customer delivery and quality.

"Moving R&D and Operations under the same roof will not only make us more efficient, but also more agile," comments Simon Benwell, Director of Advanced Optical Components, at Optelian's Versawave Division. "By having R&D work in conjunction with the production teams, our NPI times will reduce significantly while our production capacity will drastically increase. These are both essential for our new products coming onto the market in 2014 and beyond."

Advanced Photonix extends line of credit with lenders

One of the clauses is additional fees will be payable to SVB and PFG of up to $50,000 and $75,000

Advanced Photonix, Inc has reached an agreement with both Silicon Valley Bank (SVB) and Partners for Growth III, L.P. (PFG) to waive past covenant violations under the company's respective loan and security agreements with both firms.

This is subject to certain terms and conditions, and provide for an extension of the line of credit under the SVB Loan Agreement through May 31st, 2014.

The company plans to continue discussions with SVB to extend the line of credit beyond May 31st, 2014 based on the company's future business conditions.

The amendments provide for:

An extension of the SVB line of credit from March 31st, 2014 to May 31st, 2014.

SVB's and PFG's waiver of the current covenant defaults under the Loan Agreements.

A reset of the Loan Agreements' trailing three month adjusted EBITDA covenant to a negative $1.2 million for the month ended February 28th, 2014, a negative $800,000 for the month ended March 31st, 2014, a negative $600,000 for the month ended April 30th, 2014 and a positive $1 for the month ended May 31st, 2014.

A reset of the Loan Agreements' existing liquidity ratio to 1.30 as of February 28th, 2014, and 2.25 each month thereafter through May 31st, 2014.

The current interest rates under the SVB Loan Agreement to remain at the Prime Rate published in the Wall Street Journal (currently 3.25 percent) plus 4.0 percent for the line of credit and 4.5 percent on the existing term loan.

Certain changes to the SVB Loan Agreement to eliminate the Company's ability to engage in stock repurchases and to impose a uniform 30-day deadline to deliver monthly financial statements to SVB for all months, including those coinciding with the end of a fiscal quarter.

A revision to the EBITDA definition to add back fees associated with the negotiation of the Amendments.

A $10,000 fee payable to each of SVB and PFG for the modifications and waiver of the current covenant defaults and an additional $5,000 payable to SVB for the extension of the SVB line of credit.

Additional fees payable to SVB and PFG of up to $50,000 and $75,000, respectively, due upon the earlier of May 31st, 2014 and the date that all outstanding indebtedness becomes due under the Loan Agreements.

All other terms and conditions of the Loan Agreements would remain the same.

Richard Kurtz, President and CEO comments, "We are pleased to have come to agreement with both Silicon Valley Bank and Partners for Growth, both of which have a rich history of working with growing high technology businesses like API. We would like to thank Silicon Valley bank and Partners for Growth, both for their deep understanding of the high technology market and for their commitment to API in particular."

IQE initiative to boost regional supply chains

The new programme is aimed at establishing partnerships to support the development of a broad range of key enabling technologies

IQE plc, a supplier of semiconductor wafer products and services, has launched its Open Innovation programme "openiqe".

The first major project under the new programme is the IQE Open Technology Challenge, which will be marked by a launch event at the SWALEC Stadium in Cardiff on Friday 21st March 2014.

The aim of the challenge is to engage with small and medium enterprises, larger businesses and academic institutes, initially focusing primarily on the Welsh region, to develop new and enhance existing supply chains.

The project will focus on technology areas termed the Three Grand Challenges identified in the Science for Wales strategy and other major International programs, including the EU Horizon2020 Program. The three areas are life sciences and health; low carbon, energy and environment; and advanced engineering and materials.

Technology will play an increasingly important role in addressing a range of societal challenges. IQE's Open Technology Challenge is aimed at establishing partnerships along an end-to-end supply chain to develop and commercialise products that will meet real needs within the

areas defined by the Three Grand Challenges.

Drew Nelson, IQE President and CEO, comments, "IQE has more than twenty-five years' experience of working closely with partners and customers worldwide to meet demanding technical specifications. We are delighted to be contributing our experience of collaborative innovation in the form of our new Open Innovation programme."

"We are confident that the Open Technology Challenge has the potential to become a key stepping stone towards the establishment of a major technology cluster in the region, as well as building stronger links to the global technology community."

IQE's Open Innovation programme is being supported by the Welsh Government.

Infinera introduces InP based multi-layer automation for transport

The combination of the Infinera DTN-X packet optical transport networking platform with new solutions hope to enable multi-layer automation of Intelligent Transport Networks

Infinera has launched new solutions for service providers planning to simplify the operation of multi-layer transport networks through increased automation.

Multi-layer transport networks blend the efficiency of digital switching with the scale of optical switching to create the communication foundation of cloud-based services and the Internet.

The solution includes one of the industry's first super-channel FlexROADM (reconfigurable optical add drop multiplexer), the first standards based multi-layer control plane for spectrum switched optical networks (SSON) and the first 500 gigabit per second (Gb/s) flexible-grid super-channels.

"At Telefonica I+D we continuously explore innovative technologies to help create the communication services of the future," says Juan Fernandez-Palacios at Telefonica I+D lab. "Our successful testing of the innovative FlexROADM helped shape the solution Infinera is announcing today. This is one example of how Telefonica I+D collaborates with technology innovators like Infinera to shape the next generation of optical networks."

"Infinera continues to drive innovation in the optical communications industry," continues Ron Kline, Principal Analyst at Ovum. "Adding super-channel FlexROADM capabilities to its unique photonic integrated circuit based architecture deepens the company's differentiation. A unified control plane with multi-layer automation provides needed flexibility at a time when communications service providers really need it."

Infinera claims these solutions for the Infinera Intelligent Transport Network make it easier for operators to automate the digital switching and the optical transport layers of their multi-terabit transport networks:

Infinera's converged switching capabilities have been enhanced to feature a new, purpose-built super-channel FlexROADM. The FlexROADM is colourless, directionless and contention-less (CDC) and is available in C, CD, and CDC versions up to nine degrees.

When combined with the multi-terabit OTN switching of the DTN-X platform, service providers now have a converged multi-layer solution with digital grooming of client services and optical switching of efficiently filled super-channels.

Infinera's standards based control plane now extends transport automation beyond super-channels to control the FlexROADM, which is compliant with the Internet Engineering Task Force's (IETF) SSON framework.

The same standards based multi-layer control plane controls the digital OTN switching for point and click service establishment as well as the switching of flexible grid super-channels at the optical layer. This combination uniquely enables service providers to automate everything in the Intelligent Transport Network.

Flexible Grid Super-Channels for Efficient Long-Haul Transmission. Infinera's third generation of 500 Gb/s super-channels takes full advantage of large scale photonic integrated circuit technology and the FlexCoherent Processor to deliver the industry's first single-card long haul flexible grid super-channels. Infinera customers have deployed almost one petabit per second of Infinera's first and second generation FlexCoherent super-channels since the introduction of the DTN-X platform in 2012.

"At Infinera we work closely with our customers to understand when and where to best introduce technology innovations that drive the most value," says. David Welch, Infinera Co-Founder and President. "Through this collaboration, Infinera is the first to deliver multi-layer automation of transport networks to help our customers deliver services faster while simultaneously lowering operational costs."

Oclaro ramps up production of InP 100G transceivers

The company is expanding its manufacturing and testing capacity for 100G CFP2 LR4 to reach 40km

Oclaro is increasing the production capacity for its dual-rate 100G CFP2 LR4 transceiver to respond to the fast market adoption of the smaller form factor.

With an approximately 50 percent smaller footprint and 30 percent lower power consumption when compared with the deployed 100G CFP LR4, CFP2 compatible line cards could double the port density and bandwidth of a high-end core router or optical transport system.

The Oclaro 100G CFP2 LR4 is designed to simplify work for network operators by collapsing multiple network layers while continuing to increase the available bandwidth. These new converged packet-optical networks require the most economical 100G client solutions to interconnect high-end routers to the optical infrastructure.

"It is exciting to see our customers adopt the CFP2 form factor and we are delighted to ramp its production after the ongoing success of our 100G CFP LR4," says Yoshikazu Era, General Manager, Oclaro Japan Module Division. "Our solution is not only backward compatible with deployed CFP slots, but it also offers the flexibility of dual-rate operation to simplify our customers system and network design. Furthermore, our roadmap will not stop at CFP2 and we will continue to aggressively invest in laser, receiver and advanced packaging technology to further shrink the size and reduce power consumption of 100G client solutions."

After Oclaro made the 100G CFP2 LR4 available to the market in 2013, several tier 1 customers re-designed their client interface line cards to accommodate the new form factor and expedited the product qualification. With most of the design slots reaching general availability in 2014, Oclaro is now expanding its investment in manufacturing and testing capacity to stay ahead of the market demand.

Oclaro is offering a CFP2 that is fully-interoperable with existing CFP transceivers supporting both OTU-4 and 100GbE interfaces. The support of 'dual-rate operation' is critical to customers who demand the flexibility to use the product both in native Ethernet and OTN transport environments. The CFP2 dual-rate operation is made possible by leveraging the superior efficiency of the Oclaro InP Distributed Feedback laser (DFB) structure.

In addition, at OFC 2014, Oclaro is unveiling a disruptive technical solution to further expand the reach of CFP2 up to 40km. By eliminating the power-hungry Semiconductor Optical Amplifier (SOA) used in previous IEEE 100GBASE-ER4 products, power consumption can be drastically reduced to allow for the transition to a smaller form factor such as CFP2.

With the adoption of 100G from core networking into access, customers demand products that can reach beyond the LR4 10km standard.

At the show, Oclaro is demonstrating interoperability between 100G CFP2 and 25Gbps APD ROSA on a 40km transmission link.

Oclaro is planning to formally introduce this new extended reach APD-based CFP2 in 2H 2014.

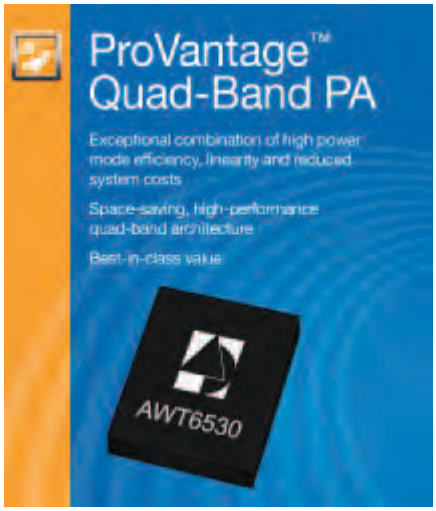
The CFP2 LR4 transceivers are fully qualified and now in volume production.

RF Electronics

Anadigics shipping InGaP quad-and 3G/4G power amplifiers

The indium gallium phosphide based PAs are suited for use inmobile devices. The AWT6530 is compatible with chipsets from suppliers,including MediaTek, HiSilicon and Qualcomm

Anadigics has commenced high-volume production shipments of the AWT6530 quad-band ProVantage power amplifier (PA).



The company says its ProVantage solutions combine high power mode efficiency, linearity and reduces system costs. By leveraging Anadigics' unique quad-band architecture, the new AWT6530 integrated power amplifier minimises space requirements in mobile devices. The AWT6530 is compatible with chipsets from leading suppliers, including MediaTek, HiSilicon and Qualcomm.

"Smartphone, tablet and datacard manufacturers increasingly value power amplifier solutions that integrate innovative features and excellent performance into compact packages," says Jerry Miller, senior vice president of Cellular Products at Anadigics.

"Our new AWT6530 quad-band ProVantage power amplifier is optimized to answer this challenge by providing an industry-leading blend of value, performance and space-saving integration. The AWT6530 has broad applicability validated by design wins at multiple OEMs and is a key element of our growth strategy in China and emerging markets," Miller adds.

Anadigics ProVantage power amplifiers leverage the firm's patented InGaP-Plus technology and help to extend battery life by offering two selectable bias modes that optimise efficiency for low and high output power levels, as well as a shutdown mode with low leakage current.

The AWT6530 quad-band power amplifier delivers 40 percent power-added efficiency (PAE) operating in UMTS bands 1, 5,

and 8 and 42 percent PAE in band 2. ProVantage solutions are also designed for use with an external switch mode power supply (SMPS) to support average power tracking (APT), which further increases efficiency and reduces current consumption at low and medium operating powers. The company's ProVantage power amplifiers are also claimed to ensure stable cellular connectivity and high data throughput.

Anadigics ProVantage Quad-Band Family Key Facts and Highlights

High-power-mode efficiency to extend battery life

Good linearity to maintain stable, high-throughput 3G and 4G connections

Two independent amplification chains to provide rxcellent performance for each band

Compact 3 mm x 4 mm x 0.9 mm packages with internal voltage regulation and integrated DC blocks on the RF ports to reduce PCB space requirements

RF matching optimised for output power, efficiency, and linearity in a 50-Ohm system

GigOptix producing GaAs E-band radio chipsets in volume

The gallium arsenide based devices are designed for the point-to-point wireless backhaul market. The company has also taken on ex RFMD veteran Sushil Kumar as Senior Director of IC Development to lead engineering efforts for the wireless product line

GigOptix, a firm that focuses on optical and wireless communications networks, has announced it has a leadership position in point-to-point (PtP) wireless backhaul with production volume delivery and continuous revenue growth of E-Band radio chipsets.

The company has also appointed industry veteran Sushil Kumar to the newly created role of Senior Director of IC Development for the Wireless Product Line. Kumar's appointment is already effective.

GigOptix's Wireless Product line was launched in June 2012 when the firm augmented its internal GaAs power amplifier program with the license of the SiGe millimetre wave technology from IBM for E-band chipsets, for both 71 to 76GHz and 81 to 86GHz frequency bands.

"Today we are proud to announce that we have received a substantial purchase order of $1.5 million of our leading E-Band devices from one Tier 1 customer. In comparison, the total fiscal 2013 revenue from the Wireless Product Line was $1.7 million," says Raluca Dinu, Vice President and General Manager of the High-Speed Communications division at GigOptix, Inc.

"With the strong demand that we have seen so far this year, and considering our current GaAs power amplifier backlog, the Wireless Product Line is in an excellent position to about double the revenue of E-Band devices in 2014 compared to the previous year," Dinu adds.

GigOptix EXP7602-DNT and EXP8603-DNT devices were claimed to be the first GaAs E-band high performance power amplifiers with general availability - since September 2013 - and include integrated power detectors specifically designed to meet ANSI and ETSI requirements.

The amplifiers are said to have exceptionally good linearity, OIP3's better than 31dBm, and typical power dissipation lower than 2.2W.

"This is an exciting time at GigOptix for the wireless product team with such positive acceptance of our products in these early stages of the market. With increasing shipments of RF chipsets we have great momentum to continue to lead the market with best in class differentiated products. The Wireless Product Line is following a visionary path demonstrating GigOptix' relentless roadmap innovation," says Dinu.

"GigOptix's roadmap continues to lead the industry with improved performance, lower costs, and higher levels of integration. Customers can expect to receive samples of the new integrated SiGe transceiver chipset in Q3 fiscal 2014."

The E-Band radio market, still in its early stages only two years ago, is entering its maturity stage with significant volume deployment. Market estimates are that approximately 3,000 E-Band radios per month are currently being shipped and, based on strong demand from Tier 1 customers, the number of deployed radios is expected to grow to 6,000 per month with total shipments in 2014 in excess of 50,000 radios.

The demand for E-Band radios in the first few months of 2014 has been very strong, driven by the deployment of LTE cellular infrastructure in support of the ever growing demand for mobile data for smartphones.

If the current trend continues it is expected that in 2015 the E-Band radio will become one of the most deployed solutions for wireless back-hauling with volumes in the range of 200,000 radios in 2015 and doubling in 2017.

The deployment of small cells will be part of the second wave of LTE deployment with volume installation to start in 2015 and it will be addressed by V-Band devices, 60GHz band. With small cell density expected to be one order of magnitude greater than regular cells in urban areas, the demand for V-band radios is expected to boom in the next two years with volumes at much higher than E-Band.

According to EJL Wireless Research's 9th Edition (May 2013) of the Global Digital PTP Radio Market Analysis and Forecast, 2013-2017 report, a shift towards high capacity radios will continue to drive more value added products in the market, based on 4G networks launched in 2010 and continuing deployments through 2015.

The market report accounts for the impact of microcells, as well as the demand for new sites and capacity upgrades within the mobile infrastructure market.

At 60 GHz Gigabit Ethernet unit shipments are forecasted to grow from 20,000 in 2014 to 200,000 in 2017. At 70 / 80GHz Gigabit Ethernet unit shipments are forecasted to grow from 18,000 in 2014 to 120,000 in 2017. Gigabit Ethernet is expected to dominate the 60GHz and 70 / 80GHz frequency bands in the forecast period.

With this rapid business growth and customer demand, GigOptix has appointed industry veteran Sushil Kumar to the newly created role of Senior Director of IC Development for the Wireless Product Line. Kumar, who will be based at GigOptix's headquarters in San Jose, will be leading the engineering teams for the Wireless Product Line.

"Now that significant GigOptix product shipments have started to ramp, we hired Mr. Sushil Kumar to take the next generation of the E-Band and other wireless band products to the next level. I am happy to welcome Sushil to the GigOptix team. Sushil has more than twenty-five years of high speed RFIC and MMIC transceiver development experience to benefit GigOptix," says Andrea Betti-Berutto, Senior Vice President and Chief Technical Officer at GigOptix, Inc.

"Sushil will lead our advanced RF and E-Band initiatives and will help us accelerate our development of the next-generation millimetre wave IC transceivers."

Prior to joining GigOptix Kumar held Director of Engineering role at RFMD. At RFMD Kumar led GaN and GaAs MMIC development in the San Jose design centre. Sushil Kumar's experience includes participation in more than 100 MMIC designs with frequencies from near base band up to E-Band.

He also worked in various engineering and research roles for more than twenty years, including Senior RFIC/MMIC Design Engineer at Avago Technologies in San Jose, Senior RFIC/ MMIC Design Engineer at Agilent Technologies in San Jose, Design Engineer at Hewlett Packard in Santa Clara, and a Senior Scientist at the Defence Research and Development Organisation in India.

Kumar has published numerous RF papers, has been awarded three patents, and is actively involved in activities of the IEEE and International Microwave Symposium. He begins his role at GigOptix immediately.

Peregrine SOI UltraCMOS PA matches GaAs performance

The firm's RF Silicon On Insulator substrates are claimed to deliver a 50-percent performance improvement over similar solutions

Peregrine Semiconductor announced the Greater China debut of UltraCMOS Global 1, a reconfigurable RF front-end (RFFE) system, at EDI CON 2014. By integrating all the components of the RFFE on a single chip, UltraCMOS Global 1 delivers one platform design - a single, global SKU - that operates in all regions worldwide.

Peregrine says the system includes the industry's first LTE CMOS power amplifier (PA) to meet the performance of gallium arsenide (GaAs) technology. The UltraCMOS Global 1 PA offers a high-band PA path that supports China's recently licensed TDD-LTE technology networks.

UltraCMOS Global 1 Is a Reconfigurable System

The rapidly growing LTE device market has put unprecedented demands on the performance of the RFFE. To support more than forty frequency bands and a more than 5,000-fold increase in the number of possible operating states, a reconfigurable and tuneable RFFE is now an industry requirement.

Peregrine's UltraCMOS Global 1 provides digitally controlled adaptation across modes and bands, high isolation to solve interoperability issues and scalability to easily support higher band counts with low-loss switching and tuneability.

This level of reconfigurability is available on Peregrine's UltraCMOS 10 technology platform, an advanced CMOS process that uses RF SOI (Silicon On Insulator) substrates and delivers a 50-percent performance improvement over comparable solutions. Global 1 is fabricated on this advanced-technology platform

On a single chip, Global 1 integrates Peregrine's RF switches and tuners with a CMOS PA.

The UltraCMOS Global 1 RFFE system has a 3-path MMMB PA, post-PA switch, antenna switch and antenna tuner. It also supports envelope tracking and has a common RFFE MIPI interface.

UltraCMOS Global 1 can benefit the entire wireless ecosystem. Platform providers and OEMs can accelerate their time to market by creating a single platform design for global markets.

Consumers can enjoy longer battery life, better reception, faster data rates and wider roaming range. Finally, wireless operators can reduce capital investments in their network with improved RFFE performance, resulting in better coverage and reductions in dropped calls.

The UltraCMOS Global 1 RFFE system will complete platform integration in 2014 and will be in volume production in late 2015.

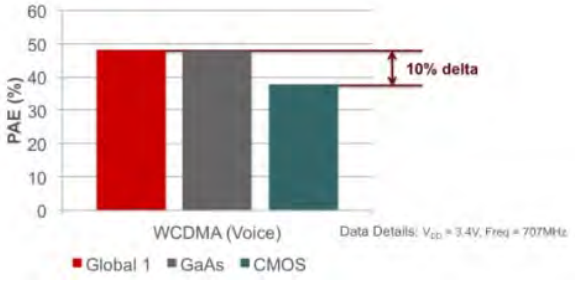
UltraCMOS Global 1 PA Delivers Several Performance Advantages

Using a WCDMA (voice) waveform at an ACLR (adjacent channel leakage ratio) of -38 dBc, the performance of the UltraCMOS Global 1 PA approaches 50-percent PAE (power-added efficiency).

This is claimed to be on par with the leading GaAs PAs and exceeds the performance of other CMOS PAs by 10 percentage points says Peregrine, which represents a 33-percent efficiency increase. Furthermore, the UltraCMOS Global 1 PA maintains GaAs-equivalent PAE for LTE waveforms with varying resource-block allocations.

This level of performance is reached without enhancements from envelope tracking or digital predistortion, which is often used when benchmarking CMOS PAs with GaAs PAs.

"Peregrine Semiconductor's UltraCMOS Global 1 PA is a market disrupter that could hasten a transition of the PA front-end market from GaAs-based to CMOS," says Christopher Taylor, director of RF and Wireless Components at Strategy Analytics. "In a demonstration at Mobile World Congress 2014, Peregrine's UltraCMOS Global 1 PA apparently matched the performance of a leading-edge GaAs PA at all power levels, and on top of this, Peregrine's PA can offer more flexibility through the integration capabilities of CMOS."



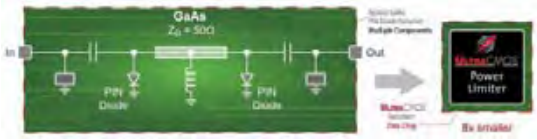
UltraCMOS Global 1 Supports TDD-LTE Networks

China's recently licensed TDD-LTE networks have increased demand for bands in the 2.3 to 2.7 GHz frequency range. The UltraCMOS Global 1 PA offers a high-band PA path that supports this frequency range.

"Peregrine is committed to the Greater China market," says Jim Cable, CEO at Peregrine Semiconductor. "To better serve our customers, we recently expanded our China office to include new lab facilities and additional technical resources. Today, at EDI CON, we introduce UltraCMOS Global 1 as a RFFE solution for TDD-LTE network demands."

GaAs competes with Peregrine SOI products for RF

The firm says incumbent gallium arsenide-based RF solutions do not rise to the challenge of new complexity in the telecoms market



Peregrine Semiconductor, a pioneer of SOI and advanced RF solutions, is debuting its new line of UltraCMOS based RF power limiters, including PE45140 and PE45450 slated for release in May.

Peregrine's Silicon on Insulator (SOI) power limiters represent turnkey, monolithic solutions to provide an alternative to discrete, PIN-diode limiters based on GaAs.

The firm says its UltraCMOS power limiters deliver simple, repeatable and reliable protection ideal for test-and-measurement, land-mobile-radio (LMR), wireless-infrastructure, military and radar systems.

"Peregrine makes best-in-class RF products, and we are pleased to extend that heritage into the new category of power limiters announced at EDI CON today," says Duncan Pilgrim, director of marketing at Peregrine. "Our customers continuously find that incumbent GaAs-based RF solutions do not rise to the challenge of new complexity in the market, and they are investing in Peregrine's SOI technology as fast as we can develop new options like this."

Turnkey Monolithic Architecture Delivers Benefits

On a chip claimed to be eight times smaller than the board space required by discrete, PIN-diode solutions, Peregrine's new power limiters are claimed to provide a ten to one hundred times improvement in response and recovery time. The company also says they deliver greater than 40 dB improvement in linearity (IP3) and offer a twenty times improvement in ESD (electrostatic discharge) protection.

Of particular interest to RF designers, Peregrine's power limiters can save PCB space with a small form factor, reduce BoM (bill of materials) by eliminating the need for extra components and improve time to market by reducing in-design time and costs.

Peregrine also says they beat existing solutions in RF performance, including higher linearity to eliminate signal

distortion, high ESD to ensure high reliability, wide bandwidth to enable design flexibility and fast response and recovery times to ensure robust protection of power-sensitive components.

Finally, because Peregrine's power limiters are based on UltraCMOS instead of GaAs, they can be closely integrated with other UltraCMOS RF components.
The table below illustrates how Peregrine's new UltraCMOS power limiters compare to GaAs-based PIN-diodes.

Attributes	UltraCMOS Power Limiter	GaAS PIN Diode Power Limiters
Small form factor	Yes	No
Requires no external components	Yes	No
Superior ESD rating	Yes	No
Adjustable limiting threshold	Yes	No
Power reflection mode	Yes	No
Protection in unpowered conditions	Yes	Yes
Excellent linearity	Yes	No
Sub-nanosecond response time	Yes	No
Wide bandwidth support	Yes	No
High power handling	Yes	Yes
Low insertion loss	Yes	Yes

Peregrine's UltraCMOS power limiters can protect:

RF ports in test-and-measurement equipment

RF front ends and low-noise amplifiers (LNAs) in LMRs

RF receivers in wireless-infrastructure equipment

Tactical radio receivers from intentional jammers in military warfare

Transceiver (TRX) modules in radar systems

In order to achieve repeatable and reliable power protection, customers currently face challenges because it takes so long to design and validate PIN-diode power-limiter circuits and the multiple external components this architecture requires.

With Peregrine's new, all-in-one architecture, customers should be able to significantly reduce time to market and cost.

Availability

On display at EDI CON Booth #512, Peregrine plans to release the first two of its UltraCMOS power limiters in May 2014:

The PE45140 is a 20 MHz - 2GHz, 50 W power limiter designed for professional portable and mobile radios, such as tactical radios and LMRs, as well as HF, VHF, UHF, L-band radar transceivers.

The PE45450 is a 9KHz - 6GHz, 50 W power limiter designed for test-and-measurement systems, L/S/C-band radar transceivers, counter-measure receivers and wireless receivers.
Both power limiters feature an adjustable limiting threshold, unbiased power limiting and operation in two modes - power limiting or power reflecting.

IQE to supply MACOM with 200mm GaN on silicon wafers

The agreement will enable MACOM to deliver GaN wafers grown on 100mm, 150mm and 200mm silicon substrates for RF applications

IQE has entered an agreement with M/A-COM Technology Solutions (MACOM), a supplier of high performance RF, microwave, and millimetre wave products, to deliver GaN-on-silicon performance with a 200mm silicon cost structure.

The agreement was announced by MACOM along with the introduction of an IP licensing program that will enable GaN insertion and large-scale production across the RF industry. As part of the licensing program, MACOM will make available its GaN-on-silicon technology to select companies for use in RF applications.

Surety of supply is critical for high volume markets such as wireless basestations, estimated by ABI Research to represent more than 60 percent of the overall $1.2 billion RF power market. As a first step in its licensing program, MACOM will license to IQE the ability to produce GaN-on-silicon wafers utilising MACOM's patent-protected technology.

The agreement will enable MACOM to deliver GaN RF products with breakthrough bandwidth and efficiency at a mainstream 200mm silicon cost structure and will enable IQE to accelerate GaN penetration into key target markets.

Today IQE says it supplies more than 50 percent of the world's compound semiconductor epitaxial wafers for RF applications and is already well-established as the leading provider of GaN high electron mobility transistor (HEMT) wafers for RF, broadband, and military power amplifiers.

Transistors for these applications have historically been fabricated using 3 inch and/or 100mm SiC substrates. To complement these products and increase market reach, IQE has developed and demonstrated growth of GaN HEMTs on industry standard silicon substrates at wafer diameters of 100mm, 150mm, and 200mm.

This technology, along with the comprehensive IP portfolio licensed from MACOM, will enable tremendous economies of scale, wafer capacity, and cost structure needed to substantially advance the GaN market.

Drew Nelson, CEO of IQE, says, "We are beginning to see very significant traction for GaN occurring in the compound semiconductor industry, across a wide range of applications. Our partnership with MACOM allows us to further penetrate this market by bringing decades of high volume production experience to create the supply chain needed to accelerate GaN adoption. "

”Combining GaN HEMT performance with low cost and large diameter silicon substrates enables these wafers to be processed through existing high volume silicon factories. Commercial availability of GaN HEMTs on 150mm and 200mm wafers represents a significant milestone toward the widespread adoption of this technology. To date, we have already delivered MACOM 200mm diameter GaN-on-silicon wafers, and we look forward to a powerful ongoing relationship,” adds Nelson.

John Croteau, President and CEO of MACOM, continues, ”MACOM is very excited to enter into this agreement with IQE, the recognised true world leader in compound semiconductor epitaxial supply. We believe that this partnership achieves a critical milestone in the mainstream commercialisation of GaN technology by establishing the manufacturing capability and capacity required to bring reliable, high volume surety of supply to the industry.”

IQE has pioneered a number of GaN-on-silicon technologies for applications spanning RF, power control and LED lighting markets, with a technology roadmap to support the emergence of compound semiconductors on silicon for next generation electronic devices such as microprocessors and embedded systems.

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“Concerns in the UK over the last year that silicon CMOS would significantly damage the Compound Semiconductor industry have proved unfounded and are not reflected in our financial performance nor in our customers’ expectation of future long term demand drivers.

“Wireless remains an attractive market for us over the coming years with demand continuing to be driven by the proliferation of wireless applications and the need for sophisticated GaAs chips to deal with the explosive growth in data traffic. Beyond this, the next waves of innovation which will drive handset replacement cycles are likely to include lasers and sensors using compound semiconductor technology, for gaming, 3D image capture, gesture recognition, and sensing for a variety of applications including healthcare monitoring devices.

“Our business diversification strategy also gained strong traction, and we achieved a number of significant technical and commercial milestones during 2013 which reflect the strong progress made in our other key markets including photonic sensors and lasers, advanced solar (CPV), power semiconductors, infrared, LED and advanced electronics.

“Our integration remains firmly on track, and we expect to realise significant reductions in our financial overheads, whilst benefiting greatly from the operational and technical synergies we are delivering.

“IQE is at the forefront of the enabling technologies that are at the very heart of many of the twenty-first century trends and products. We are confident that the Group is well positioned for continued growth in earnings and cash flow in 2014 and beyond.”

Compound Semiconductor conference hits a new high

35 presentations equipped delegates with a comprehensive overview of the compound semiconductor industry

Around 300 delegates and over 30 sponsors descended on Frankfurt for the fourth CS International Conference, which was held at the Sheraton Airport Hotel this week.

This must-attend event for the leaders of the compound semiconductor industry set a new standard for its number of presentations.

The conference covered all aspects of the industry, with presentations grouped into six key themes:

Power Electronics
LEDs
Integration of CMOS and III-Vs
Wide Bandgap RF Devices
Front-ends for Mobile Devices
Lasers, PICs & PV

Presentations on these topics highlighted the growing penetration of compound semiconductors into the silicon industry, and the use of silicon in the making of III-V chips. Leading developers of next-generation CMOS, such as IBM and Imec, are pioneering approaches to integrate high-mobility materials, for example InGaAs, into the channels of transistors in microprocessors, while silicon substrates are viewed as a low-cost platform for making LEDs, as well also power and RF electronics based on GaN.

Meanwhile, power amplifiers that are based on silicon are starting to go head-to-head with those made from GaAs for deployment in the latest smartphones. It appears that devices based on CMOS will gain market share, but GaAs will dominate the market for many years to come.

A more detailed report of the presentations at CS International Conference will appear in the April /May edition of *Compound Semiconductor* magazine. This issue will also contain details of the winners of the coveted CS Industry Awards.

For more information about CS International Conference, and opportunities available for the 2015 event, contact Stephen Whitehurst: stephen.whitehurst@angelbc.com Tel 0044 (0)2476 718 970. www.cs-international.net

IQE delivers first 150mm VCSEL epiwafers

The high volume production of the wafers will be used in a variety of applications. These will include the mobile, defence and military, computing and medical sectors

IQE says it has delivered the world's first 150mm (6") VCSEL epi wafer process for high volume, low cost applications.

Markets for VCSELs are proliferating rapidly as this advanced laser is becoming the device of choice for many high volume applications including:

• *Gesture recognition, for gaming and non-contact navigation (e.g TV, smartphone, tablet)*

• *Depth imaging for 3D vision , driving next wave of handset innovation for must have new phones*

• *Low energy optical storage and fast switching in high capacity data centres, servers and ultra-high speed computing*

• *High speed datacomms, including Active Optical Cables (AOC)*

• *UltraHigh Density magnetic Storage using Heat Assisted Magnetic Recording (HAMR)*

• *Illumination for IR cameras for security, safety, night vision*

• *Industrial heating including paint curing and commercial print shops*

• *Cosmetics and healthcare including hair removal, antiwrinkle, blemish reduction*

A number of these applications require multi-element array configurations which use greater surface areas and therefore more epiwafer material. They also offer higher optical power output compared with discrete devices.

Many of these markets are price elastic, and by moving to 150mm wafer sizes, compatible with existing well established, state of the art 150mm RF GaAs wafer processing lines, high performance VCSELs can be manufactured in large volume using fabrication and testing techniques similar to that of LEDs.

This combination will provide a high volume manufacturing technology and capability to help drive down the cost of VCSEL based photonics products for deployment in mass market, consumer applications.

The improved cost structure will allow designers to utilise the operational and performance advantages of laser devices to further develop advanced sensing applications which are expected to drive the next wave of innovation in consumer products such as cell phones, tablets and other handheld devices.

Initial engineering evaluation and product qualification wafers have already been delivered and initial performances have replicated those of existing smaller wafer sizes. Production is expected to ramp over the coming year.

Drew Nelson, IQE CEO, says, "VCSEL enabled products such as gesture recognition and 'time of flight' sensing are expected to ramp significantly over the coming period as they become incorporated into next generation handset and mobile communication devices, as well as a myriad of other high volume applications."

"By introducing our new 150mm VCSEL epiwafer process, which is compatible with existing high volume RF GaAs chip processing lines, we are enabling a new low cost manufacturing route for high performance laser devices.IQE has built a powerful technology platform for VCSELs, and recent announcements on record low power consumption VCSELs for data centres and record high speed data transmission with IBM for datacentres, servers and supercomputers are testament to the strength and depth of this platform," he adds.

RFMD and TriQuint merger to pip Skyworks at the post

The combination will increase defence market opportunities for the joint firm

The Strategy Analytics Advanced Defence Systems (ADS) service report, "TriQuint-RFMD Merger Solidifies Semiconductor Market Share Lead in Defense Sector," provides analysis on this deal and outlines the market share that the new company will command.

On February 24th, RFMD and TriQuint announced a definitive merger agreement under which the companies will combine in an all-stock transaction.

Designed to be a merger of equals, the new company (NewCo) will have a new name and shared leadership team.

Both companies have an extensive portfolio of capabilities in the areas of advanced semiconductor process technologies such as GaAs and GaN.

The combination will collate these complementary capabilities and enable the new company to successfully pursue defence market opportunities.

"In the area of Defence, TriQuint has been a leading supplier of semiconductor technologies, for example, military radar systems used on fast-jets including the F-15, F-22 and F-35. The company also holds US DoD Trusted Source accreditation," notes Eric Higham, North American Director for ADS. "RFMD has ongoing activity in the aerospace and defence sectors with products targeting radar, communications and electronic warfare applications."

"The combined infrastructure and defense unit can achieve potential revenues of around $500 million. Strategy Analytics' own estimates indicate that the new company's defence revenues will account for up to 25 percent of this unit revenue," notes Asif Anwar, Director of the ADS service.

He adds, "As a GaAs and GaN semiconductor technologies supplier, we believe TriQuint holds the number one position in the defence space, and the combined TriQuint-RFMD entity will cement this position extending a lead over contemporaries in this area such as Cree, Hittite and MACOM Technologies."

IQE initiative to boost regional supply chains

The new programme is aimed at establishing partnerships to support the development of a broad range of key enabling technologies

IQE plc, a supplier of semiconductor wafer products and services, has launched its Open Innovation programme "openiqe".

The first major project under the new programme is the IQE Open Technology Challenge, which will be marked by a launch event at the SWALEC Stadium in Cardiff on Friday 21st March 2014.

The aim of the challenge is to engage with small and medium enterprises, larger businesses and academic institutes, initially focusing primarily on the Welsh region, to develop new and enhance existing supply chains.

The project will focus on technology areas termed the Three Grand Challenges identified in the Science for Wales strategy and other major International programs, including the EU Horizon2020 Program. The three areas are life sciences and health; low carbon, energy and environment; and advanced engineering and materials.

Technology will play an increasingly important role in addressing a range of societal challenges. IQE's Open Technology Challenge is aimed at establishing partnerships along an end-to-end supply chain to develop and commercialise products that will meet real needs within the areas defined by the Three Grand Challenges.

Drew Nelson, IQE President and CEO, comments, "IQE has more than twenty-five years' experience of working closely with partners and customers worldwide to meet demanding technical specifications. We are delighted to be contributing our experience of collaborative innovation in the form of our new Open Innovation programme."

"We are confident that the Open Technology Challenge has the potential to become a key stepping stone towards the establishment of a major technology cluster in the region, as well as building stronger links to the global technology community."

IQE's Open Innovation programme is being supported by the Welsh Government.

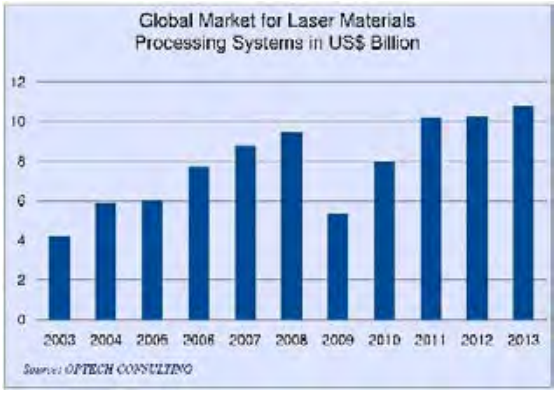
Lasers

Global laser systems market escalates 5 percent

The European market turned around in 2013 with double-digit growth

The global industrial laser systems market reached a volume of US$10.7 billion in 2013, up 5 percent compared to the previous year.

According to the annual market survey from Optech Consulting the market for laser systems for macro-processing, including mainly cutting, welding, and marking, was up 7 percent and reached a volume of US$ 8.2 billion.



The laser macro-processing systems market did better than the global machine tool market which decreased by 9 percent in 2013. The market for laser systems for micro-processing, accounting for a volume of US$ 2.5 billion, suffered a 1 percent decline in 2013, in line with globally weak demand for semiconductor capital equipment.

Laser micro-processing systems are mainly used for the manufacturing of semiconductors, solar cells, printed circuit boards, and flat panel displays.

The 5 percent growth rate of the total industrial laser systems market for 2013 falls short of the long-term compound annual growth rate of nearly 10 percent for the last ten years.

The comparably weak growth in 2013 was mainly caused by decreasing demand in the Asia Pacific Rim region in the second half of the year. Including the market heavyweights of China, Japan, and Korea the region consumes just over 50 percent of the laser materials processing systems.

Demand in Europe, accounting for a global share of about 30 percent increased by more than 10 percent on a US$ basis (the Euro/US$ exchange rate increased by 3.3 percent), spurred by increased demand in the large markets of Germany, France, and Italy.

The figures signal a remarkable turn-around from the previous year when Europe was the least performing laser systems market with a decrease of 8 percent on a US$ basis.

Laser systems demand in 2013 also increased in the Americas, which account for about 15 percent of the global volume. While the United States market cooled in 2013 after three years of strong growth, Latin America contributed a double-digit increase.

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IPG announces configurable fibre laser workstation

The firm’s UV laser systems are suited for fabricating complex 2-D and 3-D structures such as micron-scale devices. Heat-free laser ablation facilitates exact tolerances without collateral damage to the material

IPG Photonics Corporation has introduced the IX-200-F, an advanced fibre laser micromachining system for general purpose, R&D and batch-scale production applications.

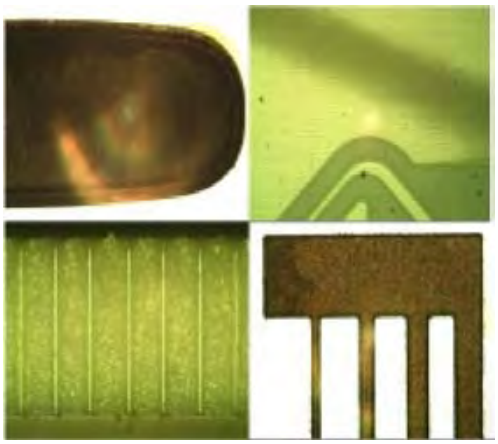
The multi-functional system can easily be configured with different combinations of fibre lasers and beam delivery systems to address high-precision, cutting, drilling and patterning micromachining applications. It represents the optimum combination of IPG’s fibre laser and materials micro-processing workstation technologies.

IPG’s IX-200-F is a fully enclosed and interlocked CDRH Class 1 system, configurable with a wide range of IPG fibre lasers and fully integrated with the system operating hardware and software. The system core consists of special structural design granite to minimise the effects of vibration and thermal drift on the overall accuracy of the product.

The IX-200-F features a high-resolution, high-performance microscope vision system which provides a continuous zoom range from 38X to 880X for sub-micron automated part alignment and inspection. System software includes macro-building tools for fast programming and generation of automated processes for complex feature machining. Additional utilities allow complex pattern input from standard CSV and DXF files.

The selection of IPG Fibre lasers currently supported on the IX-200-F includes pulsed IR to over 500 watts and pulsed green up to 50 watts as well as UV lasers. Users may select ablation or thermal cutting and scanning or fixed beam delivery configurations.

The IX-200-F includes precision, multi-axis part-handling and vision systems for accurate machined feature placement and process control and fully-integrated software enabling both ease of use and highly complex machining functions.



Top (L-R): FR-4, ITO ; Bottom (L-R): Al2O3, Copper

Applications for IPG’s IX-200-F include cutting of ceramics, metals, polymers and semiconductor materials and patterning of ITO and other thin-films. Drilling applications include hole diameters down to 15 microns in 300 micron thick ceramics, with placement accuracies of better than

5 microns, at rates of 100 holes per second. The advanced world class applications laboratories of IPG Microsystems located in Manchester, NH USA, provide demonstrations and proof of concept application studies for domestic and international customers.

“The IX-200-F combines IPG’s world-leading fibre lasers and the industry-proven IX-200 precision workstation design into a flexible product that provides users a highly cost-effective laser processing tool,” states Jeffrey Sercel, President of IPG Microsystems.

“The range of configurable options that can be either factory installed or field installed at a later date, enables users to purchase the capability they need today and preserve the value of the capital investment through future upgrades as application requirements evolve.”

Emcore develops 1550nm DFB laser module for CATV

The 1752 laser platform features 1.2 GHz operational bandwidth with low adiabatic chirp to maximise signal quality in short and long lengths of fibre

Emcore Corporation has released the 1752A 1550 nm DOCSIS 3.1 DWDM DFB laser module for CATV (Cable Television) applications.

The new 1752A is the latest model in Emcore’s 1550 nm QAM

laser platform and is fully compliant with the new DOCSIS 3.1 standard, supporting operational bandwidth up to 1.2 GHz.

1752A 1550nm laser module

DOCSIS (Data Over Cable Service Interface Specification) is the standard that facilitates the addition of high-speed data transfer over existing CATV systems for internet access through cable television services. DOCSIS 3.1 is the latest version and is designed to deliver several new benefits to cable companies including greater capacity and speed.

It allows for up to 50 percent more data throughput over the same spectrum to deliver up to 10 Gbps downstream and 1 to 2 Gbps upstream. DOCSIS 3.1 also decreases the cost-per-bit for data delivery by improving the efficiency of spectrum use, and it increases the energy efficiency of cable modems.

The 1752 laser platform has been designed specifically for CATV applications and the latest DOCSIS 3.1 standard. It features 1.2 GHz operational bandwidth with low adiabatic chirp to maximise signal quality in short and long lengths of fibre.

The 1752A is available in a wide range of ITU grid wavelengths and operates over an industrial temperature range. The laser's iis designed to minimise degradation of broadcast signals caused by Quadrature Amplitude Modulated (QAM) channels.

"We are very pleased to introduce our first DOCSIS 3.1 laser module bringing Emcore's leading-edge highly-linear DFB laser technology to the latest standard in the CATV industry," says Jaime Reloj, Vice President of Business Development for Emcore. "The 1752A DOCSIS 3.1 laser is a key enabling component allowing our customers to provide fully DOCSIS 3.1 compliant systems," adds Reloj.

All Emcore lasers utilise the highly-linear, directly-modulated DFB technology which has become synonymous with the high quality, high-speed photonics that drove the wide-scale deployment of fibre optics in CATV networks, satellite earth stations and mobile phone antenna sites.

Enhancing performance of III-V nanowires

Using InGaAs on InAs stems grown on graphene could benefit solar cell and laser technology

Imagine a field of small wires-standing at attention like a tiny field of wheat-gathering the Sun's rays as the first step in solar energy conversion.

Researchers at the University of Illinois at Urbana-Champaign have achieved new levels of performance for seed-free and substrate-free arrays of nanowires from class of materials called III-V directly on graphene.

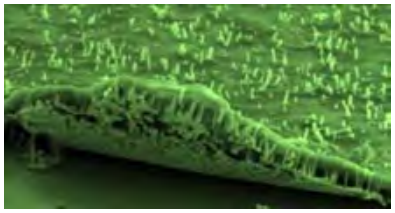
These compound semiconductors hold particular promise for applications involving light, such as solar cells or lasers.

A dense array of nanowires grown directly on graphene. The insets show a higher magnification SEM view of the array and a STEM image of a single, axially heterostructured InGaAs/InAs nanowire

"Over the past two decades, research in the field of semiconductor nanowires has helped to reshape our understanding of atomic-scale crystal assembly and uncover novel physical phenomena at the nanometre scale," explains Xiuling Li, a professor of electrical and computer engineering at Illinois.

In the March 20th issue of *Advanced Materials*, the researchers present the first report of a novel solar cell architecture based on dense arrays of coaxial *p-n* junction InGaAs nanowires on InAs stems grown directly on graphene without any metal catalysts or lithographic patterning.

"In this work, we have overcome the surprising structure (phase segregation) and successfully grown single phase InGaAs and demonstrated very promising solar cell performance," explains postdoctoral researcher Parsian Mohseni, first author of the study.



The InGaAs/InAs nanowire array can be lifted from its graphene base and transferred to alternative platforms for bendable device applications (Credit : Parsian Mohseni)

"Depending on the materials, nanowires can be used for functional electronics and optoelectronics applications," Mohseni adds. "The main benefits of this III-V photovoltaic solar cell design are that it is fairly low-cost, substrate-free, and has a built-in back side contact, while being conducive to integration within other flexible device platforms."

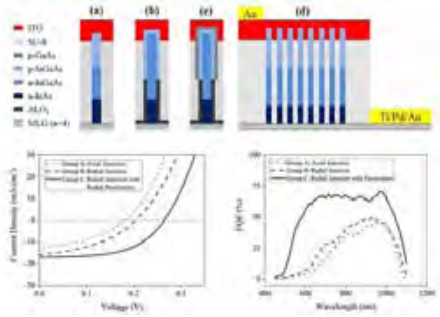
Li's research group uses a method called van der Waals epitaxy to grow nanowires from the bottom up on a two-dimensional sheet, in this case, graphene. Gases containing gallium, indium, and arsenic are pumped into a chamber

where the graphene sheet sits, prompting the nanowires self-assemble, growing by themselves into a dense carpet of vertical wires across the graphene's surface.

In their earlier work in *Nano Letters 2013* using a graphene sheet, the researchers discovered that InGaAs wires grown on graphene spontaneously segregate into an InAs core with an InGaAs shell around the outside of the wire.

To improve the materials' efficiencies for solar power conversion, the researchers bypassed the unique Van der Waals epitaxy induced spontaneous phase segregation by inserting InAs segments in between.

The resulted ternary InGaAs NW arrays are vertical, non-tapered, controllable in size, height, and doping, and broadly tunable in composition thus energy for monolithic heterogeneous integration with 2D Van der Waals sheets including graphene.



Schematic representations of the three different nanowire geometries investigated (a-c) and a diagram of a nanowire array-on-graphene prototype solar cell device structure (d). The characteristic illuminated current density-voltage (J-V) curves and external quantum efficiency (EQE) spectra obtained from the three distinct device structures are shown in the bottom left and bottom right, respectively (Credit : Parsian Mohseni)

Under air mass 1.5 global solar illumination, the core-shell In0.25Ga0.75As (Eg ~ 1.1 eV) nanowire arrays on graphene demonstrate a conversion efficiency of 2.51 percent, representing a new record for substrate-free, III-V NW-based solar cells.

"Although InGaAs is far from being the optimum bandgap materials for high efficiency solar cells, the direct epitaxy on graphene platform established here has significant implications for a wide variety of III-V compound semiconductor NW based solar cells on graphene, as well as light emitters and multi-junction tandem solar cells, all of which can be released for flexible applications," Li says.

This article has been adapted from one by Rick Kubetz, Engineering Communications Office, University of Illinois at Urbana-Champaign.

Compound Semiconductor conference hits a new high

35 presentations equipped delegates with a comprehensive overview of the compound semiconductor industry

Around 300 delegates and over 30 sponsors descended on Frankfurt for the fourth CS International Conference, which was held at the Sheraton Airport Hotel this week.

This must-attend event for the leaders of the compound semiconductor industry set a new standard for its number of presentations.

The conference covered all aspects of the industry, with presentations grouped into six key themes:

Power Electronics
LEDs
Integration of CMOS and III-Vs
Wide Bandgap RF Devices
Front-ends for Mobile Devices
Lasers, PICs & PV

Presentations on these topics highlighted the growing penetration of compound semiconductors into the silicon industry, and the use of silicon in the making of III-V chips. Leading developers of next-generation CMOS, such as IBM and Imec, are pioneering approaches to integrate high-mobility materials, for example InGaAs, into the channels of transistors in microprocessors, while silicon substrates are viewed as a low-cost platform for making LEDs, as well also power and RF electronics based on GaN.

Meanwhile, power amplifiers that are based on silicon are starting to go head-to-head with those made from GaAs for deployment in the latest smartphones. It appears that devices based on CMOS will gain market share, but GaAs will dominate the market for many years to come.

A more detailed report of the presentations at CS International Conference will appear in the April /May edition of *Compound Semiconductor* magazine. This issue will also contain details of the winners of the coveted CS Industry Awards.

For more information about CS International Conference, and opportunities available for the 2015 event, contact Stephen Whitehurst: stephen.whitehurst@angelbc.com Tel 0044 (0)2476 718 970. www.cs-international.net

EpiWorks to boost MOCVD production capacity

The manufacturer of compound semiconductor epitaxial wafers is increasing the ability to produce high volumes of 4-inch and 6-inch wafers for VCSELs, edge-emitting lasers, detectors and photovoltaics

EpiWorks is majorly expanding with a multi-faceted expansion of its production capacity.

The company makes wafers used in applications such as optical components, wireless devices and high-speed communication systems.

“A clear migration toward applications that require significantly higher volumes, particularly in the area of optical materials and photonics is underway. The markets include consumer electronics, sensors and displays, digital projection, and data communications. As the leader in the manufacture and development of high performance compound semiconductor products, we are pleased to announce a major increase in capacity. This is part of an aggressive, long-term production capacity roadmap to satisfy increasing demand from photonic and RF customers,” says Nick Kolarich, Director of Sales and Marketing at EpiWorks.

The expansion increases the ability to produce high volumes of 4-inch and 6-inch wafers for VCSELs, edge-emitting lasers, detectors and photovoltaics with a better cost structure. The new capacity includes upgrades to existing tools and the latest Aixtron 2800 G4 MOCVD technology. This allows EpiWorks to quickly and seamlessly satisfy customer demand while providing greater flexibility for new product development.

“For many years EpiWorks has been the leading US-based manufacturing and development partner for novel and advanced photonic and optical devices. Our customers have leveraged our development expertise to commercialise numerous complex advanced technologies from the lab into next generation photonic products. We are excited to now see our high-volume manufacturing expertise enabling proliferation of these products under stringent specifications and at low cost,” explains Quesnell Hartmann, EpiWorks CEO.

II-VI to speed up laser optic production with Veeco IBD tool

The SPECTOR-HT system is claimed to offer higher depostion rates than other tools

II-VI Incorporated has ordered the SPECTOR-HT Ion Beam Deposition (IBD) System and added Veeco’s new Quest Optical Monitor, for use in its high-volume production of laser optics.

Veeco says its SPECTOR-HT IBD System produces high quality optical thin films with improved levels of productivity and throughput.

SPECTOR-HT IBD reactor

The Quest Optical Monitor provides up to ten times improvement in layer thickness accuracy compared to previous generations for precise manufacturing control.

“Veeco’s SPECTOR-HT IBD System allows us to deliver high quality laser optics faster by achieving superior deposition rates while maintaining exceptional film qualities,” says Mark West, General Manager, II-VI Infrared. “The Veeco Quest Optical Monitor upgrade is an incredible breakthrough. It ensures we will have a repeatable, highly productive operation using the latest technology, enabling us to produce the highest quality laser optics.”

Headquartered in Saxonburg, Pennsylvania, II-VI specialises in engineered materials and optoelectronic components. Veeco is an focuses on MOCVD, MBE, Ion Beam and other advanced thin film process technologies.

“II-VI is an optical coating leader and their endorsement of the SPECTOR-HT is clear indication of its exceptional value,” continues Jim Northup, Vice President and General Manager of Veeco MBE, Optical Systems and Ion Sources. “As the optics industry seeks faster deposition rates and more repeatable processes, Veeco’s SPECTOR-HT IBD System, coupled with the new Quest Optical Monitor, achieves unprecedented levels of productivity by offering the highest throughput for optical thin film manufacturers.”

IQE delivers first 150mm VCSEL epiwafers

The high volume production of the wafers will be used in a variety of applications. These will include the mobile, defence and military, computing and medical sectors

IQE says it has delivered the world’s first 150mm (6”) VCSEL epi wafer process for high volume, low cost applications.

Markets for VCSELs are proliferating rapidly as this advanced laser is becoming the device of choice for many high volume applications including:

• *Gesture recognition, for gaming and non-contact navigation (e.g TV, smartphone, tablet)*

• *Depth imaging for 3D vision , driving next wave of handset innovation for must have new phones*

• *Low energy optical storage and fast switching in high capacity data centres, servers and ultra-high speed computing*

• *High speed datacomms, including Active Optical Cables (AOC)*

• *UltraHigh Density magnetic Storage using Heat Assisted Magnetic Recording (HAMR)*

• *Illumination for IR cameras for security, safety, night vision*

• *Industrial heating including paint curing and commercial print shops*

• *Cosmetics and healthcare including hair removal, antiwrinkle, blemish reduction*

A number of these applications require multi-element array configurations which use greater surface areas and therefore more epiwafer material. They also offer higher optical power output compared with discrete devices.

Many of these markets are price elastic, and by moving to 150mm wafer sizes, compatible with existing well established, state of the art 150mm RF GaAs wafer processing lines, high performance VCSELs can be manufactured in large volume using fabrication and testing techniques similar to that of LEDs.

This combination will provide a high volume manufacturing technology and capability to help drive down the cost of VCSEL based photonics products for deployment in mass market, consumer applications.

The improved cost structure will allow designers to utilise the operational and performance advantages of laser devices to further develop advanced sensing applications which are expected to drive the next wave of innovation in consumer products such as cell phones, tablets and other handheld devices.

Initial engineering evaluation and product qualification wafers have already been delivered and initial performances have replicated those of existing smaller wafer sizes. Production is expected to ramp over the coming year.

Drew Nelson, IQE CEO, says, “VCSEL enabled products such as gesture recognition and ‘time of flight’ sensing are expected to ramp significantly over the coming period as they become incorporated into next generation handset and mobile communication devices, as well as a myriad of other high volume applications.”

“By introducing our new 150mm VCSEL epiwafer process, which is compatible with existing high volume RF GaAs chip processing lines, we are enabling a new low cost manufacturing route for high performance laser devices.IQE has built a powerful technology platform for VCSELs, and recent announcements on record low power consumption VCSELs for data centres and record high speed data transmission with IBM for datacentres, servers and supercomputers are testament to the strength and depth of this platform,” he adds.

IQE VCSELs enable IBM to achieve 64 Gb/s

The new III-V based devices will enable data transmission for supercomputers high capacity servers and data centres

IQE›s vertical cavity surface emitting laser epiwafer technology has been employed to develop high-performance optical links as reported by IBM and Chalmers University of Technology.

This was announced at the Optical Fibre Communications Conference (OFC) which is taking place this week in San Francisco.

As the data transmission rates across optical interconnects continue to increase, from today’s 25 - 28 Gb/s to next generation interconnects with speeds in excess of 50 Gb/s, there is a need for step-change performance improvements in the optoelectronics and electronics hardware that support this technology.

Vertical cavity surface emitting lasers (VCSELs) provide the primary light source for optical interconnects and are now in production for high capacity interconnect cables in data centres and high performance computing systems.

Recent work by IBM and Chalmers University of Technology in Sweden used IQE’s VCSEL wafers to achieve a ‹record› speed of 64 Gb/s. Data was transmitted over 57m of multimode optical fibre.

The VCSEL epitaxial wafer material was provided by IQE’s Photonics division in Cardiff. The VCSEL device was developed and fabricated at Chalmers and the full interconnect, including drive and receive circuitry, was produced, assembled and tested at IBM.

The interconnect performance reveals the full potential of the advanced VCSEL devices enabled by the high quality of the epitaxial material provided by IQE.

The full results will be presented today at the Optical Fibre Communication conference (OFC) in San Francisco (paper Th3C.2).

IQE`s III-V MBE technology to advance silicon photonics 2014-03-11

Along with UCSB, IQE has grown 1.3µm InAs quantum dot lasers on silicon

IQE has announced that its epitaxial wafer technology has been used to help develop next generation quantum dot lasers on silicon substrates.

This is aimed at enabling the integration of photonics devices with silicon technology for low cost, high volume data communication applications.

The results of work by IQE in conjunction with the University of California Santa Barbara (UCSB) will be presented at the Optical Fibre Communications Conference (OFC) which is taking place this week in San Francisco.

Silicon photonics, which combines compound semiconductor devices with low cost silicon substrates, offers the potential to integrate highly sophisticated laser devices with more traditional low cost CMOS driver and waveguide technology.

The researchers believe this work represents an important step towards large-scale photonic integration in an ultra low-cost platform for high volume consumer applications which will lead to the mass adoption of silicon photonics.

A key feature in enabling the cost effective integration of photonic devices with silicon technology is the ability to grow compound semiconductor quantum dots onto silicon substrates using MBE growth technology that has a proven track record for high volume manufacturing of wireless products.

Researchers at UCSB demonstrated a novel quantum dot laser design that not only is grown on silicon but that performs as well as similar lasers grown on their native substrates.

IQE provided both the engineered germanium/silicon substrates and the III-V MBE template growth. The growth of the quantum dot laser structure and fabrication of the laser components were performed at UCSB.

IPG Photonics buys Veeco MBE reactor

The tool will be used for III-V laser production

IPG Photonics Corporation has purchased an additional Veeco GEN2000 production MBE system to add to its fleet of Veeco MBE systems.

GEN2000 MBE tool

Located in Oxford, Massachusetts, IPG will use the GEN2000 for high-volume manufacturing of laser diodes for fibre lasers. IPG Photonics Corporation is a manufacturer of high-power fibre lasers and amplifiers and now utilises multiple Veeco MBE systems in its laser production operations.

“Veeco’s GEN2000 is the perfect complement to our existing set of Veeco MBE systems because of its superior throughput and low production costs,” says Alex Ovtchinnikov, Senior Vice President, Components at IPG Photonics. “Having the ability to transfer production methods from our other Veeco MBE systems means we can ramp laser diode production quickly and reliably to meet increasing demand for our fibre lasers.”

With their excellent performance, low power consumption and favourable ownership costs, fibre lasers are becoming the cutting and welding method of choice for materials processing applications, particularly in the automotive industry, according to a report on the laser cutting market from Markets and Markets. As the technology continues to advance, fibre lasers are gaining adoption in other industries including semiconductor processing, 3-D printing and smartphone manufacturing.

“IPG is the clear leader in fibre laser production and has been utilising our production MBE systems for years,” says Jim Northup, Vice President, General Manager for Veeco’s MBE Operations. “The GEN2000 delivers the highest throughput and lowest cost of ownership MBE technology in the industry, making it the ideal system to manufacture IPG’s high performance laser diodes.”

The GEN2000 MBE cluster tool offers 7 x 6” epiwafer growth of devices such as lasers, multi-junction solar cells, and pseudomorphic high-electron-mobility transistors (pHEMTs). Veeco says it allows for growth of different materials in connected modules.

Optical interconnects propelled by InP based VCSELs

Furukawa, OFS And Corning say they have increased reach and distance to benefit mega data centres

Furukawa Electric has developed a VCSEL that operates at 25 Gbps and realised transmission of up to 500 metres over prototype multimode fibres developed by OFS and Corning Incorporated.

“This is a significant accomplishment for data communications as both longer reaches and higher speeds are required for warehouse-scale data centres. Our customers are raising expectations as they implement next-generation data centres and we are pleased to be innovating the technology to meet and exceed those expectations,” says Haruki Ogoshi, senior fellow of Furukawa.

The rapid growth of cloud computing and expansion of ‘big data’ is causing a dramatic increase in the volume of data handled in data centres. This has generated demand for greater throughput in servers, switches and routers in data centres. Increasing the serial speed of transmission of lasers and photo detectors is one approach to that end.

Also, there is a need to increase transmission distances between devices as data centres become larger. In mega data centres, for example, transmission distances of 300 m or longer can be required. At present, VCSELs at a wavelength of 850 nm are widely used for lowest cost optical interconnect.

However, many say that when the transmission speed is changed from 10 Gbps to higher-speed 25 Gbps, the transmission distance is limited to less than 200 m due to the influence of chromatic dispersion in multimode fibres.

In order to solve these issues, Furukawa has developed a VCSEL with a wavelength of 1060 nm that operates at 25 Gbps.

“Increasing the VCSEL wavelength from 850 to 1060 nm reduces chromatic dispersion of fibres by approximately two thirds,” says Durgesh Vaidya, Senior Manager Research and Development for OFS.

“Accordingly, use of a multimode fibre with the modal dispersion minimized at 1060 nm reduces transmission impairments and allows transmission distances to be extended. It is widely expected that it will be easier to increase VCSEL speeds in the future beyond 25 Gbps by moving from 850 to higher wavelengths.”

Furukawa created a prototype optical module integrating the newly developed 1060 nm VCSEL in a small package with a driver integrated circuit and then conducted a transmission experiment close to actual operating conditions. When a multimode fibre from OFS or Corning was used with the modal dispersion optimised for a wavelength of 1060 nm, a long-reach of 300 m was achieved.

In a joint experiment, a short length of modal dispersion-compensating fibre developed by Corning was used in conjunction with standard OM4 multimode fibre, and a transmission distance of 500 m was achieved.

These results were obtained without the use of electrical compensation technologies such as a clock data recovery or an error correction.

In this way, FEC’s new VCSEL technology can allow for an increase in speed and distance without complicating future systems.

“This collaboration shows that long wavelength VCSEL technology can meet the demands of next generation data centres when combined with new, wavelength optimised fibre, or even standard OM4 fibre with new modal dispersion compensation fibre,” says Alan F. Evans, research director, Optical Physics and Transmission Technology, Corning.

IQE initiative to boost regional supply chains

The new programme is aimed at establishing partnerships to support the development of a broad range of key enabling technologies

IQE plc, a supplier of semiconductor wafer products and services, has launched its Open Innovation programme “openiqe”.

The first major project under the new programme is the IQE Open Technology Challenge, which will be marked by a launch event at the SWALEC Stadium in Cardiff on Friday 21st March 2014.

The aim of the challenge is to engage with small and medium enterprises, larger businesses and academic institutes, initially focusing primarily on the Welsh region, to develop new and enhance existing supply chains.

The project will focus on technology areas termed the Three Grand Challenges identified in the Science for Wales strategy and other major International programs, including the EU Horizon2020 Program. The three areas are life sciences and health; low carbon, energy and environment; and advanced engineering and materials.

Technology will play an increasingly important role in addressing a range of societal challenges. IQE’s Open Technology Challenge is aimed at establishing partnerships along an end-to-end supply chain to develop and commercialise products that will meet real needs within the areas defined by the Three Grand Challenges.

Drew Nelson, IQE President and CEO, comments, “IQE has more than twenty-five years’ experience of working closely with partners and customers worldwide to meet demanding technical specifications. We are delighted to be contributing our experience of collaborative innovation in the form of our new Open Innovation programme.”

“We are confident that the Open Technology Challenge has the potential to become a key stepping stone towards the establishment of a major technology cluster in the region, as well as building stronger links to the global technology community.”

IQE’s Open Innovation programme is being supported by the Welsh Government.

O-D GaAs based QDs compete with 3-D

Zero-dimensional gallium arsenide based quantum dots may someday have a big effect on solar energy and lasers

In physics, there’s small, and then there’s nullity classed as zero-dimensional.

University of Cincinnati researchers have reached this threshold with a special structure that may one day lead to better ways of harnessing solar energy, stronger lasers or more sensitive medical diagnostic devices.

UC student Teng Shi will present her semiconductor nanowire research at the American Physical Society meeting

These structures are GaAs/AlGaAs semiconductor nanowires.

UC doctoral student Teng Shi says she and a team of researchers have observed unique optical signatures indicating that electronic excitations within these nanowires can be confined to a zero-dimensional state called a 'quantum dot'.

This latest discovery is all about going small, but its significance is anything but. The research team's ability to control the confinement energy by varying the size of the quantum dot opens up a world of possibilities.

"Exploring the basic physics of semiconductor nanowires enables one to envision applications or to design structures for applications," says Shi of UC's Department of Physics. "These structures are potential candidates for a variety of applications including photovoltaics, lasers and ultra-sensitive nanosensors."

Nearly 10,000 professionals, scholars and students will attend the APS meeting to discuss new research from industry, universities and laboratories from around the world.

This research advances work previously done on semiconductor nanowires at UC. By using a thin shell called a quantum well tube and growing it - to about 4 nanometres thick - around the nanowire core, researchers found electrons within the nanowire were distributed in an unusual way in relation to the facets of the hexagonal tube. The result is a quantum wire, like a long string many times thinner than a human hair.

Now they've taken things further, going from one-dimensional wires to zero-dimensional quantum dots. These little structures made using GaAs based materials could have a big effect on a variety of technologies.

Solar

QuantumClean achieves single ISO 9001:2008 certification

In the past, the firm's facilities were either individually ISO 9001 certified, or certified in groups of facilities under different registrars

QuantumClean, has announced that all of its global Advanced Technology Cleaning Centres are now certified under a single ISO 9001:2008 certificate.

The firm is a provider of high-purity outsourced process tool parts cleaning, surface treatment, refurbishment, analytical and engineering services to the semiconductor, solar and LED industries.

Previously, QuantumClean's facilities were either individually ISO 9001 certified, or certified in groups of facilities under different registrars.

"This achievement is another significant step forward in our global integration plan, ensuring that customers receive the same high quality service across our vast network of Advanced Technology Cleaning Centres," says Tim Burrows, QuantumClean's Director of Global Quality.

Burrows goes on to say, "QuantumClean's Quality Policy states that the Company is dedicated to consistently delivering The Perfect Order to its customers through the application of rigid standard operating procedures, well-trained technicians, quantitative metrics and analytical methods, and continual improvement practices. Achieving global ISO 9001:2008 certification under one certificate is an important accomplishment to delivering the highest standard of services to our customers, i.e. The Perfect Order."

III-V multilayer tiny solar cells enable super efficient power generation

Researchers at the University of Illinois at Urbana-Champaign have used a printing process to assemble tiny cells into multilayer stacks for extraordinary levels of photovoltaic conversion efficiency

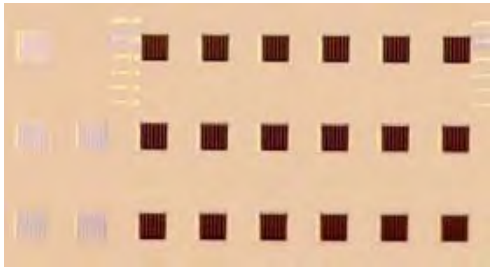
As an energy source, the sun has always been a dependable provider. Although it freely shines on everyone, the ability to capture and convert the sun's abundant energy is anything but free.

However, new technologies aimed at achieving "full spectrum" operation in utility-scale photovoltaics may soon make solar energy a viable option.

"A few simple ideas in materials science and device assembly allow us to bypass many of the limitations of traditional photovoltaic technologies," explains John Rogers, whose research group is developing these concepts. As a result of these new efficiencies, external industry experts project solar energy electricity generation costs that can reach, without subsidies, levels that are lower than coal, natural gas, and nuclear.

A professor of materials science and engineering at the University of Illinois at Urbana-Champaign, Rogers is a pioneer in semiconductor devices and manufacturing techniques. A printing approach, developed by Rogers and colleagues at Illinois, allows manipulation of ultrathin, small semiconductor elements that can be stacked on top of one another to yield an unusual type of solar cell capable of operating across the entire solar spectrum at exceptionally high efficiency.

"The strategy involves high-speed, printing-based manipulation of thin, microscale solar cells and new interface materials to bond them into multilayer stacks," Rogers says. "Quadruple-junction, four-terminal solar cells that we can build in this way have individually measured efficiencies of 43.9 percent."

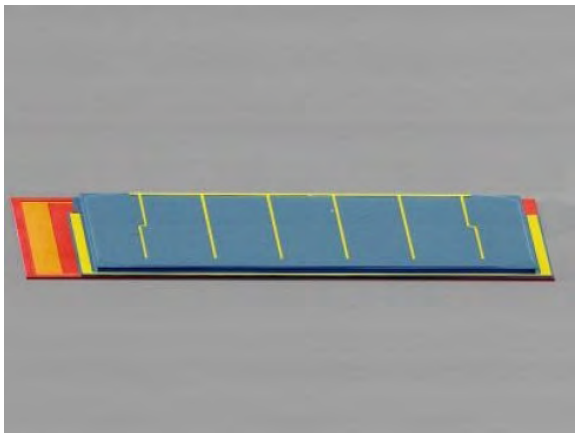


This shows printing-based assembly process yields arrays of stacked multi-junction cells in a fully automated step-and-repeat mode with high yields and accurate overlay registration (Credit : Xing Sheng, University of Illinois)

"This is a high-throughput, parallel assembly process that allows for simultaneous formation of arrays of stacked multi-junction cells in a fully automated step-and-repeat mode with high yields - greater than 95 percent - and accurate overlay registration. A newly developed interfacial material for these stacks enables ideal optical, electrical, and thermal properties, " states Xing Sheng, a postdoctoral fellow with Rogers' research group and first author of a paper published in the journal *Nature Materials*.

The project involved a collaborative team of researchers at the University of Illinois and the photovoltaic companies Semprius and Solar Junction. According to the group's paper, the module's top cell consists of a three-junction (3J) microcell with its own anti-reflective coating to ensure efficient transmission of light to the uppermost layers. The bottom cell uses a diffused-junction germanium architecture.

The 3J microcell is composed of InGaP/GaAs/InGaAsNSb layers.



The top cell in the stacked 3-junction/germanium assembly captures wavelengths between 300 nm and 1300 nm; wavelengths from 1300 nm to 1700 nm pass through to the bottom cell (Credit : Xing Sheng, University of Illinois)

In a stacked 3J/Ge assembly, the top 3J cell captures light with wavelengths between 300 nm and 1300 nm. Wavelengths from 1300 nm to 1700 nm pass through to the bottom germanium cell with minimal interface reflections, due to the use of a thin layer of a unique type of chalcogenide glass.

"We integrated these microscale, multijunction cells into Semprius' dual-stage optics - consisting of a molded primary lens and a secondary, miniature ball lens - to tightly focus incident sunlight by more than one thousand times," Rogers explains. "Advanced packaging techniques and electrical matching networks yield fully integrated modules with efficiencies of 36.5 percent evaluated under practical conditions - significantly better than any other available technology."

Dual-stage optics, consisting of a molded 2 X 2 cm2 primary lens and a secondary, 2 mm ball lens (inset) focus incident sunlight by more than one thousand times (Credit : Xing Sheng, University of Illinois)

"This is very nice work. The results are impressive, and the schemes appear to provide a route to ultra-high efficiency photovoltaics, with strong potential for utility-scale power generation," states Ali Javey, a professor of electrical engineering and computer sciences at the University of California, Berkeley. Javey, who is a program leader for electronic materials at the Lawrence Berkeley National Laboratory and a co-director of the Bay Area Photovoltaics Consortium, was not involved with this research.

This work has been published in the paper, "Printing-based assembly of quadruple-junction four-terminal microscale solar cells and their use in high-efficiency modules," by Xing Sheng *et al* in *Nature Materials* (2014). doi:10.1038/nmat3946

Calyxo secures more financing for CdTe EPC projects

The firm is confident it will be able to produce modules in the short term at a cost of €0.25 / Wp with its low-cost atmospheric deposition process and thus PV to power attractive market regardless of funding

Calyxo GmbH has concluded an agreement with the IBG Beteiligungsgesellschaft Saxony-Anhalt.

The IBG is involved in technology-oriented, innovative companies and projects, as it has found in the business model of Calyxo. The integrated value chain from the production of CdTe thin-film modules to the implementation of so-called EPC Projects [Engineering, Procurement and Construction] has the IBG convinced to finance.

The core equipment for the semiconductor deposition was thereby designed and developed by the innovative and experienced team of engineers at Calyxo itself.

Major system components are constructed by Calyxo and have been transferred to patent applications.

The participation of the IBG opens and secures the business opportunities of Calyxo GmbH with its financial commitment and know-how.

In particular, the technology will be further developed through their participation and opens up new markets for EPC projects due to the core technology.

The IBG has consistently pursued its goal of promoting the development of Calyxo GmbH as well as the efficiency of the photovoltaic unique technology, achieving the current CdTe world record of 20.4 percent efficiency, to be produced on mass soon.

QuantumClean joins EICC`s tantalum programme

The company says it is the first and only semiconductor industry outsourced process tool parts cleaner to participate in the programme

QuantumClean has announced its inclusion in the Electronic Industry Citizenship Coalition's (EICC) Conflict-Free Smelter (CFS) programme for tantalum.

QuantumClean is a global provider of high-purity outsourced process tool parts for cleaning, surface treatment and refurbishment. The firm provides analytical and engineering services to the semiconductor, solar and LED industries,

The EICC, in partnership with the Global e-Sustainability Initiative (GeSI) launched "The Conflict-Free Sourcing Initiative" in 2010. This was to meet the need for downstream companies to demonstrate with reasonable certainty the origin and validate smelter procurement processes for four "conflict minerals". These materials include tantalum which is used by many semiconductor wafer fabs. In servicing these fabs, QuantumClean strips and recycles tantalum from many semiconductor process tool chamber parts.

"QuantumClean is committed to do its part in the elimination of unlawful and immoral activities, including unthinkable work conditions surrounding the trade and use of minerals mined in conflict-afflicted areas of the world and used in the semiconductor industry, which is why we elected to participate in the EICC's Conflict-Free Smelter Program for Tantalum," says David Zuck, Vice President and COO of Quantum Global Technologies.

To achieve inclusion in the CFS program, QuantumClean demonstrated tantalum supply chain integrity and traceability at both its Fremont California and Hillsboro Oregon Advanced Technology Cleaning Centres through rigorous 3rd party audits.

QuantumClean says it is the first and only semiconductor industry outsourced process tool parts cleaner to participate in the CFS program.

"When we founded QuantumClean many years ago, we wrote six essential, governing policy statements, including an Environmental and Social Responsibility policy. Our inclusion in EICC's Conflict-Free Sourcing program is the latest affirmation of management's commitment to this policy," concludes Zuck.

CdTe thin-film solar cell mystery solved?

Perhaps. In theory, controlling the grain boundary structure could help raise CdTe cell light-to-energy conversion efficiency closer to 32 percent

Treating cadmium-telluride (CdTe) solar cell materials with cadmium-chloride improves their efficiency, but researchers have not fully understood why.

Now, an atomic-scale examination of the thin-film solar cells led by the Department of Energy's Oak Ridge National Laboratory has answered this decades-long debate about the materials' photovoltaic efficiency increase after treatment.

A research team from ORNL, the University of Toledo and DOE's National Renewable Energy Laboratory used electron microscopy and computational simulations to explore the physical origins of the unexplained treatment process.

The results are published in *Physical Review Letters (PRL)*.

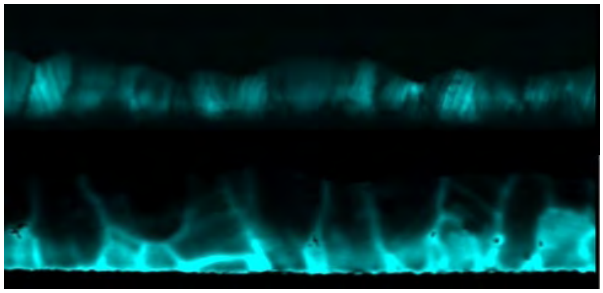
Thin-film CdTe solar cells are considered a potential rival to silicon-based photovoltaic systems because of their theoretically low cost per power output and ease of fabrication. Their comparatively low historical efficiency in converting sunlight into energy, however, has limited the technology's widespread use, especially for home systems.

Research in the 1980s showed that treating CdTe thin films with cadmium-chloride significantly raises the cell's efficiency, but scientists have been unable to determine the underlying causes. ORNL's Chen Li, first author on the PRL study, explains that the answer laid in investigating the material at an atomic level.

"We knew that chlorine was responsible for this magical effect, but we needed to find out where it went in the material's structure," Li says. "Only by understanding the structure can we understand what's wrong in this solar cell - why the efficiency is not high enough, and how can we push it further."

By comparing the solar cells before and after chlorine treatment, the researchers realised that atom-scale grain boundaries were implicated in the enhanced performance. Grain boundaries are tiny defects that that normally act as roadblocks to efficiency, because they inhibit carrier collection which greatly reduces the solar cell power.

State of the art electron microscopy revealed the thin films' structure and chemical composition after treatment. It was found that chlorine atoms replaced tellurium atoms within the grain boundaries. This atomic substitution creates local electric fields at the grain boundaries that boost the material's photovoltaic performance instead of damaging it.



Cross-sectional electron beam-induced current maps show the difference in cadmium telluride solar cells before (pictured above) and after (below) cadmium chloride treatment. The increased brightness after treatment indicates higher current collection at the grain boundaries. Cross-sectional electron beam-induced current maps show the difference in CdTe solar cells before (pictured above) and after (below) cadmium chloride treatment. The increased brightness after treatment indicates higher current collection at the grain boundaries

The research team's finding, in addition to providing a long-awaited explanation, could be used to guide engineering of higher-efficiency CdTe solar cells.

Controlling the grain boundary structure, says Li, is a new direction that could help raise the cell efficiencies closer to the theoretical maximum of 32 percent light-to-energy conversion. Currently, the record CdTe cell efficiency is only 20.4 percent.

"We think that if all the grain boundaries in a thin film material could be aligned in same direction, it could improve cell efficiency even further," Li comments.

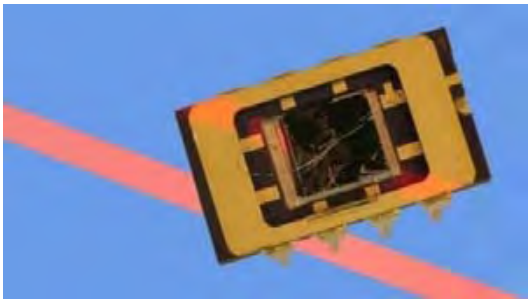
This work has been published in the paper, "Grain-Boundary-Enhanced Carrier Collection in CdTe Solar Cells," by Chen Li *et al* in *Physical Review Letters*, 2014; 112 (15). DOI: 10.1103/PhysRevLett.112.156103

The research was supported by the Department of Energy's Office of Energy Efficiency and Renewable Energy through the SunShot Initiative and the Office of Basic Energy Sciences.

The work was sponsored in part by the UK Engineering and Physical Sciences Research Council and through a user project supported by ORNL's Centre for Nanophase Materials Sciences (CNMS). This research used resources of the National Energy Research Scientific Computing Centre. Yan acknowledges support from the Ohio Research Scholar Programme.

Magic molybdenite creates solar cells and LEDs

Electronic components made up of a layer of molybdenite superposed on a layer of silicon can produce light due to the the special properties of molybdenite

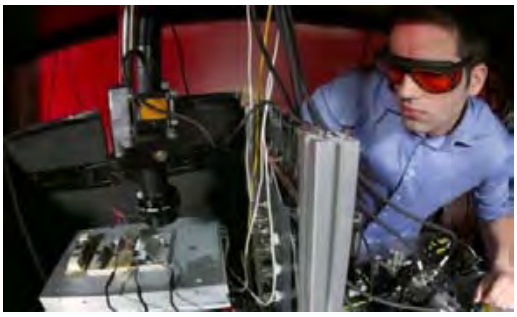


After using it to develop a computer chip, Flash memory device and photographic sensor, EPFL scientists have once again tapped into the electronic potential of molybdenite (MoS2) by creating diodes that can emit light or absorb it to produce electricity.

Molybdenite has a few surprises still up its sleeve.

EPFL professor Andras Kis and his team in the Laboratory of Nanoscale Electronics and Structures (LANES) is continuing his study of this promising semiconductor. In research recently published in the journal *ACS Nano,* they have demonstrated the possibility of creating lLEDs and solar cells.

The scientists built several prototypes of diodes - electronic components in which voltage flows in only one direction - made up of a layer of molybdenite superposed on a layer of silicon. At the interface, each electron emitted by the MoS2 combines with a "hole" - a space left vacant by an electron - in the silicon. The two elements lose their respective energies, which then transforms into photons. "This light production is caused by the specific properties of molybdenite," explains Kis. "Other semiconductors would tend to transform this energy into heat."



Working in tandem

Even better, by inversing the device, electricity can be produced from light. The principle is the same: when a photon reaches the molybdenite, it ejects an electron, thus creating a "hole" and generating voltage.

"The diode works like a solar cell," says Kis. "Our tests showed an efficiency of more than 4 percent. Molybdenite and silicon are truly working in tandem here. The MoS2 is more efficient in the visible wavelengths of the spectrum, and silicon works more in the infrared range, thus the two working together cover the largest possible spectral range."

The scientists want to study the possibility of building electroluminescent diodes and bulbs. This discovery could, above all, reduce the dissipation of energy in electronic devices such as microprocessors, by replacing copper wires used for transmitting data with light-emitters.

Solar Frontier and State University of New York Consider R&D and Manufacturing JV

MOU initiates feasibility study to bring Japanese CIS solar PV technology to U.S

Tokyo based Solar Frontier and the State University of New York College of Nanoscale Science and Engineering have signed a memorandum (MOU) of understanding to conduct a technical and economic feasibility study for potential joint R&D and manufacturing of CIS thin-film modules in Buffalo, New York.

This move is part of Solar Frontier's plans to establish production bases for its proprietary technology outside of Japan, the company's home market that currently accounts for 100% of its production.

"Solar Frontier will continue to advance itself as a global leader in the solar energy segment, and establishing overseas production bases is at the core of our mid-term growth plan," said Hiroto Tamai, President and Representative Director of Solar Frontier. "We are honored to work with the CNSE to study the potential for joint R&D and manufacturing of our proprietary CIS technology in New York State."

"Governor Andrew Cuomo challenged the State of New York to become a leading high-tech knowledge economy. Our feasibility study with Solar Frontier, the holder of a proprietary CIS thin-film solar photovoltaic technology, is a step toward unveiling that vision – toward the reality of new high-tech jobs, new economic growth, and to becoming a centre for advanced nanotechnologies," said Dr. Alain Kaloyeros, CEO of CNSE.

CNSE is a global education, research, development, and technology deployment resource supporting New York's job creation and growth agenda for emerging high-tech industries. CNSE has made more than $20 billion in high-tech investments since its foundation in 2004, representing the world's most advanced university-driven research enterprise. CNSE's Solar Energy Development Center in Halfmoon provides a prototyping and demonstration line for next-generation CIGS thin-film solar cells and supports CNSE's leadership of the U.S. Photovoltaic Manufacturing Consortium (PVMC).

Under the leadership of Governor Andrew Cuomo and the New York State Assembly, New York is making multi-billion strategic investments in high-tech programs, ranging from long-term innovative R&D to workforce development and product commercialization. Public-private partnerships are a cornerstone of this program, inviting foreign investment and driving economic development and job creation across the state.

Solar Frontier has developed CIS technology for 20 years, achieving world-record 20.9% conversion efficiency on CIS solar cell (0.5 cm2). In 2007, the company entered commercial production in southern Japan before ramping up its 900MW Kunitomi manufacturing plant in 2011. Its advanced production process has enabled it to achieve the highest level of mass production thin-film efficiencies at world-class production costs. The upcoming 150 MW Tohoku Plant, a model for future overseas manufacturing facilities, is the latest step in Solar Frontier's mid-term growth plan, enabling production of CIS at higher conversion efficiencies and best-in-class cost levels.

"Solar Frontier's proprietary CIS technology is unlike today's standard solar module technologies. Our CIS generates a higher electricity yield than crystalline silicon modules in real operating conditions – where environmental factors show that labelled efficiency isn't everything. Together with high-quality, high-precision manufacturing, Solar Frontier is creating cost-competitive and reliable returns on investments in the solar energy market," concluded Charles Pimentel, Chief Operating Officer of Solar Frontier Americas.

University of Arkansas achieve record efficiency in solar cell made of gallium arsenide

Researchers use zinc oxide coating to achieve higher efficiency from gallium arsenide solar cell

Engineering researchers at the University of Arkansas have

achieved the highest efficiency ever in a 9 millimeter-squared solar cell made of gallium arsenide.

After coating the cufflink-sized cells with a thin layer of zinc oxide, the research team reached a conversion efficiency of 14 percent.

A small array of these cells (as few as nine to twelve) generate enough energy for small light-emitting diodes and other devices. But surface modification can be scaled up, and the cells can be packaged in large arrays of panels to power large devices such as homes, satellites, or even spacecraft.

The research team, led by Omar Manasreh, professor of electrical engineering, published its findings in Applied Physics Letters and the April 2014 issue of Solar Energy Materials and Solar Cells.

An alternative to silicon, gallium arsenide is a semiconductor used to manufacture integrated circuits, light-emitting diodes and solar cells. The surface modification, achieved through a chemical synthesis of thin films, nanostructures and nanoparticles, suppressed the sun's reflection so the cell could absorb more light. But even without the surface coating, the researchers were able to achieve 9-percent efficiency by manipulating the host material.

"We want to increase the efficiency of small cells," said Yahia Makableh, doctoral student in electrical engineering. "With this specific material, the theoretical maximum is 33 percent efficiency, so we have some work to do. But we're making progress. The beauty of zinc oxide is that it's cheap, non-toxic and easy to synthesize."

Yahia Makableh demonstrates how a small array of 9-millimeter, gallium-arsenide solar cells can provide energy for small devices.

Makableh said the surface modification could also be applied to other solar cells, including those made of indium-arsenide and gallium-arsenide quantum dots. Solar cells made of these materials may be able to achieve 63-percent conversion efficiency, which would make them ideal for future development of solar cells.

Makableh used equipment and instrumentation in the College of Engineering's Optoelectronics Research Lab, which is directed by Manasreh. Researchers in the lab grow and functionalize semiconductors, nanostructured anti-reflection coatings, self-cleaning surfaces and metallic nanoparticles to be used in solar cells. Their ultimate goal is to fabricate and test photovoltaic devices with greater solar-energy conversion efficiency.

Manasreh focuses on experimental and theoretical optoelectronic properties of semiconductors, superlattices, nanostructures and related devices. Since joining the University of Arkansas in 2003, he has received more than $8 million in public research funding from the National Aeronautics and Space Administration, the U.S. Air Force and the National Science Foundation.

Journal Reference:

Y.F. Makableh, R. Vasan, J.C. Sarker, A.I. Nusir, S. Seal, M.O. Manasreh. Enhancement of GaAs solar cell performance by using a ZnO sol–gel anti-reflection coating. Solar Energy Materials and Solar Cells, 2014; 123: 178 DOI: 10.1016/j.solmat.2014.01.007

Future of solar cells brightens with shiny quantum dots

Photovoltaic solar-panel windows composed of CdSe/CdS quantum dots could be the next technology used in housing

A house window that doubles as a solar panel could be on the horizon, thanks to recent quantum-dot work by Los Alamos National Laboratory researchers in collaboration with scientists from University of Milano-Bicocca (UNIMIB), Italy.

Their project demonstrates that superior light-emitting properties of quantum dots can be applied in solar energy by helping more efficiently harvest sunlight.

"The key accomplishment is the demonstration of large-area luminescent solar concentrators that use a new generation of specially engineered quantum dots," says lead researcher Victor Klimov of the Centre for Advanced Solar Photophysics (CASP) at Los Alamos.

Quantum dots are ultra-small bits of semiconductor matter that can be synthesised with nearly atomic precision via modern methods of colloidal chemistry.

A luminescent solar concentrator (LSC) is a photon management device, representing a slab of transparent material that contains highly efficient emitters such as dye molecules or quantum dots. Sunlight absorbed in the slab is re-radiated at longer wavelengths and guided towards the slab edge equipped with a solar cell.

Klimov explains, "The LSC serves as a light-harvesting antenna which concentrates solar radiation collected from a large area onto a much smaller solar cell, and this increases its power output."

"LSCs are especially attractive because in addition to gains in efficiency, they can enable new interesting concepts such as photovoltaic windows that can transform house facades into large-area energy generation units," adds Sergio Brovelli, a faculty member at UNIMIB.

Quantum dot luminescent solar concentrator devices (embedded in the glowing pink bar) under ultraviolet illumination

Because of highly efficient, colour-tuneable emission and solution processability, quantum dots are attractive materials for use in inexpensive, large-area LSCs. To overcome a nagging problem of light re-absorption, the Los Alamos and UNIMIB researchers developed LSCs based on quantum dots with artificially induced large separation between emission and absorption bands (called a large Stokes shift).

These "Stokes-shift" engineered quantum dots represent cadmium selenide/cadmium sulphide (CdSe/CdS) structures in which light absorption is dominated by an ultra-thick outer shell of CdS, while emission occurs from the inner core of a narrower-gap CdSe.

Los Alamos researchers created a series of thick-shell (so-called "giant") CdSe/CdS quantum dots, which were incorporated by their Italian partners into large slabs (sized in tens of centimetres) of polymethylmethacrylate (PMMA). While being large by quantum dot standards, the active particles are still tiny - only about hundred angstroms across. For comparison, a human hair is about 500,000 angstroms wide.

The details of this work have been published in the article, "Large-area luminescent solar concentrators based on 'Stokes-shift-engineered' nanocrystals in a mass-polymerized PMMA matrix," by Francesco Meinardi *et al* in *Nature Photonics,* published online on 13th April 2014. doi:10.1038/nphoton.2014.54

BHSU student honoured for QD solar cell research

The study regarded CdSe and CdTe quantum dots

Four Black Hills State University students were recently honoured for their research projects at the 16th annual Black Hills Research Symposium.

Nearly thirty students took part in the two-day interdisciplinary symposium that featured poster displays and presentations highlighting the undergraduate research projects.

One of the top recognised students was Ashley D. Wingert, a chemistry major from Custer, for her research, "Analysis of CdSe and CdTe Quantum Dots in Solar Cells". Her advisor is Daniel J. Asunskis, chemistry.

Ashley Wingert, chemistry major from Custer, received top recognition for her research: Analysis of CdSe and CdTe Quantum Dots in Solar Cells

The BHSU Research Symposium began in 1995 when three faculty members met to create an event in which exceptional BHSU students from a variety of disciplines could showcase their unique research projects.

The symposium incorporates a variety of topics from several academic disciplines and gives students unique opportunities to work closely with a faculty mentor in developing a research project suitable for presentation.

Antimonides surf the invisible wave

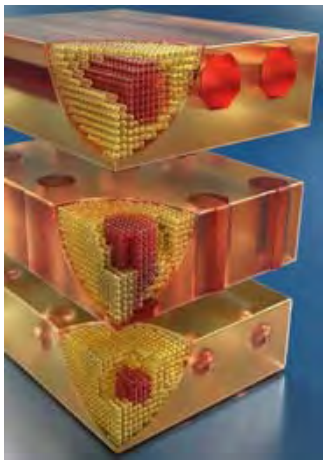
Researchers have created a semiconductor incorporating erbium antinonide, that manipulates light in the invisible infrared/terahertz range, paving the way for new and enhanced applications

Promising to address an array of applications, from energy efficiency to telecommunications to enhanced imaging, researchers at UC Santa Barbara say they have created a compound semiconductor of nearly perfect quality.

The material comprises embedded nanostructures containing ordered lines of atoms that can manipulate light energy in the mid-infrared range.

More efficient solar cells, less risky and higher resolution biological imaging, and the ability to transmit massive amounts of data at higher speeds are only a few applications that this unique semiconductor will be able to support.

"This is a new and exciting field," says Hong Lu, researcher in UCSB's Department of Materials and Department of Electrical and Computer Engineering, and lead author of a study that appears as a cover story of the March issue in the journal *Nano Letters*, a publication of the American Chemical Society.



Artist's concept of nanometre-size metallic wires and metallic particles embedded in semiconductors, as grown by Hong Lu (Credit: Peter Allen, UCSB}

Key to this technology is the use of erbium, a rare earth metal that has the ability to absorb light in the visible as well as infrared wavelength - which is longer and lower frequency wavelength to which the human eye is accustomed - and has been used for years to enhance the performance of silicon in the production of fibre optics.

Pairing erbium with the element antimony, the researchers embedded the resulting compound - erbium antimonide (ErSb) - as semi-metallic nanostructures within the semiconducting matrix of gallium antimonide (GaSb).

ErSb, according to Lu, is an ideal material to match with GaSb because of its structural compatibility with its surrounding material, allowed the researchers to embed the nanostructures without interrupting the atomic lattice structure of the semiconducting matrix. The less flawed the crystal lattice structure of a semiconductor is, the more reliable and better performing the device in which it is used will be.

"The nanostructures are coherently embedded, without introducing noticeable defects, through the growth process by molecular beam epitaxy," notes Lu. "Secondly, we can control the size, the shape and the orientation of the nanostructures."

Epitaxy is a process where layers of material are deposited atom by atom, or molecule by molecule, one on top of the other with a specific orientation.

"It's really a new kind of heterostructure," says Arthur Gossard, professor in the Materials Department and in the Department of Electrical and Computer Engineering.

Semiconductors incorporating different materials have been studied for years. But a technology UCSB professor and Nobel laureate Herbert Kroemer pioneered was a single crystal heterostructured semiconductor/metal which was rather different.

The nanostructures allow the compound semiconductor to absorb a wider spectrum of light due to a phenomenon called surface plasmon resonance, explains Lu, and that the effect has potential applications in broad research fields, such as solar cells, medical applications to fight cancer, and in the new field of plasmonics.

Optics and electronics operate on vastly different scales, with electron confinement being possible in spaces far smaller than light waves. Therefore, it has been an ongoing challenge for engineers to create a circuit that can take advantage of the speed and data capacity of photons and the compactness of electronics for information processing.

The highly sought bridge between optics and electronics may be found with this compound semiconductor using surface plasmons, electron oscillations at the surface of a metal excited by light.

When light (in this case, infrared) hits the surface of this semiconductor, electrons in the nanostructures begin to resonate. This means that they move away from their equilibrium positions and oscillate at the same frequency as the infrared light .

This preserves the optical information but shrinks it to a scale that would be compatible with electronic devices.

In the realm of imaging, embedded nanowires of ErSb offer a strong broadband polarisation effect, according to Lu, filtering and defining images with infrared and even longer-wavelength terahertz light signatures.

This effect can be used to image a variety of materials, including the human body, without the risk posed by the higher energies that emanate from X-rays, for instance.

Chemicals such as those found in explosives and some illegal narcotics have unique absorption features in this spectrum region. The researchers have already applied for a patent for these embedded nanowires as a broadband light polariser.

"For infrared imaging, if you can do it with controllable polarisations, there's information there," says Gossard.

While infrared and terahertz wavelengths offer much in the way of the kind of information they can provide, the development of instruments that can take full advantage of their range of frequencies is still an emerging field.

Lu credits this latest breakthrough to the collaborative nature of the research on the UCSB campus, which allowed her to merge her materials expertise with the skills of researchers who specialise in infrared and terahertz technology.

"It's amazing here," she says. "We basically collaborated and discovered all these interesting features and properties of the material together."

"One of the most exciting things about this for me is that this was a 'grassroots' collaboration," says Mark Sherwin, professor of physics, director of the Institute for Terahertz Science and Technology at UCSB, and one of the paper's co-authors.

The idea for the direction of the research came from the junior researchers in the group, he continues, grad students and undergrads from different laboratories and research groups working on different aspects of the project, all of whom decided to combine their efforts and their expertise into one study. "I

think what's really special about UCSB is that we can have an environment like that."

Since the paper was written, the researchers have gone into industry, into companies such as Intel and Agilent, or pursued careers in academia.

Researchers on campus are also exploring the possibilities of this technology in the field of thermoelectrics, which studies how temperature differences of a material can create electric voltage or how differences in electric voltages in a material can create temperature differences.

UCSB researchers John Bowers (solid state photonics) and Christopher Palmstrom (heteroepitaxial growth of novel materials) are investigating the potential of this new semiconductor.

The research has been described in detail in the publication, "Self-Assembled ErSb Nanostructures with Optical Applications in Infrared and Terahertz," by Hong Lu *et al* in *Nano Letters*, 2014, 14 (3), pp 1107–1112. DOI: 10.1021/nl402436g

Ascent Solar releases slim EnerPlex Jumpr Slate 10k

The CIGS based charger is just 6.7mm thick and has a 10,000 mAh power bank

Ascent Solar Technologies, a developer and manufacturer has announced the immediate availability of the Red Dot design EnerPlex Jumpr Slate at company owned kiosks, as well as online at www.goenerplex.com.

The product will be available at partner retailers both domestically and internationally later this month.

The Red Dot award-winning Jumpr Slate 10k is 6.7mm thick, barely thicker than a USB port

The EnerPlex Jumpr Slate, at less than 7mm thick, is claimed to be the thinnest large-format power bank available on the market. With a substantial capacity of 10,000 mAh, the Slate can re-charge smartphones such as the iPhone 5 up to five times, freeing consumers from being tethered to the outlet. Also equipped with dual 2.4 amp outputs, the Jumpr Slate can simultaneously charge power hungry tablets and e-readers, such as the iPad.

The Jumpr Slate 10k which has dual 2.4amp USB outputs

Justin R. Jacobs, Ascent's Manager of Brand Development says, "The Jumpr Slate 10k exemplifies the ingenuity and creativeness of the EnerPlex brand; the Slate's combination of power, thinness and weight provides a truly unique product proposition for those consumers who do not want to be burdened by thick and heavy traditional power banks."

Nanoparticles create skinny solar cells

Nanostructures on top of an active solar material might be able to capture the light and increase efficiency

Nanostructures could enable more light to be directed into the active layer of solar cells, increasing their efficiency.

Martina Schmid at Helmholtz Zentrum Berlin (HZB), has now measured how irregularly distributed silver particles influence the absorption of light. She demonstrated that nanoparticles interact with one another via their electromagnetic near-fields, so that local "hot spots" arise where light is concentrated especially strongly.

The work has been described in *Europhysics News*, the magazine of the European Physical Society, and points the way for improved designs of these kinds of nanostructures.

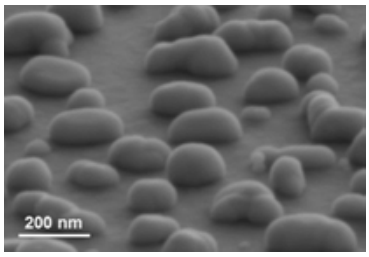
It is desirable, even with thin-film solar cells, to utilise less material and so save on fabrication costs. For example, chalcopyrite cells (i.e. copper-indium-gallium-diselenide, or 'CIGS' cells) in part consist of rare-earth elements like indium and gallium.

If the active layer is made too thin, however, it absorbs too little light and the efficiency level drops. Nanostructures on top of the active material might be able to capture the light and thus increase the efficiency. This idea is being pursued by Martina Schmid, who heads the NanooptiX group of junior scientists at HZB and holds a junior professorship at Freie Universität Berlin.

"Our objective is to optimise nanostructures so they selectively direct certain wavelengths of the solar spectrum into the cells," she says.

Irregularly distributed nanoparticles

One option to achieve this is to construct simple nanostructures from metallic particles that self-organise by heat-treatment of a thin metallic film. Schmid initially coated a glass substrate with a 20nm film of silver, which she subsequently subjected to heat treatment. Irregular silver particles are formed in this way having diameters of around 100nm.



The silver nanoparticles are irregularly shaped and randomly distributed over the surface, as shown by the scanning electron microscope image (Image: HZB)

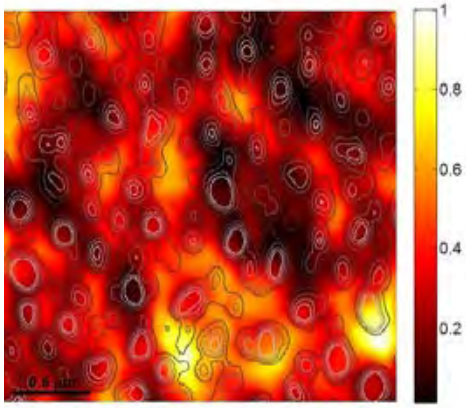
Traversing the sample with the "light pick"

In collaboration with colleagues at the California Institute of Technology (CalTech), Schmid investigated how these types of randomly distributed nanoparticles influence the incidence of light on a cell below. They used a particularly sensitive method known as scanning near-field optical microscopy (SNOM). In this technique, an extremely tiny point scans the sample, determining the topography as with atomic force microscopy.

However, it also simultaneously illuminates the sample through an even smaller aperture in the probe point to create optical excitations (plasmons) in the nanoparticles. These optical excitations can either couple the light into the solar cell as desired - or instead transform the light into heat, whereby it is lost to the solar cell.

It's all about neighbourhood; interactions determine the light scattering

Measurements showed that there can be strong interactions between densely situated, irregularly distributed nanoparticles leading to local "hot spots".



The topography of the sample surface can be seen here (white lines around the nano-particles) as well as the local optical excitations. The image displays several "hot spots" (yellow) that arise through interactions of the nanoparticles with the light and also with one another (Image: HZB/CalTech)

"Whereas the darker regions tend to absorb light and transform it into heat, the hot spots show where nanoparticles strongly interact via their electromagnetic near-fields. In these regions of enhanced fields, energy transformation in the solar cell could potentially be enhanced," Schmid explains.

In the end, areas of stronger fields but also of comparatively weaker ones arise. However, it is difficult to establish a clear relationship between the occurrence of these hot spots and specific nanoparticles.

"The particles mutually affect one another through their electromagnetic near-fields, which are notably more complex than suspected until now. We need to ascertain how we can intentionally create the desired field distributions," says Schmid. She will investigate these questions further at HZB and at the Freie Universität Berlin together with the research group headed by Paul Fumagalli.

More details of this work have been published in the paper, "Scanning near-field optical microscopy on dense random assemblies of metal nanoparticles," by M. Schmid *et al* in *Journal of Optics*, 15, 125001 (2013).

doi:10.1088/2040-8978/15/12/125001.

Sun can create solar energy materials

A new process could provide more precise control of the processing temperature needed to create CIS and CZTS solar cells

In a recent advance in solar energy, researchers have discovered a way to tap the sun not only as a source of power, but also to directly produce the solar energy materials that make this possible.

This breakthrough by chemical engineers at Oregon State University could soon reduce the cost of solar energy, speed production processes, use environmentally benign materials, and make the sun almost a "one-stop shop" that produces both the materials for solar devices and the eternal energy to power them.

The findings were published in *RSC Advances*, a journal of the Royal Society of Chemistry, in work supported by the National Science Foundation.

"This approach should work and is very environmentally conscious," comments Chih-Hung Chang, a professor of chemical engineering at Oregon State University, and lead author of the paper.

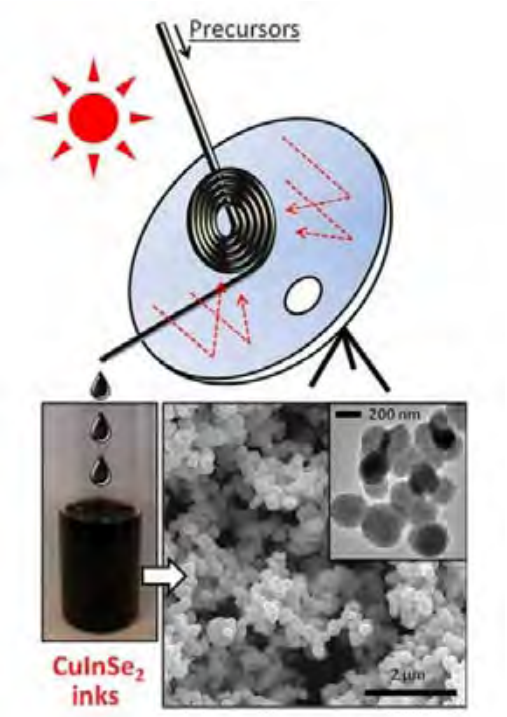
"Several aspects of this system should continue to reduce the cost of solar energy, and when widely used, our carbon footprint," Chang believes. "It could produce solar energy materials anywhere there's an adequate solar resource, and in this chemical manufacturing process, there would be zero energy impact."

The work is based on the use of a "continuous flow" microreactor to produce nanoparticle inks that make solar cells by printing. Existing approaches based mostly on batch operations are more time-consuming and costly.

In this process, simulated sunlight is focused on the solar microreactor to rapidly heat it, while allowing precise control of temperature to aid the quality of the finished product. The light in these experiments was produced artificially, but the process could be done with direct sunlight, and at a fraction of the cost of current approaches.

"Our system can synthesise solar energy materials in minutes compared to other processes that might take thirty minutes to two hours," Chang notes. "This gain in operation speed can lower cost."

In these experiments, the solar materials were made with copper indium diselenide (CuInSe2 or CIS), but to lower material costs it might also be possible to use a compound such as copper zinc tin sulphide (Cu2ZnSnS4 or CZTS), Chang continues.



Solar reactor: A new technology invented at Oregon State University uses sunshine directly in the production of solar energy materials. (Graphic by Ki-Joong Kim)

And to make the process something that could work twenty-four hours a day, sunlight might initially be used to create molten salts that could later be used as an energy source for the manufacturing. This could provide more precise control of the processing temperature needed to create the solar energy materials.

State-of-the-art chalcogenide-based, thin film solar cells have already reached a fairly high solar energy conversion efficiency of about 20 percent in the laboratory, the researchers say, while costing less than silicon technology. Further improvements in efficiency should be possible, they add.

Another advantage of these thin-film approaches to solar energy is that the solar absorbing layers are, in fact, very thin; about 1 - 2 microns, instead of the 50 - 100 microns of more conventional silicon cells. This could ease the incorporation of solar energy into structures, by coating thin films onto windows, roof shingles or other possibilities.

The work is described in detail in the paper, "Two-step continuous-flow synthesis of CuInSe2 nanoparticles in a solar microreactor," by Peter B. Kreider *et al* in RSC Adv., 2014,4, 13827-13830

DOI: 10.1039/C4RA00467A

Additional support for this work was provided by the Oregon Nanoscience and Microtechnologies Institute, or ONAMI, and the Oregon Built Environment and Sustainable Technologies Centre, or Oregon BEST.

Solar Frontier's 20.3% CIS cell breaks thin-film PV record

The cell was cut from a 30cm by 30cm substrate and produced using a sputtering-selenisation formation method

Solar Frontier, together with the New Energy and Industrial Technology Development Organisation (NEDO), has achieved 20.9 percent conversion efficiency on a 0.5cm2 CIS cell.

This is a world record conversion efficiency for thin-film photovoltaic technologies.

It beats Solar Frontier's previous world record of 19.7 percent conversion efficiency for CIS thin-film cells that do not contain cadmium, on top of the previous-best 20.8 percent cell efficiency record set for all thin-film PV technologies.

The result has been independently verified by the Fraunhofer Institute, Europe's largest application-oriented research organisation.

"Solar Frontier's new 20.9 percent efficiency record resulted from a CIS cell cut from a 30cm by 30cm substrate produced using a sputtering-selenisation formation method - the same method we use in our factories. The significance is twofold: it ensures we can transfer our latest achievement into mass production faster, and it proves the long-term conversion efficiency potential of Solar Frontier's proprietary CIS technology," says Satoru Kuriyagawa, Chief Technology Officer of Solar Frontier. "Solar Frontier has entered into the next phase in the development of CIS technology, and we look forward to building on this achievement and driving our efficiency even higher."

Conversion efficiency is a popular measurement used to compare the performance of solar modules. Actual performance after installation, however, depends on how differing PV technologies react to their surrounding environment and climate.

Solar Frontier's CIS modules are proven to generate more electricity (kWh/kWp) in real operating conditions than crystalline silicon modules. Together with high automation and precision manufacturing in Japan, CIS modules provide long-term competitive and reliable returns on investments for customers.

The company's latest efficiency record was achieved at the Atsugi Research Centre (ARC) in Kanagawa, Japan. As part of the ARC's customer-centric approach, it focuses on boosting the conversion efficiency of its CIS modules, developing its proprietary mass production machinery, and reducing overall system costs for end users. The ARC has been at the forefront of advancing CIS technology, setting numerous world records since it was established in 2009.

Solar Frontier CIS cells to be used in 29 MW project at Nagasaki Airport

Along with Chopro, Solar Frontier will build and operate Prefecture's largest megasolar power plant Mainbody:

Solar Frontier and Chopro has signed a letter of agreement with the Nagasaki Prefectural Government and the Land Development Public Corporation of Nagasaki Prefecture for a 29 MW megasolar power plant on land adjoining Nagasaki Airport, Japan.

The agreement, regarding the construction and operation of the solar power plant, was signed on March 31st, 2014. The upcoming megasolar project will be the largest in Nagasaki Prefecture and one of the largest in Japan.

"Our Nagasaki project integrates the economical advantages of Solar Frontier's CIS solar energy system solutions, from supplying high-performance CIS modules through to Operation & Maintenance, with Chopro's expertise as an energy supplier local to Nagasaki," says Hiroto Tamai, President and Representative Director of Solar Frontier. "Together with leading regional companies like Chopro, we will continue to meet the high demand for solar projects that offer competitive and reliable returns on investment."

After the Kansai International Airport Megasolar Power Plant, this will be the second large-scale installation at an airport that leverages Solar Frontier's CIS thin-film technology. Compared to crystalline silicon modules, Solar Frontier's CIS modules have a higher electricity yield (kWh/kWp) in real operating conditions, while their anti-glare properties ensure they don't affect aircraft operations.

"Our joint project is built on a history of trust with Solar Frontier. We now look forward to working on one of the world's largest installations at an airport - at home in Nagasaki - and to contributing to the region's economic growth and renewable energy initiative," explains Kenji Araki, Representative Director of Chopro.

Chopro is a liquefied petroleum gas (LPG) distributor and more recently a solar power producer headquartered in Nagasaki Prefecture.

The Nagasaki Prefectural Government announced its partner selection on December 27th, 2013, as part of its solar and renewable energy initiative, the "Nagasaki Green New Deal." In addition to working with local companies, a pre-determined percentage of proceeds from this project will also go to Nagasaki Prefecture to support its economic growth.

Samco to distribute VPE`s MOCVD tools

Regions where Samco will distribute the reactors include the Far East and Europe. The systems are used in GaN and solar cell production

Valence Process Equipment (VPE) of Branchburg New Jersey has signed an agreement with Samco Inc., based in Kyoto, Japan, to distribute VPE's MOCVD equipment.

The agreement gives Samco exclusive distribution rights in Japan as well as non-exclusive rights to sell the products in a number of other countries including China, South Korea and Europe.

VPE is a technology company that has developed a novel MOCVD reactor for GaN based semiconductor devices including High Brightness LED's for Solid State Lighting.

The unique patented design of the VPE system is claimed to reduces consumption of expensive gases and metal-organic precursors by up to 40 percent in comparison with competing products. VPE's initial product was the GaN-500 reactor, announced in 2011, with a current capacity of 59 x 2" or 18 x 4" wafers. VPE has recently released the GaN-550 MOCVD reactor with a capacity of 72 x 2" or 20 x 4" wafers.

Valence GaN_500 Reactor

Samco is a provider of dry etch and plasma CVD systems to the global Compound Semiconductor Industry.

Recently, Samco has placed a focus on selling next-generation production equipment for GaN power devices that are a cornerstone of "green electronics" and have a large impact on energy efficiency. The addition of MOCVD strengthens Samco's product line-up as MOCVD, plasma-CVD, dry etching and surface treatment systems can be bundled to provide a "one stop solution" for customers involved in GaN semiconductor applications.

As part of the agreement Samco will purchase and install a GaN-550 MOCVD system in its facility in Kyoto for customer demonstrations. Installation is planned for July 2014 and the system will be used to develop novel power device epitaxial structures on large diameter wafers in collaboration with a key customer.

VPE CEO and Founder, Frank Campanale, comments, "We are delighted to embark on this partnership with a highly respected and capable company like Samco. Our MOCVD system complements Samco's existing product range and creates a unique suite of products for the GaN semiconductor community".

Altatech wins CVD system order from U.S. university

The tool will be used in the production of advanced LEDs and solar cells and silicon based devices

Altatech, a subsidiary of Soitec, has received an order from the University of Washington in Seattle for an AltaCVD system.

The tool offers a combination of capabilities that allows users to develop new process materials with higher added value.

Altatech's CVD system will be installed at the University's Washington Nanofabrication Facility (WNF), where it will be used by both internal and external researchers in fabricating a broad range of semiconductor-based devices.

These will include advanced LEDs, solar cells, CMOS transistors, MEMS and ICs built with the latest in through-silicon-via (TSV) technology,

Altatech's pulsed CVD systems are currently used n R&D iand pilot production facilities throughout Europe. However, the University of Washington's order represents the first such system to be delivered to a North American university R&D and pilot production facility.

The university's acquisition of the AltaCVD system, along with recent installations of an advanced deep reactive ion etcher (DRIE) and a plasma-enhanced CVD (PECVD) tool, provides the capability to assemble an electroplated TSV fill process.

Commenting on the tool's capabilities, Michael Khbeis, acting director of the WNF, claims, "The AltaCVD system provides a unique capability that enables researchers to deposit conformal metal films for TSV applications as well as metal oxides and nitrides for high-k dielectrics and piezoelectric materials."

"The higher deposition rate enabled by pulsed CVD makes ALD (atomic layer deposition) films a tractable solution for scale-up paths toward high-volume manufacturing for our researchers and industrial clients. This ensures a viable pathway from academia to real economic impact in our region," he adds.

"Extending the use of our CVD systems into this acclaimed user facility in North America continues to demonstrate the widely recognised advantages of our pulsed deposition technology," says Jean-Luc Delcarri, general manager of Soitec's Altatech subsidiary. "We are very pleased to add the University of Washington to the growing list of our CVD equipment adopters."

Altatech will support its AltaCVD installation at the University of Washington from its U.S.-based business and service operation centre.

The AltaCVD system uses pulsed deposition technology to offer a unique combination of capabilities for developing new materials. It can perform ALD for exceptional 3D coverage at deposition rates matching those of more conventional CVD techniques.

This allows superior stoichiometry control while creating highly conformal thin and thick films, which cannot be achieved using many of today's existing technologies.
Altatech's system design combines a unique vaporiser technology, gas/liquid panel integration, dual-channel showerhead and chamber design. The combination of Altatech's proprietary reactor design and precursor introduction path with pulsed liquid injection and vaporisation enables nanoscale control of film thickness, uniformity, composition and stoichiometry in complex materials.

Midsummer launches R&D platform for CIGS and CZT solar cells

The tool can also be used for a variety of applications where a sputtered material stack in an unbroken vacuum chain is required

Swedish firm Midsummer, a supplier of equipment manufacturing of CIGS thin film flexible solar cells, has launched the UNO, a low cost versatile research and development platform for thin film deposition specifically developed for universities and research facilities.

UNO tool

The cost effective UNO tool derives from the production of CIGS solar cells. With its generic design and optional configurations, UNO is the ideal solution for a range of thin film research applications. It has a high throughput, flexibility, stability and ability to design complex test series.

"There has been a lot of interest from universities and institutes for a lower cost version of our commercial DUO production tool for research and development," says Sven Lindström, CEO, Midsummer. "We are happy to announce the launch of the UNO in response to these requests, and hope that a research tool like this will contribute to accelerate the development of cost-effective and efficient thin film CIGS and CZTS solar cells on a global scale."

The UNO is a platform for CIGS and CZTS (copper, zinc, tin and sulphide) solar cell research. In addition, it can be used for a multitude of applications where a sputtered material stack in an unbroken vacuum chain is required (thin film batteries, fuel cells, small display screens etc.).

The UNO can have up to thirteen sputtering cathodes and warm the substrate up to 750°C (1,400°F). It can load up to 300 substrates and run automatic test series, where each substrate has different parameter settings. It can also be supplemented with co-evaporation, analytical tools, database and various options.

The UNO has many of the features and design of the DUO, including a small footprint. The biggest difference between the two tools is that the UNO has only one main vacuum chamber and that sputtering takes place in only one process station at a time, which is suitable for R&D.

Another R&D feature is that the UNO can use both glass and stainless steel substrates and can be equipped with more in-site measurement stations. The UNO is a pure R&D tool and not a low cost production tool. The price of the UNO starts at under $1 million, but depends on configuration.

Midsummer's commercial production line is the DUO, a compact CIGS turn-key system with a 5 MW annual production capacity. Midsummer's CIGS cells looks like crystalline silicon solar cells, but are made on stainless steel substrates. This makes the cells suitable not only for regular solar panels, but also for flexible, light weight panels that can be used on membrane roofs, landfills or other structures where the traditional glass modules cannot be applied.

"We firmly believe that thin film CIGS solar cells are the solar cells of the future," concludes Sven Lindström, CEO, Midsummer. "They are increasingly efficient and have many advantages over traditional silicon-based solar cells. They are durable, can withstand vibrations, can be curved and bent, and can be manufactured cost-efficiently in small volumes."

Thin film CIGS solar panels are thinner and lighter than traditional silicon solar cells made of glass. They are also non-toxic (no cadmium) and can be made frameless, thus ideal for buildings and moving vehicles in cities. They are flexible and can be bent.

IQE revenues up 44 percent thanks to wireless

The robust wireless business and diversification strategy drives strong rises in revenues, profit and earnings

IQE has announced its final results for the year ended 31st December 2013.

The firm achieved a new Group record of £126.8 million, up from £88.0 million in 2012.

This includes £30.9 million revenues from Kopin Wireless, acquired in January 2013. However, the company was affected by adverse H2 currency impact as sterling appreciated 3 percent against the US dollar.

H2 wireless sales were up 3 percent over H1 in constant currency and H2 photonic sales were up 12 percent over H1 (in constant currency). The adjusted PBT was up 51 percent to £13.0 million from £8.6 million (Reported PBT £5.2 million).

The adjusted fully diluted EPS increased 43 percent to 2.00p from 1.40p (Reported fully diluted EPS 0.89p). Cash inflow from operations before exceptional items was up 346 percent from £4.7 million to £16.2 million.

Cash conversion before exceptional items was 111 percent up from 51 percent. Net debt was £34.4 million (opening net debt £15.5 million increased primarily due to £25 million of debt to part fund the Kopin acquisition.

Drew Nelson, IQE Chief Executive, made the following statement:

"IQE's core wireless division has again delivered a robust performance, with continued growth despite a significant downstream inventory correction in the major chip companies due to softness in the high end smartphone market. As a direct result of our customer risk mitigation strategy, which we have executed over the last 18 months and completed with the acquisition of Kopin Wireless, we are much less sensitive to market share shifts between the major chip supply companies.

"Concerns in the UK over the last year that silicon CMOS would significantly damage the Compound Semiconductor industry have proved unfounded and are not reflected in our financial performance nor in our customers' expectation of future long term demand drivers.

"Wireless remains an attractive market for us over the coming years with demand continuing to be driven by the proliferation of wireless applications and the need for sophisticated GaAs chips to deal with the explosive growth in data traffic. Beyond this, the next waves of innovation which will drive handset replacement cycles are likely to include lasers and sensors using compound semiconductor technology, for gaming, 3D image capture, gesture recognition, and sensing for a variety of applications including healthcare monitoring devices.

"Our business diversification strategy also gained strong traction, and we achieved a number of significant technical and commercial milestones during 2013 which reflect the strong progress made in our other key markets including photonic sensors and lasers, advanced solar (CPV), power semiconductors, infrared, LED and advanced electronics.

"Our integration remains firmly on track, and we expect to realise significant reductions in our financial overheads, whilst benefiting greatly from the operational and technical synergies we are delivering.

"IQE is at the forefront of the enabling technologies that are at the very heart of many of the twenty-first century trends and products. We are confident that the Group is well positioned for continued growth in earnings and cash flow in 2014 and beyond."

Emcore wins solar panel contract for NASA's Cyclone project

The III-V multijunction cells will be used for the SNC global navigation satellite system

Emcore wins contract for NASA's Cyclone project for solar panels

Emcore Corporation has been awarded a contract by Sierra Nevada Corporation (SNC) to design and manufacture solar panels for SNC to be used on NASA's Cyclone Global Navigation Satellite System (CYGNSS).

The CYGNSS mission will be managed by Southwest Research Institute (SwRI) and is planned for launch, October 2016.

Emcore will populate solar panels with its most advanced ZTJ triple-junction solar cells. SNC will then deliver the finished panels to SwRI for integration into the eight Low-Earth Orbiting (LEO) satellites that will be carried into orbit on a single launch vehicle.

The goal of NASA's CYGNSS mission is a fundamental improvement in hurricane forecasting. CYGNSS will make frequent and accurate measurements of ocean surface winds throughout the life cycle of tropical storms and hurricanes.

The data generated will enable scientists to probe key air-sea interaction processes that take place near the core of storms, which play a critical role in the genesis and intensification of hurricanes.

"Emcore is a valued and strategic partner supporting a critical element of SNC's growing, complete and integrated satellite Electrical Power System (EPS) offering," says Matt Johnson director of programs for SNC's Space Systems. "We look forward to working with Emcore as we continue to expand the EPS market with higher value, lower cost and turn-key system solutions."

"Emcore is proud to play a key role with Sierra Nevada Corporation in this important NASA mission to advance the forecasting and tracking of extreme weather conditions," adds. Brad Clevenger, Executive Vice President and General Manager of Emcore's Photovoltaics Division.

"Emcore previously delivered solar panels to SNC for the ORBCOMM Generation 2 (OG2) satellites in 2010. We are very pleased to receive this award and are appreciative of SNC's continued confidence in our ability to deliver the highest reliability solar panels for their missions," continues Clevenger.

Emcore is manufacturer of radiation-hard solar cells for space power applications. With a Beginning-Of-Life (BOL) conversion efficiency nearing 30 percent and the option for a patented, onboard monolithic bypass diode, Emcore's multi-junction solar cells provide high levels of performance to interplanetary spacecraft and earth orbiting satellites.

Enhancing performance of III-V nanowires

Using InGaAs on InAs stems grown on graphene could benefit solar cell and laser technology

Imagine a field of small wires-standing at attention like a tiny field of wheat-gathering the Sun's rays as the first step in solar energy conversion.

Researchers at the University of Illinois at Urbana-Champaign have achieved new levels of performance for seed-free and substrate-free arrays of nanowires from class of materials called III-V directly on graphene.

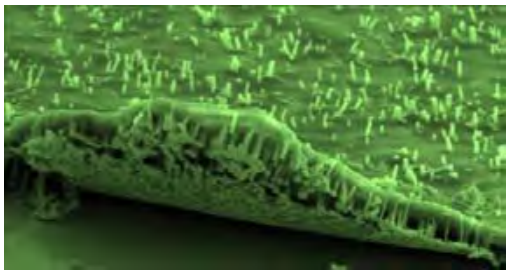
These compound semiconductors hold particular promise for applications involving light, such as solar cells or lasers.

A dense array of nanowires grown directly on graphene. The insets show a higher magnification SEM view of the array and a STEM image of a single, axially heterostructured InGaAs/InAs nanowire

"Over the past two decades, research in the field of semiconductor nanowires has helped to reshape our understanding of atomic-scale crystal assembly and uncover novel physical phenomena at the nanometre scale," explains Xiuling Li, a professor of electrical and computer engineering at Illinois.

In the March 20th issue of *Advanced Materials*, the researchers present the first report of a novel solar cell architecture based on dense arrays of coaxial *p-n* junction InGaAs nanowires on InAs stems grown directly on graphene without any metal catalysts or lithographic patterning.

"In this work, we have overcome the surprising structure (phase segregation) and successfully grown single phase InGaAs and demonstrated very promising solar cell performance," explains postdoctoral researcher Parsian Mohseni, first author of the study.



The InGaAs/InAs nanowire array can be lifted from its graphene base and transferred to alternative platforms for bendable device applications (Credit : Parsian Mohseni)

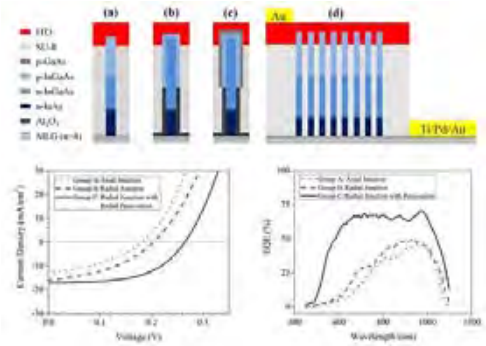
"Depending on the materials, nanowires can be used for functional electronics and optoelectronics applications," Mohseni adds. "The main benefits of this III-V photovoltaic solar cell design are that it is fairly low-cost, substrate-free, and has a built-in back side contact, while being conducive to integration within other flexible device platforms."

Li's research group uses a method called van der Waals epitaxy to grow nanowires from the bottom up on a two-dimensional sheet, in this case, graphene. Gases containing gallium, indium, and arsenic are pumped into a chamber where the graphene sheet sits, prompting the nanowires self-assemble, growing by themselves into a dense carpet of vertical wires across the graphene's surface.

In their earlier work in *Nano Letters 2013* using a graphene sheet, the researchers discovered that InGaAs wires grown on graphene spontaneously segregate into an InAs core with an InGaAs shell around the outside of the wire.

To improve the materials' efficiencies for solar power conversion, the researchers bypassed the unique Van der Waals epitaxy induced spontaneous phase segregation by inserting InAs segments in between.

The resulted ternary InGaAs NW arrays are vertical, non-tapered, controllable in size, height, and doping, and broadly tunable in composition thus energy for monolithic heterogeneous integration with 2D Van der Waals sheets including graphene.



Schematic representations of the three different nanowire geometries investigated (a-c) and a diagram of a nanowire array-on-graphene prototype solar cell device structure (d). The characteristic illuminated current density-voltage (J-V) curves and external quantum efficiency (EQE) spectra obtained from the three distinct device structures are shown in the bottom left and bottom right, respectively (Credit : Parsian Mohseni)

Under air mass 1.5 global solar illumination, the core-shell In0.25Ga0.75As (Eg ~ 1.1 eV) nanowire arrays on graphene demonstrate a conversion efficiency of 2.51 percent, representing a new record for substrate-free, III-V NW-based solar cells.

"Although InGaAs is far from being the optimum bandgap materials for high efficiency solar cells, the direct epitaxy on graphene platform established here has significant implications for a wide variety of III-V compound semiconductor NW based solar cells on graphene, as well as light emitters and multi-junction tandem solar cells, all of which can be released for flexible applications," Li says.

This article has been adapted from one by Rick Kubetz, Engineering Communications Office, University of Illinois at Urbana-Champaign.

IQE`s stake in Solar Junction acquired by strategic investor

This is aimed at accelerating the global commercialisation of SJ's CS multijunction technology

IQE has announced that its minor equity stake in the share capital of Solar Junction Corporation (SJC), has been acquired by a new strategic investor, as part of an acquisition of SJC.

The new investor has a strong interest in accelerating the large scale global adoption and commercialisation of SJC's CPV technology.

The identity of the new investor, and specific terms of the acquisition, are not yet public and covered under non disclosure agreements.

IQE can confirm, however, that its exclusive long term wafer supply agreement using SJC's dilute nitride technology, agreed when IQE invested in SJC in 2012, will be unaffected by this

transaction. The return to SJC equity shareholders, including IQE, will be deferred and contingent upon specific aspects of SJC's future business development. Further details will be provided in due course.

In February 2012, IQE invested $5 million in a 9.8 percent equity stake in order to obtain exclusive rights to supply SJC with high efficiency advanced Concentrated PhotoVoltaic (CPV) wafers using SJC's dilute nitride materials technology through a long term supply agreement.

The primary investors in SJC at that time were several US-based venture capitalists. The technology has subsequently been successfully transferred to IQE's large volume production tools, and world record efficiencies of 44.1 percent have been achieved from this production platform for standard triple junction cells.

IQE has since been supplying wafers to SJC on a commercial basis under the terms of the Wafer Supply Agreement.

As anticipated at the time, SJC has required subsequent equity fundraisings, which were supported by its venture capital investors, but in which IQE did not participate.

However, the longer term objective of SJC, having obtained volume manufacturing credibility through the technology transfer and manufacturing agreements with IQE, has always been to secure a major strategic investor to better facilitate and accelerate the commercialisation and global adoption of its technology. IQE has fully supported this initiative.

SJC's success in attracting this strategic investor marks another major milestone in accelerating the company's growth and commercialisation plan of its unique CPV technology.

First Solar breaks ground on CdTe 250MW project

The Moapa Southern Paiute Solar project is the first utility-scale solar project on tribal land and will deliver much needed economic benefits to the Tribe and Nevada

The U.S. Senate Majority Leader Harry Reid (NV) joined representatives from the Moapa Band of Paiutes, executives from First Solar and the Los Angeles Department of Water and Power (LADWP) and community, government and energy industry leaders celebrated the start of construction of the 250 Megawatt (MW)AC Moapa Southern Paiute Solar Project.

The project is located on the Moapa River Indian Reservation just north of Las Vegas, and has a Power Purchase Agreement (PPA) with the LADWP to deliver clean, solar energy for twenty-five years to Los Angeles.

(*From right to left) Harry Reid joins Moapa Band of Paiutes Chairwoman Aletha Tom, First Solar CEO James Hughes, LADWP director of power system planning and development Randy Howard, and the Moapa Band of Paiutes Tribal Council to break ground on the 250 MW Moapa Southern Paiute Solar Project*

"Today's event marks a very important milestone for NevadaC," said Reid. "The Moapa Southern Paiute Solar project is the first utility-scale solar project on tribal land and will deliver much needed economic benefits to the Tribe and Nevada. It will also create about 400 construction jobs, and replace dirty energy with clean solar power."

The power plant, anticipated to be fully operational by the end of 2015, is expected to generate enough clean solar energy to serve the needs of more than 93,000 homes. This amount of renewable energy will displace approximately 313,000 metric tons of CO2 annually-the equivalent of taking about 60,000 cars off the road.

The project will play a key role in LADWP's efforts to build a clean energy future by expanding renewable energy to 33 percent of its total power supply and eliminating coal power. Solar energy from the Moapa plant will contribute 2.4 percent toward LADWP's renewable energy portfolio.

This transformational goal also includes reducing energy use by at least 10 percent through energy efficiency measures; expanding local solar and other forms of distributed generation; initiating a robust demand-response program; and rebuilding local power plants to better integrate renewable energy and be more flexible to meet peak demand.

"The Moapa Southern Paiute Solar Project is a significant step toward the Los Angeles Department of Water and Power's effort to achieve a major transformation of the city's power supply-one that has greater reliance on renewable energy resources and zero coal power," said Marcie L. Edwards, LADWP General Manager.

For the Moapa Band of Paiutes, the utility-scale solar project is an ideal opportunity for the Tribe to create economic opportunities while preserving the land and their cultural heritage.

"This is an important step in becoming a leader in Indian Country and will help to create a model for other Tribes to follow," said Aletha Tom, Chairwoman of the Moapa Paiute Tribal Council. "If our small Tribe can accomplish this, then others can also. There are endless opportunities in renewable

energy, and Tribes across the nation have the available land on which to build them."

Moapa Southern Paiute Solar, LLC, a subsidiary of First Solar Electric, LLC, is the project owner and will construct the project using First Solar's advanced photovoltaic (PV) thin film solar modules.

The project will be built on 2,000 acres of land on the Moapa River Indian Reservation and include an onsite substation and a new 5.5 mile 500 kV transmission line that will connect the project to the existing Crystal Substation, serving energy users in California.

"First Solar is thrilled to celebrate this important milestone with Senator Reid and distinguished guests, and honored to work with the Moapa Band of Paiutes on this landmark project," said Jim Hughes, CEO of First Solar. "By working together, we will provide jobs and significant economic benefits to the Tribe and Clark County as well as helping LADWP deliver clean, renewable energy to its customers."

Once the Moapa Southern Paiute Solar facility becomes fully operational, LADWP will be able to repurpose existing transmission systems that now bring high-carbon coal power from Navajo Generating Station.

The Moapa plant, along with a second utility-scale solar power plant in that region of Nevada, will enable LADWP to stop receiving coal power from the Navajo plant by the end of 2015.

This is four years before it is required by California state law-reducing greenhouse gas emissions by 8.4 million metric tonnes between 2014 and 2019 cumulatively. The renewable energy from the two solar power projects in Nevada will contribute over 4 percent to LADWP's goal of 33 percent renewable energy by 2020.

Compound Semiconductor conference hits a new high

35 presentations equipped delegates with a comprehensive overview of the compound semiconductor industry

Around 300 delegates and over 30 sponsors descended on Frankfurt for the fourth CS International Conference, which was held at the Sheraton Airport Hotel this week.

This must-attend event for the leaders of the compound semiconductor industry set a new standard for its number of presentations.

The conference covered all aspects of the industry, with presentations grouped into six key themes:

Power Electronics
LEDs
Integration of CMOS and III-Vs
Wide Bandgap RF Devices
Front-ends for Mobile Devices
Lasers, PICs & PV

Presentations on these topics highlighted the growing penetration of compound semiconductors into the silicon industry, and the use of silicon in the making of III-V chips. Leading developers of next-generation CMOS, such as IBM and Imec, are pioneering approaches to integrate high-mobility materials, for example InGaAs, into the channels of transistors in microprocessors, while silicon substrates are viewed as a low-cost platform for making LEDs, as well also power and RF electronics based on GaN.

Meanwhile, power amplifiers that are based on silicon are starting to go head-to-head with those made from GaAs for deployment in the latest smartphones. It appears that devices based on CMOS will gain market share, but GaAs will dominate the market for many years to come.

A more detailed report of the presentations at CS International Conference will appear in the April /May edition of *Compound Semiconductor* magazine. This issue will also contain details of the winners of the coveted CS Industry Awards.

For more information about CS International Conference, and opportunities available for the 2015 event, contact Stephen Whitehurst: stephen.whitehurst@angelbc.com Tel 0044 (0)2476 718 970. www.cs-international.net

EpiWorks to boost MOCVD production capacity

The manufacturer of compound semiconductor epitaxial wafers is increasing the ability to produce high volumes of 4-inch and 6-inch wafers for VCSELs, edge-emitting lasers, detectors and photovoltaics

EpiWorks is majorly expanding with a multi-faceted expansion of its production capacity.

The company makes wafers used in applications such as optical components, wireless devices and high-speed communication systems.

"A clear migration toward applications that require significantly higher volumes, particularly in the area of optical materials and photonics is underway. The markets include consumer electronics, sensors and displays, digital projection, and data communications. As the leader in the manufacture and development of high performance compound semiconductor products, we are pleased to announce a major increase in

capacity. This is part of an aggressive, long-term production capacity roadmap to satisfy increasing demand from photonic and RF customers," says Nick Kolarich, Director of Sales and Marketing at EpiWorks.

The expansion increases the ability to produce high volumes of 4-inch and 6-inch wafers for VCSELs, edge-emitting lasers, detectors and photovoltaics with a better cost structure. The new capacity includes upgrades to existing tools and the latest Aixtron 2800 G4 MOCVD technology. This allows EpiWorks to quickly and seamlessly satisfy customer demand while providing greater flexibility for new product development.

"For many years EpiWorks has been the leading US-based manufacturing and development partner for novel and advanced photonic and optical devices. Our customers have leveraged our development expertise to commercialise numerous complex advanced technologies from the lab into next generation photonic products. We are excited to now see our high-volume manufacturing expertise enabling proliferation of these products under stringent specifications and at low cost," explains Quesnell Hartmann, EpiWorks CEO.

First Solar and GE to set up next generation CdTe power plant

The firms' combined expertise is aimed at improving PV plant production and reduce costs in 1500VDC applications

First Solar and GE's Power Conversion business are utilising their recently established technology and commercial partnership to develop a more cost effective and productive utility-scale PV power plant design.

It will combine First Solar's thin-film CdTe modules with GE's new ProSolar 1500 Volt inverter/transformer system.

First Solar has integrated new technology into its modules and optimised them for 1500VDC applications.

This development enables power plant engineering design that could increase the size of the solar array served by each inverter and reduces the number of inverter/transformer stations required for each plant to convert the power from direct current (DC) to alternating current (AC) and feed electricity to a commercial electrical grid.

The resulting plant design is claimed to maintain high power delivery while lowering installation and maintenance costs.

"This is a significant step in establishing the next generation of utility-scale PV power plants," says Mahesh Morjaria, First Solar's Vice President of Product Management. "Partnering with an industry giant such as GE, we are able to take our power plant design to the next level, and bring additional value to our customers."

Morjaria also notes that future generations of First Solar modules will increase optimisation, benefiting from advances gained in part from the acquisition last fall of GE thin-film PV technology.

"GE is known throughout the industry as an established leader in power generation technology. With our ProSolar inverters, we were able to draw from our experience developing and manufacturing technology for traditional power plants to create a highly efficient solution with industry-leading capabilities," adds Joe Mastrangelo, CEO of GE Power Conversion.

"The inverters' design enable our customers to apply engineering design that significantly increases efficiency of energy production. Together with First Solar, we can help customers get the most out of their solar power systems."

Morjaria also says First Solar has already identified projects under construction for initial deployment of the new 1500v system. The 4MW ProSolar 1500V station is the largest inverter in the industry capable of accommodating 1,500 volt DC solar arrays, which is a major factor in utilising economies of scale by significantly increasing the array size and reducing the number of inverters required by a solar power plant.

First Solar says its CdTe 17 percent efficiency is top

The firm's total area efficiency cadmium-telluride module has been confirmed by NREL. This result is expected to expand the opportunity for constrained space and C&I installations

First Solar has announced that it has set a world record for CdTe photovoltaic (PV) module conversion efficiency,.

The firm achieved a 17 percent total area module efficiency in tests performed by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL).

The new record is an increase over the prior record of 16.1 percent efficiency, which the company set in April 2013.

This announcement comes weeks after First Solar said it achieved a world record in CdTe research cell efficiency of 20.4 percent.

The record-setting module was created at First Solar's Research and Development Centre in Perrysburg, Ohio, using production-scale processes and materials, and included several recent technology enhancements that are incrementally being implemented on the company's commercial production lines.

Notably, the First Solar research module also has a confirmed 'aperture area' conversion efficiency of 17.5 percent. Many manufacturers often quote this aperture area efficiency when claiming record performance, particularly for small mini-modules custom-built in R&D labs. First Solarclaims its record is all the more significant because it is full production size.

"This achievement demonstrates our ability to rapidly and reliably transfer research results to full-size modules. We can take CdTe innovation from the lab to production faster and more reliably than other technologies due to our robust,

adaptable manufacturing processes and the accommodating nature of CdTe material technology," says Raffi Garabedian, First Solar's Chief Technology Officer.

He adds, "Our R&D efforts are delivering technology that will quickly be scaled to real-world application as part of our integrated power plant systems, which are engineered to deliver the best performance, reliability and value for our customers."

Garabedian adds that the efficiency milestone is also a signal that First Solar's CdTe modules are becoming a more attractive option for application in constrained space projects and commercial/industrial installations. "With the highest demonstrated thin-film module performance, we are positioned to pursue new deployment opportunities around the world," he continues.

Based on the company's sustained high velocity in technology development, Garabedian says First Solar has accelerated its production module conversion efficiency roadmap, raising its lead-line production nameplate efficiency target for YE2015 to 15.6 to 15.8 percent.

First Solar also extended its module conversion efficiency roadmap to 2017, with targets for year-end lead-line production nameplate efficiency of 17.7 to 18.4 percent in 2016 and 18.1 to 18.9 percent in 2017.

Thin film material market to shoot to $10.25 billion by 2018

This is estimated by MarketsandMarkets which analysed different sectors including the CdTe, CIGS and CIS solar cell sectors

According to the report "Thin Film Material Market, By Type (CdTe, CIGS, a-Si, Others), End-User Industry [Photovoltaic Solar Cells, MEMS, Semiconductors and Electrical (Circuit Boards), Optical Coating, Others], and Deposition Processes," the thin film material market value is expected to grow by significant CAGR to reach $10.25 billion by 2018.

The advantages offered by thin film material in industrial as well as domestic operations, coupled with the rising demand for efficiency and minituarisation, will continue to drive the thin film material market. The growing demand from end-user industries would be responsible for the growth of thin film material market at a very swift pace in the future.

Globally, thin film material manufacturing companies are dependent on the government funding and subsidies. During the global economic crisis, U.S. and the European countries were affected the most.

Many countries such as the U.S. and Germany stopped the funding subsidies provided to the thin film material manufacturing companies. This resulted in bankruptcy, closure, or acquisition of these companies by their Chinese counterparts.

It also affected the thin film material market adversely causing the revenues to decline in 2013. But the recovering global economy combined with the stringent government regulation and funding from venture capitalists is estimated to provide the market with a necessary boost in the future.

The Thin Film Material Market is growing steadily in Europe, but will continue to grow at a rapid pace in Asia-Pacific. Countries such as China and Japan are the major contributors to the growing market of Asia-Pacific.

The North American markets for thin film material will also continue to grow at a significant rate. The African and Latin American markets have still not realised their full potential but their growth rates would be considerably higher as compared to others owing to low base effect.

The thin film material market is highly competitive and most companies don't offer all types of thin film material. First Solar (U.S.) is a major player which has dominated the CdTe market, accounting for nearly 90 percent of the total CdTe market in 2012.

Hanergy (China) dominated the CIS/CIGS market; occupying around one-third of the market by acquiring other bankrupt companies in 2012. Ascent Solar (U.S.), Kaneka Solar Energy (Japan), and Solar Frontier (Japan) are the other major companies offering CIS/CIGS technology. The a-Si technology is majorly used by Asian companies such as Anwell Solar (Hong Kong), Suntech Power Co. Ltd. (China), and Moser Baer (India).

Thin film materials are appropriate for high-density and high-frequency applications. Thin film materials are used for number of applications in several industries such as photovoltaic solar cells, MEMS, semiconductor, electrical and optical coating.

One of the key factors contributing to this market growth is the increasing use of solar energy. The market has also witnessed growth due to various governments investing increasingly in the solar industry globally. However, the shortage of raw material used for the production of thin films could pose a challenge for the growth of this market.

More research endorses the benefits of WSe2 for LEDs

By making diodes using tungsten diselenide, researchers have shown it is possible to produce photodetectors, photovoltaic cells, and LEDs

A team of MIT researchers has used a novel material that's just a few atoms thick to create devices that can harness or emit light.

This could lead to ultrathin, lightweight, and flexible photovoltaic cells, LEDs and other optoelectronic devices, they say.

Their report is one of three papers by different groups

describing similar results with this material, published in the March 9th issue of *Nature Nanotechnology*.

The MIT research was carried out by Pablo Jarillo-Herrero, the Mitsui Career Development Associate Professor of Physics, graduate students Britton Baugher and Yafang Yang, and postdoc Hugh Churchill.

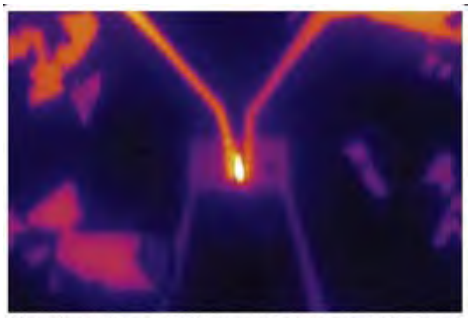
The material they used, tungsten diselenide (WSe2), is part of a class of single-molecule-thick materials under investigation for possible use in new optoelectronic devices - ones that can manipulate the interactions of light and electricity. In these experiments, the MIT researchers were able to use the material to produce diodes, the basic building block of modern electronics.

Typically, diodes (which allow electrons to flow in only one direction) are made by doping, a process of injecting other atoms into the crystal structure of a host material. By using different materials for this irreversible process, it is possible to make either of the two basic kinds of semiconducting materials, *p*-type or*n*-type.

But with the new material, either *p*-type or*n*-type functions can be obtained just by bringing the vanishingly thin film into very close proximity with an adjacent metal electrode, and tuning the voltage in this electrode from positive to negative. That means the material can easily and instantly be switched from one type to the other, which is rarely the case with conventional semiconductors.

In their experiments, the MIT team produced a device with a sheet of WSe2 material that was electrically doped half *n*-type and half *p*-type, creating a working diode that has properties "very close to the ideal," Jarillo-Herrero says.

By making diodes, it is possible to produce all three basic optoelectronic devices - photodetectors, photovoltaic cells, and LEDs; the MIT team has demonstrated all three, Jarillo-Herrero says. While these are proof-of-concept devices, and not designed for scaling up, the successful demonstration could point the way toward a wide range of potential uses, he says.



In the team's experimental setup, electricity was supplied to a tiny piece of tungsten selenide (small rectangle at center) through two gold wires (from top left and right), causing it to emit light (bright area at center), demonstrating its potential as an LED material.

IMAGE COURTESY OF BRITT BAUGHER AND HUGH CHURCHILL

"It's known how to make very large-area materials" of this type, Churchill says. While further work will be required, he says, "there's no reason you wouldn't be able to do it on an industrial scale."

In principle, Jarillo-Herrero says, because this material can be engineered to produce different values of a key property called bandgap, it should be possible to make LEDs that produce any colour - something that is difficult to do with conventional materials. And because the material is so thin, transparent, and lightweight, devices such as solar cells or displays could potentially be built into building or vehicle windows, or even incorporated into clothing, he says.

While selenium is not as abundant as silicon or other promising materials for electronics, the thinness of these sheets is a big advantage, Churchill points out, "It's thousands or tens of thousands of times thinner" than conventional diode materials, "so you'd use thousands of times less material" to make devices of a given size.

In addition to the diodes the team has produced, the team has also used the same methods to make p-type and n-type transistors and other electronic components, Jarillo-Herrero says. Such transistors could have a significant advantage in speed and power consumption because they are so thin, he says.

Microscope image shows the teams experimental setup.

IMAGE COURTESY OF HUGH CHURCHILL AND FELICE FRANKEL

Kirill Bolotin, an assistant professor of physics and electrical engineering at Vanderbilt University, says, "The field of two-dimensional materials is still at its infancy, and because of this, any potential devices with well-defined applications are highly desired. Perhaps the most surprising aspect of this study is that all of these devices are efficient. ... It is possible that devices of this kind can transform the way we think about applications where small optoelectronic elements are needed."

The research was supported by the U.S. Office of Naval Research, by a Packard fellowship, and by a Pappalardo fellowship, and made use of National Science Foundation-supported facilities.

Ascent Solar appoints VP and GM of EnerPlex division

The developer of CIGS flexible thin-film photovoltaic modules integrated into the company's EnerPlex series of consumer products has taken on Richard Hashim

Ascent Solar Technologies has announced that Richard Hashim has been appointed Vice President & General Manager of the EnerPlex consumer electronics division.

The EnerPlex brand represents Ascent Solar's line of consumer

products. These products, many of which are integrated with Ascent Solar's transformational CIGS technology, provide consumers with the ability to integrate solar into their everyday lives, while enabling them to free themselves and their electronics from the outlet.

Hashim brings a wealth of international C-level experience in the technology and consumer electronics sectors. He has a track record of seventeen years with Corsair Components.

He was one of its pioneering employees, growing and managing a team which built a successful profitable international company and a global brand from start-up stage. He has held various executive roles in leadership, general management, sales and marketing, internationally, in Asia and Europe.

Victor Lee, CEO of Ascent Solar, says, "We are honoured to have an industry veteran coming onboard Ascent Solar. Mr. Hashim is perfectly suited to helm the continued rapid expansion of our EnerPlex brand globally. His depth of experience in both international and domestic sales, as well as his complex understanding of the marketing and product development cycles of consumer-oriented businesses are invaluable assets as we continue to grow the EnerPlex brand worldwide."

Hashim says, "The EnerPlex brand represents an extremely exciting opportunity. I am excited by both the revolutionary technology behind the brand, and also the extremely talented team which I will have the privilege to lead; I look forward to bringing EnerPlex - "The Ultimate Portable Power Solution" to consumers around the globe."

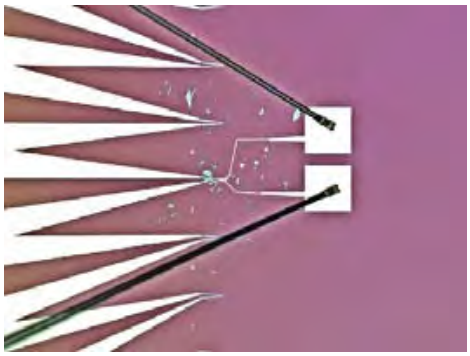
Prior to Corsair, Hashim worked with Shell Petroleum in Malaysia, managing their national branding and advertising campaigns. He holds a Bachelor's degree in International Business from Tufts University and a MBA with a Marketing concentration from Boston University.

Atomically thin solar cells

Ultrathin layers made of tungsten and selenium may be used as flexible, semi-transparent solar cells

The novel material graphene consists of only one atomic layer of carbon atoms and exhibits very special electronic properties. As it turns out, there are other materials too, which can open up intriguing new technological possibilities if they are arranged in just one or very few atomic layers.

Researchers at the Vienna University of Technology have now succeeded in creating a diode made of tungsten diselenide (WSe2). Experiments show that this material may be used to create ultrathin flexible solar cells. Even flexible displays could become possible.



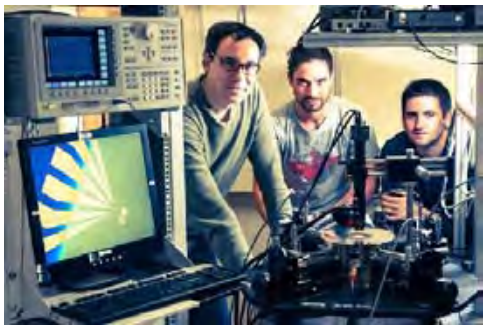
Microscope photograph of WSe2-samples, connected to electrodes

Thin layers are different.

At least since the Nobel Prize in physics was awarded in 2010 for creating graphene, the "two dimensional crystals" made of carbon atoms have been regarded as one of the most promising materials in electronics. In 2013, graphene research was chosen by the EU as a flagship-project, with a funding of one billion euros.

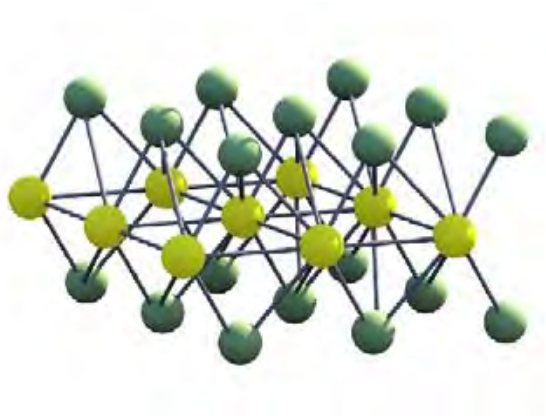
Graphene can sustain extreme mechanical strain and it has great opto-electronic properties. With graphene as a light detector, optical signals can be transformed into electric pulses on extremely short timescales.

For one very similar application, however, graphene is not well suited for building solar cells. "The electronic states in graphene are not very practical for creating photovoltaics", says Thomas Mueller. Therefore, he and his team started to look for other materials, which, similarly to graphene, can arranged in ultrathin layers, but have even better electronic properties.



Thomas Müller, Marco Furchi, Andreas Pospischil (left to right)

The material of choice was WSe2. It consists of one layer of tungsten atoms, which are connected by selenium atoms above and below the tungsten plane. The material absorbs light, much like graphene, but in WSe2, this light can be used to create electrical power.



Tungsten diselenide

The layer is so thin that 95 percent of the light just passes through - but a tenth of the remaining five percent, which are absorbed by the material, are converted into electrical power. Therefore, the internal efficiency is quite high.

A larger portion of the incident light can be used if several of the ultrathin layers are stacked on top of each other - but sometimes the high transparency can be a useful side effect. “We are envisioning solar cell layers on glass facades, which let part of the light into the building while at the same time creating electricity,” says Thomas Mueller.

Today, standard solar cells are mostly made of silicon, they are rather bulky and inflexible. Organic materials are also used for opto-electronic applications, but they age rather quickly. “A big advantage of two-dimensional structures of single atomic layers is their crystallinity. Crystal structures lend stability,”notes Mueller.

The results of the experiments at the Vienna University of Technology have now been published in the journal *Nature Nanotechnology*. The research field is extremely competitive: in the same issue of the journal, two more papers are published, in which very similar results are shown.

Researchers at the MIT (Cambridge, USA) and at the University of Washington (Seattle, USA) have also discovered the great advantages of WSe2. There seems to be little doubt that this material will soon play an important role in materials science all over the world, much like graphene has in the last couple of years.

Promising news for solar fuels

A hybrid formed from interfacing GaP with a cobaloxime catalyst could enable renewable solar fuels

Interfacing gallium phosphide (GaP) with a cobaloxime catalyst provides an inexpensive photocathode for bionic leaves that produce energy-dense fuels from nothing more than sunlight, water and carbon dioxide.

Interfacing the semiconductor GaP with a cobaloxime catalyst provides an inexpensive photocathode for bionic leaves that produce energy-dense fuels from nothing more than sunlight, water and carbon dioxide

There’s promising news from the front on efforts to produce fuels through artificial photosynthesis. A new study by Berkeley Lab researchers at the Joint Centre for Artificial Photosynthesis (JCAP) shows that nearly 90 percent of the electrons generated by a hybrid material designed to store solar energy in hydrogen are being stored in the target hydrogen molecules.

Gary Moore, a chemist and principal investigator with Berkeley Lab’s Physical Biosciences Division, led an efficiency analysis study of a unique photocathode material he and his research group have developed for catalysing the production of hydrogen fuel from sunlight.

This material, a hybrid formed from interfacing the GaP with a molecular hydrogen-producing cobaloxime catalyst, has the potential to address one of the major challenges in the use of artificial photosynthesis to make renewable solar fuels.

“Ultimately the renewable energy problem is really a storage problem,” Moore says. “Given the intermittent availability of sunlight, we need a way of using the sun all night long. Storing solar energy in the chemical bonds of a fuel also provides the large power densities that are essential to modern transport systems. We’ve shown that our approach of coupling the absorption of visible light with the production of hydrogen in a single material puts photoexcited electrons where we need them to be, stored in chemical bonds.”

Bionic leaves that produce energy-dense fuels from nothing more than sunlight, water and atmosphere-warming carbon dioxide, with no by-products other than oxygen, represent an ideal sustainable energy alternative to fossil fuels. However, realising this artificial photosynthesis ideal will require a number of technological breakthroughs including high performance photocathodes that can catalyse fuel production from sunlight alone.

Last year, Moore and his research group at JCAP took an important step towards the photocathode goal with their GaP/cobaloxime hybrid.

Gallium phosphide is an absorber of visible light, which enables it to produce significantly higher photocurrents than semiconductors that only absorb ultraviolet light. The cobaloxime catalyst is also Earth-abundant, meaning it is a relatively inexpensive replacement for the highly expensive precious metal catalysts, such as platinum, currently used in

many solar-fuel generator prototypes.

From left, Diana Cedeno, Gary Moore and Alexandra Krawicz of the Joint Centre for Artificial Photosynthesis conducted an efficiency analysis study of a unique photocathode material designed to store solar energy in hydrogen molecules. (Photo by Roy Kaltschmidt)

"The novelty of our approach is the use of molecular catalytic components interfaced with visible-light absorbing semiconductors," Moore says. "This creates opportunities to use discrete three-dimensional environments for directly photoactivating the multi-electron and multi-proton chemistry associated with the production of hydrogen and other fuels."

The efficiency analysis performed by Moore and his colleagues also confirmed that the light-absorber component of their photocathode is a major bottleneck to obtaining higher current densities. Their results showed that of the total number of solar photons striking the hybrid-semiconductor surface, measured over the entire wavelength range of the solar spectrum (from 200 to 4,000 nm) only 1.5 percent gave rise to a photocurrent.

"This tells us that the use of light absorbers with improved spectral coverage of the sun is a good start to achieving further performance gains, but it is likely we will also have to develop faster and more efficient catalysts as well as new attachment chemistries. Our modular assembly method provides a viable strategy to testing promising combinations of new materials," Moore says.

"Efficiency is not the only consideration that should go into evaluating materials for applications in solar-fuel generator technologies. Along with the durability and feasible scalability of components, the selectivity of photoactivating a targeted reaction is also critical. This is where molecular approaches offer significant opportunities, especially in catalysing complex chemical transformations such as the reduction of carbon dioxide."

This work is described in the paper, "Energetics and efficiency analysis of a cobaloxime-modified semiconductor under simulated air mass 1.5 illumination." by Alexandra Krawicz *et al* in *Phys. Chem. Chem. Phys*., 2014.

DOI: 10.1039/C4CP00495G

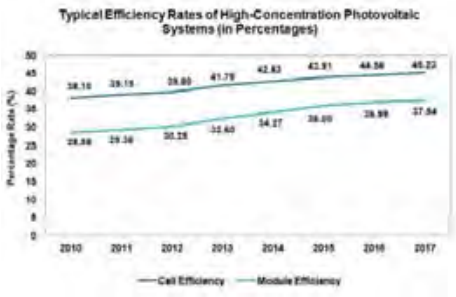
IHS: HCPV to boost solar cell efficiency above 45 percent

High-concentration photovoltaic solar cells will increase the appeal against conventional solutions

Consistent improvements in technology and gradually lower costs will drive HCPV systems to superior efficiencies.

This will make HCPV an increasingly viable rival to conventional solar-generating solutions, according to the latest analysis from IHS Technology.

IHS believes the cell efficiency of HCPV systems, currently at 40 to 42 percent, will exceed 45 percent by 2017. Such cells, used with concentrating optics, will then lead to commercial-system efficiencies approaching 40 percent, compared to the less than 35 percent conversion rates typical at present, as shown in the figure below.



"Efficiency is the most important requirement in CPV technology in order to generate competitive energy costs," says Karl Melkonyan, photovoltaic analyst at IHS. "And with the solar industry continuing to be firmly engaged in a quest for ongoing improvements through the development of new technologies, the efficiency of HCPV cells will advance over the years."

The anticipated improvements in HCPV systems are based on cell efficiencies having reached 44.7 percent in laboratory conditions, indicating that further advances are possible.

Even so, the gains in efficiency will have to be balanced against the additional manufacturing costs expected to be incurred when implementing the improvements, Melkonyan notes.

These findings can be found in the report, "CPV on the Edge of Breakthrough," from the solar research service at IHS.

Top HCPV regions in the world

Driven by falling system prices, HCPV is gradually becoming attractive in several regions of the world. IHS forecasts that the United States and Central America will install the largest number of HCPV systems between 2012 and 2017, serving as the world's biggest regional market. Installations for the region reached 54.1 megawatts in 2012.

Most HCPV suppliers are, in fact, based in the United States, and their forays into the domestic U.S. market will provide notice to rival conventional PV suppliers. Mexico is also forecast to become a large part of this regional market, with

plans in place for a 450-megawatt installation.

Meanwhile, enormous growth will occur in South America, where the HCPV market is projected to surge by 560 percent from the time installations start in 2013 until the end of the forecast period in 2017. The primary driver of South American expansion is Chile, which has the world's highest solar irradiation levels important for solar-power generation.

But the greatest increase in the HPCV market will take place in the Middle East and Africa region. HCPV installations for the region-excluding South Africa, which is tracked separately because of its more advanced PV market-will grow to 155 megawatts in 2017, up from just 1.8 megawatts in 2012. Morocco and Saudi Arabia will be the main drivers.

China could also emerge as an important player soon as suppliers from the country grow in number, with parts of southwest China shaping up to become prime HCPV locations.

Competitive landscape changing turbulently

Unable to keep pace with the dramatic cost and price reductions that conventional PV saw, many CPV pioneers faced financial difficulties in the course of the PV price collapse that took place in 2011 and 2012.

Numerous formerly leading companies-among them SolFocus and GreenVolts from California, as well as Opel Solar from Connecticut-ceased operations or became insolvent.

The industry has regained stability since 2013, however, and advances in new technologies continue to reduce costs. Just the same, only a few survivors are left from that tumultuous period, and those that remain are the ones with large cash balances and the most cost-efficient technologies. .

Among the major players, the two biggest CPV manufacturers-Suncore Photovoltaics from China and Soitec Solar from France-will each be expecting HCPV installations of about 50 megawatts by the end of the year.

Suncore and Soitec-along with top five suppliers Solaria and SunPower from California, and Magpower SA from Portugal-account for more than 80 percent of the CPV market at present. Two other manufacturers-Heliotrop from France and North Carolina-based Semprius-could also join the ranks of the top ten this year.

The HCPV supplier base will continue to change in the next five years as the current market is still in its early phases of growth, with several newcomers and start-ups expected to liven up the competition, IHS believes.

IQE initiative to boost regional supply chains

The new programme is aimed at establishing partnerships to support the development of a broad range of key enabling technologies

IQE plc, a supplier of semiconductor wafer products and services, has launched its Open Innovation programme "openiqe".

The first major project under the new programme is the IQE Open Technology Challenge, which will be marked by a launch event at the SWALEC Stadium in Cardiff on Friday 21st March 2014.

The aim of the challenge is to engage with small and medium enterprises, larger businesses and academic institutes, initially focusing primarily on the Welsh region, to develop new and enhance existing supply chains.

The project will focus on technology areas termed the Three Grand Challenges identified in the Science for Wales strategy and other major International programs, including the EU Horizon2020 Program. The three areas are life sciences and health; low carbon, energy and environment; and advanced engineering and materials.

Technology will play an increasingly important role in addressing a range of societal challenges. IQE's Open Technology Challenge is aimed at establishing partnerships along an end-to-end supply chain to develop and commercialise products that will meet real needs within the areas defined by the Three Grand Challenges.

Drew Nelson, IQE President and CEO, comments, "IQE has more than twenty-five years' experience of working closely with partners and customers worldwide to meet demanding technical specifications. We are delighted to be contributing our experience of collaborative innovation in the form of our new Open Innovation programme."

"We are confident that the Open Technology Challenge has the potential to become a key stepping stone towards the establishment of a major technology cluster in the region, as well as building stronger links to the global technology community."

IQE's Open Innovation programme is being supported by the Welsh Government.

O-D GaAs based QDs compete with 3-D

Zero-dimensional gallium arsenide based quantum dots may someday have a big effect on solar energy and lasers

In physics, there's small, and then there's nullity classed as zero-dimensional.

University of Cincinnati researchers have reached this threshold with a special structure that may one day lead to better ways of harnessing solar energy, stronger lasers or more sensitive medical diagnostic devices.

UC student Teng Shi will present her semiconductor nanowire research at the American Physical Society meeting

These structures are GaAs/AlGaAs semiconductor nanowires.

UC doctoral student Teng Shi says she and a team of researchers have observed unique optical signatures indicating that electronic excitations within these nanowires can be confined to a zero-dimensional state called a 'quantum dot'.

This latest discovery is all about going small, but its significance is anything but. The research team's ability to control the confinement energy by varying the size of the quantum dot opens up a world of possibilities.

"Exploring the basic physics of semiconductor nanowires enables one to envision applications or to design structures for applications," says Shi of UC's Department of Physics. "These structures are potential candidates for a variety of applications including photovoltaics, lasers and ultra-sensitive nanosensors."

Nearly 10,000 professionals, scholars and students will attend the APS meeting to discuss new research from industry, universities and laboratories from around the world.

This research advances work previously done on semiconductor nanowires at UC. By using a thin shell called a quantum well tube and growing it - to about 4 nanometres thick - around the nanowire core, researchers found electrons within the nanowire were distributed in an unusual way in relation to the facets of the hexagonal tube. The result is a quantum wire, like a long string many times thinner than a human hair.

Now they've taken things further, going from one-dimensional wires to zero-dimensional quantum dots. These little structures made using GaAs based materials could have a big effect on a variety of technologies.

Power Electronics

Ultra-high voltage devices for future power infrastructure

Fast growth of high-quality SiC epilayers has paved the way to the fabrication of power devices with blocking voltages exceeding 20 kV

By Tsunenobu Kimoto from Kyoto University, Japan

Following research stretching back more than forty years, shipments of SiC power devices are now significant and rising fast. Two of the biggest sellers are Schottky barrier diodes (SBDs) and power MOSFETs, which are increasingly displacing silicon incumbents and enabling the construction of smaller, more efficient power converters and inverters.

Thanks to this, SiC chips will be winning deployment in power supplies, motor controls, photovoltaic converters, telecommunications equipment, heating, robotics, electric/hybrid vehicles, traction and electric power transmission (see Figure 1).

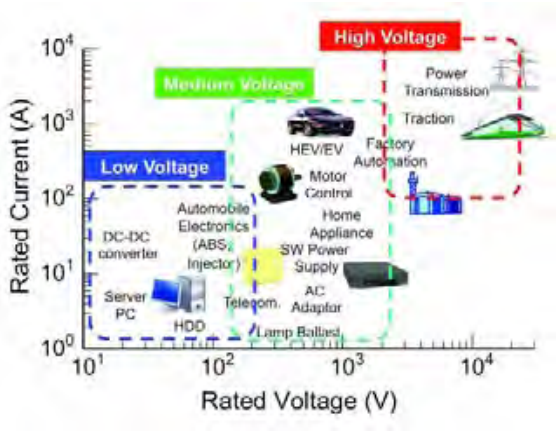


Figure 1. Different voltage ratings are required for different applications

According to several institutes, one impact of this trend is that by 2025, SiC power devices will produce a combined electric power saving exceeding 10 GW – that's comparable to the power generated by about ten nuclear plants.

Today, a time when the revolution in power electronics is still in its infancy, the operating voltages of commercial SiC diodes and transistors are predominantly in the 600 V - 1.7 kV range.

But that's by no means the limit of what is possible - recent progress in the labs shows that blocking voltages of more than 20 kV are attainable. This opens up the possibility for innovative hardware for electric power infrastructure, advanced traction applications and accelerators of particles, such as electrons and protons.

Devices that combine ultra-high blocking voltages with very low losses can also play a key role in the future of electric power transmission/distribution infrastructure and smart grids. They could feature in distributed power lines, which operate in the 6.6 - 7.2 kV range, and could be the 13 -15 kV power devices required for the construction of single-level converters. Another attractive opportunity for the deployment of ultra-high-voltage SiC devices is in solid-state transformers (see Figure 2).

Figure 2. Ultra-high-voltage SiC power devices can enable a substantial trimming of the size and weight of power converters

In high-voltage DC power transmission, voltages can be as high as 150 - 250 kV. Today, a number of 6 - 8 kV silicon thyristors are stacked in series to provide conversion of electrical power at such high voltages, but this has the downsides of enormous energy dissipation and self-heating. If ultra-high-voltage SiC chips could replace these devices, this would lead to considerable energy savings.

To help turn this dream into a reality, our team of researchers at Kyoto University has been developing SiC devices that are now setting a new benchmark for high-voltage operation. These chips, which are formed using the high epitaxial growth rates needed for a viable production process, can withstand voltages of almost 27 kV.

Why SiC?

Interest in SiC has been driven by its wide bandgap - it is 3.26 eV in the 4H polytype commonly used for making power devices. This wide bandgap is responsible for a breakdown electric field strength ten times that of silicon and a thermal conductivity that is three times that of silicon.

Furthermore, SiC is an exceptional wide bandgap semiconductor, which offers the opportunity to control the doping concentration over a very wide range (*n*-type: 1014 - 1019 cm−3, *p*-type: 1014 - 1020 cm−3). In addition, SiC devices can operate at high temperatures, such as in excess of 250°C. Drawing on all of these attractive attributes enables the simplification of the bulky cooling units often required in silicon-based power converters.

The higher field strengths permitted with SiC aid device design. Compared to silicon, blocking-layer thickness can be tens times thinner, while the doping concentration can be increased by two orders of magnitude (see Figure 3). Thanks to this, it is possible to realise huge reductions in the voltage-blocking region resistance, and ultimately achieve low levels of power dissipation.

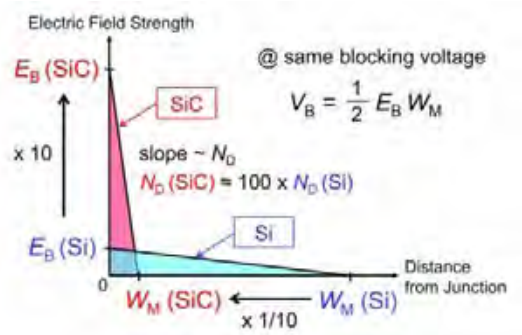


Figure 3. Electric field distributions in one-sided abrupt junction in SiC and silicon are markedly different, even though they have the same breakdown voltages. That's because: the breakdown field strength for SiC is ten times that for silicon, so the thicknesses of the voltage-blocking layers of SiC power devices can be one-tenth of that in the corresponding silicon devices; and the doping concentration in the SiC devices can be two orders of magnitude higher than that in the silicon counterparts

The tried and tested route for realising a high blocking voltage in any semiconductor device is to increase material thickness and trim doping concentration in the voltage-blocking region. Calculating the impact of these changes is easy, and helps to guide device designers that must also consider the doping-dependent breakdown electric field of the material (see Table 1).

Blocking Voltage	Silicon		SiC	
	Thickness	Doping	Thickness	Doping
1 kV	80 μm	2×10^{14} cm^{-3}	8 μm	2×10^{16} cm^{-3}
5 kV	500 μm	2×10^{13} cm^{-3}	40 μm	2×10^{15} cm^{-3}
10 kV	1100 μm	8×10^{12} cm^{-3}	90 μm	1×10^{15} cm^{-3}
20 kV	2300 μm	3×10^{12} cm^{-3}	170 μm	4×10^{14} cm^{-3}
30 kV	3500 μm	1×10^{12} cm^{-3}	250 μm	2×10^{14} cm^{-3}

Table 1. Typical thicknesses and doping concentrations required for specific blocking voltages in silicon and SiC devices. Calculations took into account the doping-dependent breakdown electric field of the materials

These back-of-the-envelope calculations also reveal why it is impossible to build a 20 kV device from silicon: the required doping concentration would have to be close to the intrinsic carrier concentration at room temperature, while the required thickness would be impractical. Fortunately, with SiC, it's an entirely different story - a 20 kV device falls easily within the limits of what is possible.

Manufacturing such a device in high volumes is not out of the question, given the rapid progress in SiC bulk growth processes that has led to the availability of single crystalline SiC wafers of reasonable quality with 100 mm and 150 mm diameters.

There have also been remarkable advances in SiC epitaxy and device processing technologies, such as ion implantation and metallization, and, on top of this, it is possible to draw on the development of devices operating at lower voltages.

Back in 1991 NASA reported the first 1 kV SiC *pin*diode, while our group announced the first SiC Schottky barrier diode operating at that voltage two years later, and since then many

more groups from all over the world have started to develop high-voltage SiC power devices (see Figure 4 for an overview of the increases in SiC blocking voltage).

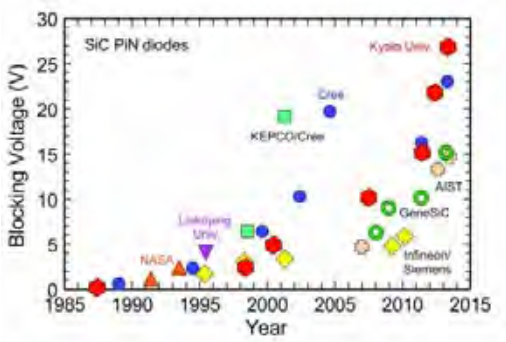


Figure 4. The last decade has witnessed a significant increase in blocking voltages of SiC pindiodes

Why bipolar?

One decision facing designers of power electronic systems and modules is whether to select a unipolar device, such as an SBD or a FET, or deploy a bipolar device, such as a *pin*diode, thyristor, or insulated-gate bipolar transistor (IGBT). The decision partly depends on the blocking voltage required.

An SBD is an attractive option at lower blocking voltages, such as 1 kV, because in this regime it exhibits very good on-state characteristics. However, when the voltage requirement increases to 20 kV, the on-resistance climbs to unacceptable levels (see Figure 5). So, at these ultra-high voltages, the SiC *pin*diode is a better choice, thanks to the long lifetime of its injected carriers. This long lifetime is due to the indirect band gap and high crystalline quality, and is a key factor for attaining the conductivity modulation effect.

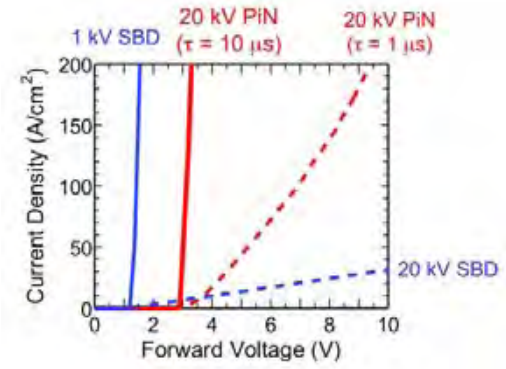


Figure 5. Forward characteristics for a 1 kV SiC SBD, a 20 kV SiC SBD, and a 20 kV SiC pindiode with two different carrier lifetimes (simulated). For 20 kV applications, a pindiode with sufficiently long carrier lifetime is the most promising

However, a long carrier lifetime is not guaranteed in a SiC device. Back in 2007 we identified a carrier-lifetime killer in this wide bandgap material − a deep level, known as a Z1/2 centre, that is located 0.62 eV below the conduction band. But by 2009 we had succeeded in eliminating this defect, an acceptor level of a single carbon vacancy, by thermal oxidation.

This thermal oxidation process leads to the formation of SiO2 on the surface of SiC. But what happens to the carbon? That's a long-standing and still-open question, but in our view most carbon atoms diffuse out as a form of CO, while a smaller number remain near the SiO2/SiC interface. Here they can even be emitted into the SiC side, where they will diffuse in the bulk region. Carbon vacancies here are filled with diffusing carbon interstitials, ensuring that the lifetime killer is eliminated from the surface right down to deep in the epilayers.

Armed with this this innovative defect-elimination technique, we realised a lifetime of over 30 ms (see Figure 6). Surface recombination is now the barrier to longer lifetimes, which should be in excess of 50 ms. But even with our current values for carrier lifetime, we can realise conductivity modulation of 20 kV devices.

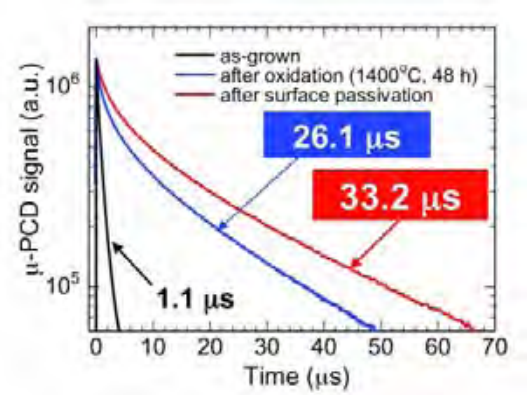


Figure 6. Eliminating defects increases the carrier lifetime in SiC. Lifetimes are revealed by microwave-detected photoconductance decay measurements, which show the improvement in a 220 mm-thick epilayer that results from the defect-elimination process

To ultra-high voltages

Fabrication of 20 kV SiC devices requires the growth of a voltage-blocking layer at least 150 mm-thick and doped to a carrier concentration of no more than low ~1014 cm−3. Such a film can be grown homoepitaxially by CVD at 1650°C on low-resistivity *n*-type SiC (0001) substrates.

Fast growth rates are very attractive for such a thick layer. In our group, we have successfully increased the SiC growth rate from 10 mm/h to beyond 50 mm/h. This has been accomplished while avoiding issues related to nitrogen donor contamination, by either reducing the growth pressure or increasing the ratio of carbon-to-silicon in the precursor gases.

These refinements enable background doping concentrations in the SiC epitaxial layers of less than 1×1013 cm−3, which is sufficiently low for the development of ultra-high voltage devices.

Fabrication of our SiC *pin*diode involved epitaxial growth of an *n*-type, very thick voltage-blocking layer, and a highly doped *p*-type emitter that acts as an anode. Diode isolation followed, using an improved bevel mesa structure with a rounded bottom.

To alleviate electric field crowding near the junction edge - which causes the device to breakdown at a much lower voltage than what should be expected from calculations based on thickness and doping concentration − we then employed an Al+

implantation process and subsequent activation annealing to create an appropriate junction termination structure (see Figure 7).

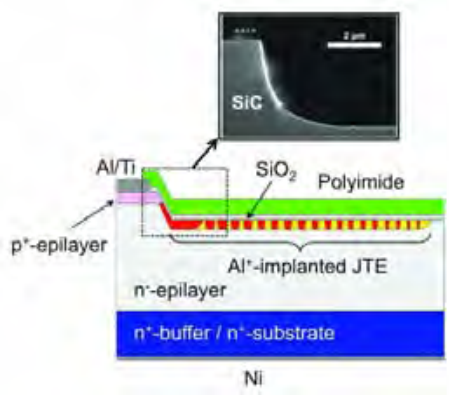


Figure 7. Fabrication of the SiC pindiode involved epitaxial growth of a very thick n-type voltage blocking layer and a highly-doped p-type emitter, followed by diode isolation that resulted from formation of an improved bevel mesa with a rounded bottom. This alleviates electric field crowding near the junction edge

After this, we added ohmic contacts for the *p*-type anode and the *n*-type cathode from Al/Ti layers and a nickel layer sintered at 1000 °C. Thermal oxidation and deposition of a 4 mm-thick polyimide film passivated the surface and prevented surface arcing. Note that fabrication also involved a thermal oxidation-based lifetime enhancement process, performed after the epitaxial growth of the*n*-type voltage-blocking layer.

Alleviating electric field crowding is one of the greatest challenges associated with forming an ultra-high-voltage SiC device. To prevent this from impacting device performance, the structure and the doping profile of the Al+-implanted junction-termination-extension (JTE) region have to be carefully designed and optimised. If the aluminium doping concentration is too low, severe electric field crowding occurs near the mesa edge; but if this doping is too high, crowding is present at the outer edge of the JTE region.

We address this issue with a 'space-modulated' JTE structure featuring multiple rings formed inside a reduced surface field-type, Al+-implanted JTE region. By modulating the widths and spacing of individual rings, the effective JTE dose gradually decreases as it progresses toward the outer edge. In turn, this minimises electric field crowding and provides a wide optimum JTE dose range. Device simulations enabled optimisation of the structure and the doping profile of the JTE region (see Figure 8).

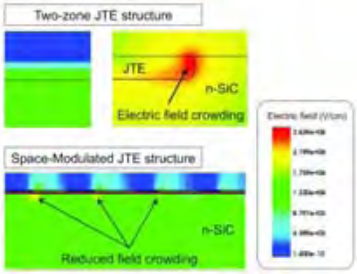


Figure 8. Device simulations enabled optimisation of the junction termination structure, which was improved by understanding the electric field strength distribution near the edge of a pindiode under high-voltage (18 kV) reverse bias. The original structure with its multiple space-modulated rings offers reduced electric field crowding near the edge

Our most recent *pin*diodes have a 260 mm-thick voltage-blocking layer. Mesa diameter and the JTE length are just 300 mm and 1050 mm, respectively – that's because the aim of producing this diode is to provide a proof of the concept and not a power device capable of handling very high currents.

Device testing involved immersion of the diode in the dielectric liquid Fluorinert, and on-wafer testing with a DC voltage sweep (see Figure 9). Determining device performance is not easy, because no suitable commercial UHV testing systems are available at present, and we had to address several technical issues related to cable connections and the probe configuration to prevent air sparking.

Figure 9. A fabricated diode during high-voltage testing

Our devices can withstand voltages up to 26.9 kV (see Figure 10), the limit of our measurement set-up, and they set a new benchmark for any solid-state device. We estimate that the real breakdown voltage is more than 30 kV, but we will only be able to prove this after improving our measurement system. On-resistance of this diode is just 19 mW cm2, compared with 430 mWÊcm2 for a SBD (no carrier injection) processed on the same wafer without a *p*-type anode. This pair of results underlines how the conductivity modulation effect can slash the resistance of a very thick, lightly-doped layer. The original carrier-lifetime enhancement technique has helped to realise a low on-resistance in our devices. Analysing the resistance components with our test-element-group characterisation tool indicates that the contact resistivity of the anode contact is approximately 4 - 5 mWÊcm2. This indicates that further improvements in on-resistance could result from increasing the acceptor concentration in the anode's top layer and optimising the process.

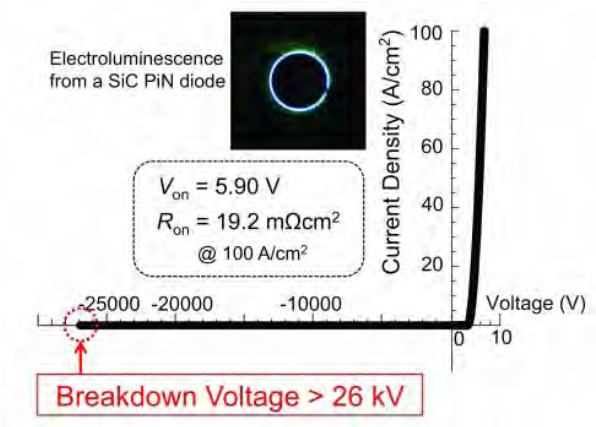


Figure 10.Current density-voltage characteristics of a mesa SiC pindiode with a space-modulated JTE structure (total JTE length of 1050 mm). The voltage-blocking layer is 260 mm-thick and doped to a density of 1×1014 cm-3. At a reverse voltage of 26.9 kV (the limit of our measurement set-up), this diode did not exhibit breakdown

One of our next goals is to eliminate basal-plane dislocations in SiC. These imperfections, which lead to carrier-recombination-induced dislocation glide that can in turn create Shockley-type stacking faults, degrade device performance: on-resistance and leakage current both increase. In our latest devices, the device area is typically just 2 - 3 mm in diameter, including the termination region.

But if this class of device is to be considered for electric power infrastructure, its area will need to increase to more than 1 cm2, so that it can handle currents far greater than 100 A. The density of basal-plane dislocations in our latest SiC epitaxial layers is in the 0.1 - 3 cm-2 range, and this must be plummet to below 0.01 cm-2 to enable high-yield production of devices with high current-handling capabilities.

Another target is the development of 20 kV-class power-switching devices, such as thyristors, IGBTs, and bipolar junction transistors (BJTs). We have started with a preliminary study on UHV BJTs, demonstrating a 21 kV BJT with a current gain of 63. Now we will try to improve the performance of these devices, while undertaking trials to fabricate other types of UHV power switching device.

The author would like to acknowledge J. Suda, H. Miyake, H. Niwa, T. Okuda, N. Kaji, and S. Ichikawa from Kyoto University for their contributions to this study.

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IQE revenues up 44 percent thanks to wireless

The robust wireless business and diversification strategy drives strong rises in revenues, profit and earnings

IQE has announced its final results for the year ended 31st December 2013.

The firm achieved a new Group record of £126.8 million, up from £88.0 million in 2012.

This includes £30.9 million revenues from Kopin Wireless, acquired in January 2013. However, the company was affected by adverse H2 currency impact as sterling appreciated 3 percent against the US dollar.

H2 wireless sales were up 3 percent over H1 in constant currency and H2 photonic sales were up 12 percent over H1 (in constant currency). The adjusted PBT was up 51 percent to £13.0 million from £8.6 million (Reported PBT £5.2 million).

The adjusted fully diluted EPS increased 43 percent to 2.00p from 1.40p (Reported fully diluted EPS 0.89p). Cash inflow from operations before exceptional items was up 346 percent from £4.7 million to £16.2 million.

Cash conversion before exceptional items was 111 percent up from 51 percent. Net debt was £34.4 million (opening net debt £15.5 million increased primarily due to £25 million of debt to part fund the Kopin acquisition.

Drew Nelson, IQE Chief Executive, made the following statement:

“IQE’s core wireless division has again delivered a robust performance, with continued growth despite a significant downstream inventory correction in the major chip companies due to softness in the high end smartphone market. As a direct result of our customer risk mitigation strategy, which we have executed over the last 18 months and completed with the acquisition of Kopin Wireless, we are much less sensitive to market share shifts between the major chip supply companies.

“Concerns in the UK over the last year that silicon CMOS would significantly damage the Compound Semiconductor industry have proved unfounded and are not reflected in our financial performance nor in our customers’ expectation of future long term demand drivers.

“Wireless remains an attractive market for us over the coming years with demand continuing to be driven by the proliferation of wireless applications and the need for sophisticated GaAs chips to deal with the explosive growth in data traffic. Beyond this, the next waves of innovation which will drive handset replacement cycles are likely to include lasers and sensors using compound semiconductor technology, for gaming, 3D image capture, gesture recognition, and sensing for a variety of applications including healthcare monitoring devices.

“Our business diversification strategy also gained strong traction, and we achieved a number of significant technical and commercial milestones during 2013 which reflect the

strong progress made in our other key markets including photonic sensors and lasers, advanced solar (CPV), power semiconductors, infrared, LED and advanced electronics.

“Our integration remains firmly on track, and we expect to realise significant reductions in our financial overheads, whilst benefiting greatly from the operational and technical synergies we are delivering.

“IQE is at the forefront of the enabling technologies that are at the very heart of many of the twenty-first century trends and products. We are confident that the Group is well positioned for continued growth in earnings and cash flow in 2014 and beyond.”

Compound Semiconductor conference hits a new high

35 presentations equipped delegates with a comprehensive overview of the compound semiconductor industry

Around 300 delegates and over 30 sponsors descended on Frankfurt for the fourth CS International Conference, which was held at the Sheraton Airport Hotel this week.

This must-attend event for the leaders of the compound semiconductor industry set a new standard for its number of presentations.

The conference covered all aspects of the industry, with presentations grouped into six key themes:

Power Electronics
LEDs
Integration of CMOS and III-Vs
Wide Bandgap RF Devices
Front-ends for Mobile Devices
Lasers, PICs & PV

Presentations on these topics highlighted the growing penetration of compound semiconductors into the silicon industry, and the use of silicon in the making of III-V chips. Leading developers of next-generation CMOS, such as IBM and Imec, are pioneering approaches to integrate high-mobility materials, for example InGaAs, into the channels of transistors in microprocessors, while silicon substrates are viewed as a low-cost platform for making LEDs, as well also power and RF electronics based on GaN.

Meanwhile, power amplifiers that are based on silicon are starting to go head-to-head with those made from GaAs for deployment in the latest smartphones. It appears that devices based on CMOS will gain market share, but GaAs will dominate the market for many years to come.

A more detailed report of the presentations at CS International Conference will appear in the April /May edition of *Compound Semiconductor* magazine. This issue will also contain details of the winners of the coveted CS Industry Awards.

For more information about CS International Conference, and opportunities available for the 2015 event, contact Stephen Whitehurst: stephen.whitehurst@angelbc.com Tel 0044 (0)2476 718 970. www.cs-international.net

Silicon carbide goes quantum

Carbon anti-site vacancy pairs in SiC are sufficiently bright to allow detection at the single-photon level enabling the generation of single photons at a high repetition rate, This makes them potentially useful qubits for quantum information processing and applications in photonics

Silicon carbide is a semiconductor that is now widely used in a variety of micro-electromechanical systems (MEMS), LEDs and high-power electronics.

Its technological appeal stems from the fact that it is amenable to mature, robust nanofabrication methodologies and possesses both a high Young’s modulus and excellent thermal conductivity.

To many, silicon carbide (SiC) is a material that offers few surprises. Nevertheless, the increasing need for novel materials for implementing quantum technologies and nanophotonic integrated circuits is forcing scientists to revisit several traditional materials - SiC is one of them.

The crucial step in manipulating a material in the quantum regime is the ability to modify and probe individual quantum states, which can be employed as qubits.

Until recently, only diamond has offered a solid-state platform for optically stable, room-temperature single quantum emitters.

The game has changed now, say scientists Stefania Castelletto and Hannes Kraus and their colleagues. who have isolated single emitters and identified microwave spin qubits in SiC.

The results were reported in the journal *Nature Materials*. The researchers, including those at the University of Sydney, identified individual defects, known as carbon anti-site vacancy pairs, in SiC that are sufficiently bright to allow detection at the single-photon level.

These emitters can generate single photons at a high repetition rate, which makes them potentially useful qubits for quantum information processing and applications in photonics. The defects have the practical benefit that they are optically active

at room temperature.

Another notable advantage is their natural abundance in the host matrix. Consequently, there is no need for external ion implantation, as in the case of diamond, or for the epitaxial growth typical of III-V semiconductors.

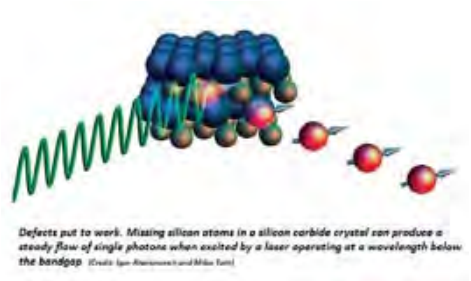
Electron irradiation and annealing provide the material restructuring needed to optically activate the defects. It is thought that the defects are clusters comprising carbon atoms that reside in silicon sites adjacent to carbon vacancies.

In a parallel report in *Nature Physics*, Kraus and his colleagues describe optically induced population inversion of the spin states of another type of single defect in SiC - a silicon vacancy. This result could pave the way to SiC solid-state masers and extremely sensitive travelling-microwave amplifiers.

What's more, by exploiting the double radio optical resonance technique, the team proved that the silicon vacancy has a spin-3/2 ground state - a topic that has been under debate for many years. They are therefore able to detect an optical magnetic-resonance signature from a silicon-vacancy defect at room temperature.

The ability to focus exclusively on a known defect at room temperature in a forest of paramagnetic centres is crucial for practical and scalable engineering of sensors and solid-state devices for quantum information processing.

Missing silicon atoms in a SiC crystal can produce a steady flow of single photons when excited by a laser operating at a wavelength below the bandgap. This is shown in the figure below.



Defects put to work. Missing silicon atoms in a silicon carbide crystal can produce a steady flow of single photons when excited by a laser operating at a wavelength below the bandgap.

So, despite many years of intense research on SiC and its spectroscopic characterisation, why have single-photon emission and unambiguous identification of paramagnetic defects not been previously observed?

The answer to this question is rather simple. In traditional semiconductor physics, most spectroscopy is performed using above-bandgap laser excitation that predominantly excites near-gap emissions.

However, this approach cannot address deep-level states. Instead, individual defect states that reside within the forbidden energy gap must be optically accessed using sub-bandgap excitation. This is a critical issue for wide-bandgap semiconductors.

Indeed, this is the case for the infamous negatively charged nitrogen-vacancy centre in diamond, which is visible on green excitation but inaccessible by ultraviolet excitation.

SiC, not surprisingly, shows similar behaviour. Red and infrared excitation, as was used by Castelletto, Kraus and their colleagues, is not sufficiently energetic to promote electrons into the conduction band, but provides an excellent way to identify new quantum systems at room temperature.

Both works highlight the urgent need to revisit other wide-bandgap materials, including zinc oxide and AlN. Hopefully, it will not be long before more robust room-temperature quantum systems are unveiled.

The pivotal observation of single-photon sources and stimulated microwave emission from SiC complements the recent discovery of novel fluorescent SiC nanostructures (tetrapods) and ushers in a new era for this technologically important material.

Integration of single defects into nanomechanical systems will hopefully pave the way to the burgeoning field of optomechanics and enable unprecedented applications in sensing, quantum information processing and magnetometry.

At last, we may have a convincing candidate for scalable quantum devices at our fingertips.

Transphorm transforms its GaN-on-silicon power portfolio

The new devices include PQFN-packaging and smaller die sizes targeting smaller, low-power applications

Transphorm has announced what it says is the industry's first 600V GaN-based low-profile PQFN products and the expansion of its product portfolio in the industry-standard TO220 packages.

This follows the introduction of its GaN-on-silicon transistor family at the APEC 2013 trade show JEDEC-qualified 600V GaN device platform.

Transphorm's 600V GaN HEMTs (high electron mobility transistors) utilise the company's patented, EZ-GaN technology that combines low switching and conduction losses, reducing the overall system energy dissipation up to 50 percent compared with using conventional silicon-based power conversion designs.

The new PQFN products, feature 290 mΩ RDSON 29 nC Qrr and low inductance for high-frequency switching capability. The PQFN88-packaged LD devices also feature a Kelvin connection to better isolate the gate circuit from the high-current output circuit to further reduce EMI.

In addition, the TPH3002PD and TPH3002PS GaN HEMTs have been released for use in smaller, lower power applications such as adapters and all-in-one computer power supplies. These devices also feature 290 mΩ RDSON 29 nC Qrr and high- frequency switching capability.

The devices were introduced at APEC 2014.

“Every year since 2011 we have announced new advancements of our GaN technology at this major tradeshow - and this year is no exception,” says Primit Parikh, President of Transphorm.

“Now by introducing the industry’s first qualified 600V GaN PQFN-packaged products, we have increased the types of applications where GaN can enable dramatically more efficient, compact and low-cost solutions.This dispels the widespread misconception that GaN isn’t ready for prime-time.Once again we’ve shown GaN products are available today and are actually being used in a multitude of real-world applications.”

The TO220-packaged TPH3002PD and TPH3002PS and the PQFN-packaged TPH3002LD and TPH3002LS are available for sale to qualified customers worldwide, directly or through Transphorm’s distribution channels.

The evaluation boards are also available with the 600V TO220 GaN HEMT devices in configurations for LLC DC-DC converter, totem-pole PFC and all-in-one power supply.

IQE initiative to boost regional supply chains

The new programme is aimed at establishing partnerships to support the development of a broad range of key enabling technologies

IQE plc, a supplier of semiconductor wafer products and services, has launched its Open Innovation programme “openiqe”.

The first major project under the new programme is the IQE Open Technology Challenge, which will be marked by a launch event at the SWALEC Stadium in Cardiff on Friday 21st March 2014.

The aim of the challenge is to engage with small and medium enterprises, larger businesses and academic institutes, initially focusing primarily on the Welsh region, to develop new and enhance existing supply chains.

The project will focus on technology areas termed the Three Grand Challenges identified in the Science for Wales strategy and other major International programs, including the EU Horizon2020 Program. The three areas are life sciences and health; low carbon, energy and environment; and advanced engineering and materials.

Technology will play an increasingly important role in addressing a range of societal challenges. IQE’s Open Technology Challenge is aimed at establishing partnerships along an end-to-end supply chain to develop and commercialise products that will meet real needs within the areas defined by the Three Grand Challenges.

Drew Nelson, IQE President and CEO, comments, “IQE has more than twenty-five years’ experience of working closely with partners and customers worldwide to meet demanding technical specifications. We are delighted to be contributing our experience of collaborative innovation in the form of our new Open Innovation programme.”

“We are confident that the Open Technology Challenge has the potential to become a key stepping stone towards the establishment of a major technology cluster in the region, as well as building stronger links to the global technology community.”

IQE’s Open Innovation programme is being supported by the Welsh Government.

Cree releases power SiC Schottky diodes

The firm says its CPW5 Z-Rec diodes extend benefits of silicon carbide into Megawatt power systems market, improving efficiency and reducing costs

Cree has launched its new CPW5 Z-Rec high-power SiC Schottky diodes.

The firm says this is the industry’s first commercially available family of 50 Amp SiC rectifiers.

Designed to deliver the cost reduction, high efficiency, system simplicity and improved reliability of SiC technology to high power systems these diodes have been designed to address demanding applications.

These include solar / PV inverters, industrial power supplies,

induction heating, battery charging stations, wind turbine converters and traction inverters and work from 50kW to over 1MW;

Developed to facilitate the direct matching of 50 Amp diodes to 50 Amp MOSFETs or IGBTs, Cree(R) CPW5 Schottky diodes reduce system complexity and cost by enabling the replacement of multiple low-voltage, low-current SiC Schottky diodes, or silicon PiN diodes, with a single CPW5 rectifier.

Additional cost savings can be achieved through reduced maximum voltage ratings and the elimination of snubber circuitry due to the diminished voltage overshoot during switching in SiC.

“Cree’s CPW5 family of SiC Schottky diodes are a critical component in our high performance power modules and power electronic systems,” says Ty McNutt, director of business development, APEI, Inc. “The low forward voltage drop, fast switching speed and extended temperature capability allow us to push power density and efficiency across many applications, such as high power motor drives and solar inverters.”

Cree CPW5 diodes enable a new generation of high-current Si/SiC IGBT modules. Hybrid Si/SiC IGBT modules can deliver up to a 43 percent reduction in switching losses over conventional modules, while also reducing voltage- and current-overshoot, switching dead time and cooling requirements.

As an added benefit, design engineers can use the same gate driver design and circuits used with conventional modules, allowing easy and immediate implementation. Cree CPW5 diodes also provide a peak forward surge resistance greater than 500 Amps repetitive and 2000 Amps non-repetitive, delivering increased reliability under the harshest electrical conditions.

“As the sole distributor of Cree SiC-based power products in wafer and die form, SemiDice is excited to offer the CPW5 family of Z-Rec Schottky diodes,” says Dan Cormack, CEO of SemiDice, Inc. “We are seeing increased customer demand for 50 Amp Schottky diodes and we know that as a global leader in the manufacture of advanced SiC diodes, Cree will deliver the quality and performance that our customers expect to help them minimise system cost and size.”

The CPW5 family of Z-Rec Schottky diodes includes 1700V/50A, 1200V/50A, 650V/50A and 650V/30A combinations.

The CPW5 diodes are available immediately in bare die form from SemiDice.

Equipment and Materials

QuantumClean achieves single ISO 9001:2008 certification

In the past, the firm’s facilities were either individually ISO 9001 certified, or certified in groups of facilities under different registrars

QuantumClean, has announced that all of its global Advanced Technology Cleaning Centres are now certified under a single ISO 9001:2008 certificate.

The firm is a provider of high-purity outsourced process tool parts cleaning, surface treatment, refurbishment, analytical and engineering services to the semiconductor, solar and LED industries.

Previously, QuantumClean’s facilities were either individually ISO 9001 certified, or certified in groups of facilities under different registrars.

“This achievement is another significant step forward in our global integration plan, ensuring that customers receive the same high quality service across our vast network of Advanced Technology Cleaning Centres,” says Tim Burrows, QuantumClean’s Director of Global Quality.

Burrows goes on to say, “QuantumClean’s Quality Policy states that the Company is dedicated to consistently delivering The Perfect Order to its customers through the application of rigid standard operating procedures, well-trained technicians, quantitative metrics and analytical methods, and continual improvement practices. Achieving global ISO 9001:2008 certification under one certificate is an important accomplishment to delivering the highest standard of services to our customers, i.e. The Perfect Order.”

QuantumClean joins EICC`s tantalum programme

The company says it is the first and only semiconductor industry outsourced process tool parts cleaner to participate in the programme

QuantumClean has announced its inclusion in the Electronic Industry Citizenship Coalition's (EICC) Conflict-Free Smelter (CFS) programme for tantalum.

QuantumClean is a global provider of high-purity outsourced process tool parts for cleaning, surface treatment and refurbishment. The firm provides analytical and engineering services to the semiconductor, solar and LED industries,

The EICC, in partnership with the Global e-Sustainability Initiative (GeSI) launched "The Conflict-Free Sourcing Initiative" in 2010. This was to meet the need for downstream companies to demonstrate with reasonable certainty the origin and validate smelter procurement processes for four "conflict minerals". These materials include tantalum which is used by many semiconductor wafer fabs. In servicing these fabs, QuantumClean strips and recycles tantalum from many semiconductor process tool chamber parts.

"QuantumClean is committed to do its part in the elimination of unlawful and immoral activities, including unthinkable work conditions surrounding the trade and use of minerals mined in conflict-afflicted areas of the world and used in the semiconductor industry, which is why we elected to participate in the EICC's Conflict-Free Smelter Program for Tantalum," says David Zuck, Vice President and COO of Quantum Global Technologies.

To achieve inclusion in the CFS program, QuantumClean demonstrated tantalum supply chain integrity and traceability at both its Fremont California and Hillsboro Oregon Advanced Technology Cleaning Centres through rigorous 3rd party audits.

QuantumClean says it is the first and only semiconductor industry outsourced process tool parts cleaner to participate in the CFS program.

"When we founded QuantumClean many years ago, we wrote six essential, governing policy statements, including an Environmental and Social Responsibility policy. Our inclusion in EICC's Conflict-Free Sourcing program is the latest affirmation of management's commitment to this policy," concludes Zuck.

IQE bags $1 million order for Infrared InSb substrates

The wafers will be used for advanced mid-wave infrared imaging technology.

IQE plc has received its first $1 million purchase order agreement for InSb substrates.

IQE's Infrared's US substrate division, Galaxy Compound Semiconductor Inc., has been contracted to deliver volume quantities of InSb substrates to an industry leader and long term customer of the group. This represents the firm's largest order to date for this new range of Infrared substrates.

InSb is suited for mid-wavelength infrared (MWIR) imaging technology. Cameras fabricated from InSb are used in a wide variety of advanced imaging applications (defence, security, medical and industrial).

IQE says it is the exclusive supplier of all InSb to industry, with IQE's US (Galaxy) and UK (Wafer Technology) operations collectively meeting the requirements of its customers to provide a secure, dual source supply of InSb substrates.

Drew Nelson, CEO of IQE plc, comments, "We are very pleased to receive this order from a long term customer of our InSb substrate product range. The scale of this commitment reflects our success in being able to offer a volume manufacturing capability for InSb materials."

He continues, "The investments that we have made to enhance our crystal growth, wafering and substrate polishing capabilities at both Galaxy and Wafer Technology will enable us to fully meet the InSb product demands of our customers, both in terms of volume and quality, across a full 2" to 6" product range.

Obducat reveals mass production tool for LEDs and Optics

The second generation SINDRE system enables throughputs of up to sixty wafers per hour. It has been delivered and passed customer final approval in January

Obducat, a manufacturer of lithography solutions based on nanoimprint lithography (NIL), has launched its 2nd generation SINDRE.

With the improved performance it will represent a cost effective NIL production solution on the market. The system is based on Obducat's patented SoftPress, IPS and STU technologies.

SINDRE 400 G2

The fully automated SINDRE system enables throughputs of up to sixty wafers per hour.

The new SINDRE integrates the latest advances in manufacturing technology which enables high throughput, high repeatability at a defectivity level which surpass industry requirements.

The first system has already been delivered and passed customer final approval in January this year and the next system will be delivered in third quarter this year.

The new SINDRE platform is a fully integrated NIL system which includes integrated fabrication of the Intermediate Polymer Stamp (IPS). This is a proven and reliable process which was also integrated in previous generation of SINDRE systems delivered by Obducat during the last five years.

Obducat's patented IPS technology covers the use of a transparent flexible stamp in any kind of imprint process. The use of the IPS technology ensures a long life time of the stampers which minimise the stamp related costs per imprint.

The patented SoftPress technology, applied in the system, ensures the necessary level of conformity between the stamp and substrate vital for establishing high imprint uniformity. This enables a large process window for downstream processes leading to a high yield and low Cost of Ownership. All this has been integrated into a very compact system having a small footprint.

The new SINDRE system also offers a wide flexibility which includes the possibility to use different resists and IPS materials to support customisation of the imprint process. In addition the system can run both UV as well as thermal based NIL processes, giving the capability to imprint structure sizes ranging from 20nm and upwards, on substrate sizes up to 200 mm in diameter.

"The versatility and superior performance of our patented key technologies has been extended further to safeguard Obducat's continued technological leadership in the NIL industry," says Babak Heidari, CTO of Obducat.

Example of components which are ideally produced with this system are optical, photonic, LEDs, fluidic and other biomedical components.

"Obducat again confirms its leading position with this launch. With more than 130 NIL systems delivered during the last decade and several of these being used for manufacturing purposes in LEDs, photonics and biomedical applications, we are breaking new barriers in terms of performance and cost efficiency" says Patrik Lundström, CEO of Obducat.

Lake Shore launches 7-inch magnet Hall measurement system

The new AC/DC version of the system can characterise III-V materials with a mobiility range from 1 to 0.001 V

The new Model 8407 Hall effect measurement system from Lake Shore Cryotronics features a 7-inch magnet for measuring mobilities at the low end of the DC field measurement range, from 1 to 106 cm2/V s.

The Hall effect is the production of a voltage difference across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current.

When a current-carrying semiconductor is kept in a magnetic field, the charge carriers of the semiconductor experience a force in a direction perpendicular to both the magnetic field and the current. At equilibrium, a voltage appears at the semiconductor edges.

Like Lake Shore's existing Model 8404 with 4-inch magnet, the 8407 system can be ordered with AC field measurement capabilities. With AC field measurement added, the system is capable of measuring materials with extremely low mobilities (down to 10-3/ V s).

Model 8407 Hall measurement system

These can include photovoltaic (solar cell), thermoelectric and organic electronic materials, which have electronic properties that can be difficult to measure with DC field Hall methods.

Software included with the system enables both van der Pauw and Hall bar measurements. It is capable of measuring samples with gated Hall bars to account for gate bias, setting up loops with varying temperatures and gate voltages, performing time loops of measurements for longer unattended operation, and more.

Lake Shore develops characterisation tool for THz materials

The new system would be suited to researchers studying emerging materials for high-speed computing, spin-based computing and thin-film III-V semiconductor applications

Lake Shore's new 8500 Series THz system is a fully integrated hardware/software platform for the characterisation of electronic, magnetic and chemical materials.

8500 Series THz System for Materials Characterisation

Many tetrahertz (THz) materials are based on III-V materials and incorporate GaAs.

The system uses non-contact THz-frequency energy and an integrated low-temperature, high-field cryostat to measure material spectroscopic responses across a wide range of frequencies, temperatures and field strengths.

As the first affordable, integrated solution specifically tailored for characterisation of research-scale electronic and magnetic materials, the system should be of interest to researchers studying emerging materials for high-speed computing, organic electronic, spin-based computing and thin-film semiconductor applications.

The system performs continuous wave spectroscopic response measurements to derive key material properties such as dielectric constant, dynamic conductivity, carrier scattering times and mobilities, vibrational resonances, and magnetic resonances.

O-ring manufacturing facility to support global growth

Building of a 30,000 square foot facility has started and it should be up and running by October

Precision Polymer Engineering (PPE), a manufacturer of advanced elastomer O-rings and components, will open a new manufacturing site in Brenham, Texas later this year.

O-rings are used extensively in III-V MOCVD growth reactors and characterisation equipment.

The ceremony, held on Wednesday, April 2nd, initiated the build of a 30,000 square foot facility which will be up and running by October. The new factory will specialise in the manufacture of custom O-rings and other critical elastomer sealing components to high quality standards and short delivery times.

The capabilities will include clean room facilities which will enable the manufacture to the exacting standards needed for semiconductor applications. The factory will also have its own tool making, extrusion and inspection facilities.

PPPE's materials, including their Endura brand, are suited for use in high temperature and high pressure applications. For other critical applications such as in the semiconductor industry, PPE's Perlast range has the chemical and plasma resistance needed to assure the required performance and process cleanliness.

Paul Gillyon, managing director of PPE comments, "At PPE we strive to develop the most advanced materials for the most difficult applications. But on top of that, we operate our manufacturing so that we can be extraordinarily responsive to customers' needs. We believe we have the fastest lead times and our customers tell us that our on-time delivery record is outstanding. We will reproduce all of these attributes in our Texas operation. We know that's what our oil & gas customers need when the pressure is on their projects and we are 100 percent confident we can provide the necessary support to contribute to their success."

SemiTEq sells second R&D MBE tool to University of Toronto

SemiTEq JSC, a Russian manufacturer of MBE systems, has sold a STE75 research MBE system to the Centre for Advanced Nanotechnology University of Toronto, Canada.

STE75 MBE system

SemiTEq is actively expanding into foreign markets and, in particular, it's the second contract for MBE System supply to the Centre for Nanotechnology at the University of Toronto.

The new STE75 is intended as a compact, versatile and power tool for wide range of R&D in the field of modern semiconductor applications based on III-V, II-VI and III-nitrides. The system is claimed to be one of the most compact in the world in the R&D machines class. The compact "footprint" flexible design and all necessary tools for *in-situ* monitoring of growth process data in basic configuration make the STE75 system suitable for research centres and universities.

STE75 MBE system in use

Trifortune buys Aixtron tool for GaN LED growth

The 56 x 2 inch reactor will be used to grow gallium nitride on alternative substrates

Jiangsu Trifortune Electronic Technology, China, has ordered an AIX G5 HT system to develop GaN based high brightness LEDs.

The Aixtron system will be equipped to handle 56 x 2 inch wafers per run and will be installed at Trifortune's R&D centre.

AIX G5 HT reactor

The developed process will be transferred to mass production in the Jiangsu area upon successful completion of the research.

Hu, Technical Head of Trifortune, comments, "We are developing GaN processes to grow LEDs on substrates that offer some advantages compared to the well-established sapphire substrates. To compete in the HB-LED market, there is a real need to achieve the maximum yield in our manufacturing process, so that products with better performance in lumen per dollar can be established."

Hu adds, "The AIX G5 HT system is widely acknowledged as having the top yields in LED mass production, along with excellently repeatable performance at high growth rates."

Andreas Toennis, Aixtron Chief Technology Officer, continues, "We are very pleased to contribute to Trifortune's success and to share our comprehensive expertise in optimisation of epitaxy yields with them."

Trifortune Electronic Technology Co. Ltd, headquartered in Jintan City, China, was founded in May 2013. In phase one of its strategic business plan the company made an initial investment into a preproduction demo line located at Shahe, Beijing.

GaN discrete, IC and substrate market to soar to over $15 billion

The gallium nitride market will be dominated by power devices and draw most of its revenue from the communication infrastructure sector
MarketsandMarkets estimates that the GaN discrete, IC and substrate market will be worth $15607.85 million by 2022.

This is stated in the "Gallium Nitride (GaN) Semiconductor Devices and Substrate Wafer Market research report," which analyses the global market by market dynamics & trends. Key

players are Fujitsu Limited, Toshiba Corporation, Koninklijke Philips N.V., Texas Instruments, Mitsubishi Chemical Corporation and Aixtron SE among others. The specific sub sector where GaN-based semiconductors and wafers have an edge over normal silicon-based counterparts are in Power Semiconductors & Electronics and in terms of end-user application sectors.

The two major upcoming sectors facilitating the huge demand for GaN semiconductor devices are the Industrial & Power sector and Communication Infrastructure sector. The Communication Infrastructure sector has found use for GaN power discretes, particularly for transistors in power amplification, rectification, and high-frequency switching. Gallium nitride, along with SiC devices have turned out to be the choice for most power semiconductor applications and are quickly replacing the existing silicon technology. GaN has a wider band gap, high break-down voltage, larger critical electric field, and higher thermal conductivity than silicon. This enables GaN devices to operate at higher voltages and high switching frequencies and handle higher power density. They also offer enhanced power efficiency compared to pure silicon devices. These properties allow GaN discretes such as Schottky diodes, FETs, HEMTs and other advanced transistors to operate efficiently at much higher voltage levels, exceeding the limits of their silicon counterparts.

GaN power semiconductors also help in reducing the conduction and switching losses, thereby offering higher efficiency in electronic systems. Currently, the major application segments of GaN power semiconductors are inverters and converters, RF devices, power supply modules and motor drives which are being used across all the end user sectors. The market of GaN power semiconductor devices is primarily growing due to penetration into the medium-voltage power electronics market and applications across all the major end-user verticals. It is obvious that most of the market revenue comes from the rising number of advanced power applications of industrial, power, solar and wind sector and the sector's developing globally. Gallium nitride power devices draw most of their revenue from the Communication Infrastructure sector.

They have been solely focusing on replacing their silicon counterparts in various RF power devices, particularly in RF communication applications over the past few years. GaN devices are smaller, lighter but tougher and efficient compared to silicon semiconductor devices and serve as ideal replacements for silicon devices which have hit maturity. GaN devices and wafers also feature low sensitivity to ionising radiation, better stability in some radiation environments, They also have a future in solar cell arrays, satellites and high-end power appliances in the Military, Defence & Aerospace sector. These devices also have huge revenue potential in the automotive and transportation sector, mainly in the electric vehicles & hybrid electric vehicles segment of the automotive sector. GaN power semiconductors possess the potential to operate at higher temperatures, higher power levels and voltages, high frequencies (microwave ranges). The number of applications is increasing day by day in various industries that include telecommunication, consumer electronics, automotive, industrial, power and clean-tech applications.

The GaN market's total competitive landscape had only a handful of players at the beginning of the previous decade, but it quickly emerged into a significant network of key players for both power and opto-semiconductors. Currently, the overall GaN power semiconductors market accounts for less than 1 percent of the total power semiconductors market (currently at $34 billion including power discrete and power ICs), but over the next ten years, the entire base for power semiconductors & electronics players is expected to penetrate into this new value chain, thereby rapidly increasing the percentage share. Today's world includes numerous suitable power applications for GaN in several application segments, such as power distribution systems, industrial systems, heavy electrical systems, turbines, heavy machinery, advanced industrial control systems, electro-mechanical computing systems, and so on. They also include several new power applications (clean-tech) such as High-Voltage Direct Current (HVDC), Smart Grid Power Systems, Wind Turbines, Wind Power Systems, Solar Power Systems, Electric & Hybrid Electric Vehicles. Another application sector is ICT, with several communication application segments such as RF, RADAR, and Satellite communication offering huge revenue potentials owing to the unbeatable ability of GaN to operate at high-frequency ranges, including microwave frequencies. The potential market size of these massive applications is currently in trillions, making the total addressable market for the GaN power semiconductors worth billions.

Oerlikon unleashes new vacuum technology for R&D analysis

The firm has released new pumps for ultra-high vacuum applications and for installation in compact pump-system solutions and processes with small backing pumps

With the official launch of its TURBOVAC i product line, Oerlikon Leybold Vacuum is strengthening its market position in the area of turbomolecular vacuum pumps for analytical instruments and for research-and-development applications.

The new pumps were showcased at last week's Analytica, the international trade fair for laboratory technology, analytics and biotechnology in Munich. The pumping speed is claimed to be 60 percent higher than that of comparable products as well as a compression ratio that is a hundred times higher than the previous generation.

"With the new TURBOVAC family, we offer the leading product for analytics and research applications as well as for other industrial applications and intend to systematically expand our market position," says Segment CEO, Martin Füllenbach.

The firm says its new TURBOVAC pumps series, differentiates from competitive products with exceptional versatility and low maintenance needs. The TURBOVAC 350 i and 450 i models, for instance, which are specifically designed for ultra-high vacuum applications and for installation in compact pump-system solutions, are suitable for processes with small backing pumps.

TURBOVAC T i/iX pump

This reduces procurement and operating costs. By contrast, the TURBOVAC T 350 i and T 450 i models are designed for process applications and high gas throughput. They offer exceptionally fast run-up times and insensitivity to particulates. Both model variations provide a range of options for the most diverse special requirements.

TURBOVAC i pumps are extremely easy to maintain thanks in part to their maintenance- and oil-free hybrid bearings. In addition to being extremely reliable and durable, they also produce minimal vibration and noise during operation.

If needed, their ceramic ball bearing can be replaced on site. A purge port that protects the bearings from critical gases and particles also increases the pumps' lifespan and uptime. Installation and maintenance are simplified with intelligent design solutions and integrated drive electronics. A versatile interface with all standard ports allows for data communication.

"Successful test runs with various customers demonstrate that TURBOVAC i pumps can make full use of the advantages they offer in the field. The models are the highest-performing, most versatile and lowest-maintenance pumps on the market," says Segment CEO Füllenbach.

5N Plus expands semiconductor substrate business

The company has completed its acquisition of Sylarus and changed its name to '5N Plus Semiconductors'

5N Plus Inc., a producer of specialty metal and chemical products, has acquired the remaining 33.33 percent ownership interest in its subsidiary Sylarus Technologies, LLC, located in St. George, Utah.

The firm has now changed its name to 5N Plus Semiconductors LLC and says it is the sole U.S. domestic space□qualified germanium substrate supplier to National Security Space (NSS) customers. It is one of only two National Defence Stockpile (NDS) qualified germanium substrate suppliers worldwide.

Since its inception, 5N Plus Semiconductors has been awarded over US $10 million in contracts from the U.S. Government including a US $1.32 million contract by the Defence Logistics Agency (DLA) to upgrade a portion of the NDS high purity germanium metal inventory to unfinished germanium substrates for multifunction photovoltaic solar cells employed in NSS applications.

The DLA award was strategic in nature as 5N Plus Semiconductors LLC is now part of the U.S. NDS for strategic materials, with the potential for follow□on business both as a strategic metal supplier and NDS inventory manager.

Jacques L'Ecuyer, President and Chief Executive Officer, says, "We are pleased to have acquired the outstanding interest in Sylarus. Through this platform that we have renamed 5N Plus Semiconductors, we intend to grow our semiconductor substrate business."

Uvotech unveils new UV-Ozone cleaning tool

The firm has developed a fast method of obtaining ultra-clean surfaces free of organic contaminants on most substrates including gallium arsenide and silicon

Uvotech Systems, a manufacturer and distributor of surface treatment equipment, is releasing a new UV-Ozone Cleaning System Model called HELIOS-500.

This is the first product in the HELIOS series of UV-Ozone Cleaners by Uvotech.

HELIOS-500

The HELIOS-500 system is designed to be very compact, lightweight and economical. It includes an ultraviolet grid lamp for increased uniformity as well as a digital process timer which

allows more accurate control over the process time.

The drawer loading sample stage can accommodate up to 5" x 5" substrates. Included pedestals allow for adjusting the distance between the UV source and substrate. This system also comes with a built-in hour-counter which will record the total hours of the UV lamp usage for maintenance purposes.

The UV Ozone Cleaning process is a photo-sensitised oxidation process in which the contaminant molecules of photo resists, resins, human skin oil, cleaning solvent residues, silicone oils, and flux are excited and/or dissociated by the absorption of short wavelength UV radiation.

Atomic oxygen is simultaneously generated when molecular oxygen is dissociated by 185nm and ozone by 254nm ultraviolet wavelengths. The 254nm UV radiation is absorbed by most hydrocarbons and also by ozone.

The products of this excitation of contaminant molecules react with atomic oxygen to form simpler, volatile molecules, which desorbs from the surface. Therefore, when both UV wavelengths are present atomic oxygen is continuously generated, and ozone is continually formed and destroyed.

Using a UV-Ozone Cleaner, Uvotech says near atomically clean surfaces can be achieved in minutes without any damage to devices. This fast method of obtaining ultra-clean surfaces free of organic contaminants on most substrates, including GaAs and silicon, can easily be achieved by utilising a UV-Ozone Cleaner in just a few minutes.

Uvotech Systems, Inc., headquartered in Concord, California is a manufacturer and distributor of surface treatment equipment for the Semiconductor, Electronics, Medical, and Photovoltaic industries. Current products include UV-Ozone Cleaning Systems, Plasma Cleaners, RIE and ICP Etching Systems, UV Curing Machines and Molecular Printers used mainly in the manufacturing of Biosensors.

Edwards to open new US service centre to boost growth

The new Ohio centre will support remanufacturing and repair methodology. It will also expand the firm's product repair capability

Edwards Limited, a manufacturer of sophisticated vacuum products and abatement systems, is to open its new vacuum and abatement Service Centre in Glenwillow, Ohio.

The company's products are used in many applications including the MOCVD growth of III-V and III-nitride semiconductors.

This state-of-the-art centre will replace its current remanufacturing hub in Strongsville, and will include Edwards' latest remanufacturing and repair methodology as well as expanded product repair capability.

"This is not simply a relocation," comments Stephen Abate, the Americas Service Director at Edwards. "We have reached the capacity of our Strongsville centre and, in looking to the future, are eager to expand and improve our operations in Ohio."

The Glenwillow site has been designed to upgrade to the latest service processes and global best operating practices and will allow Edwards' service teams to better support its customers in the United States.

Overall, the new service hub will facilitate the lean manufacturing standards that Edwards holds itself to around the world. New training facilities will provide a forum for hub staff, field service engineers and customers to benefit from hands-on instruction. Brand new equipment and a streamlined layout will improve efficiency. The combination of increased capacity and upgraded technology will support Edwards' planned future growth and additional product lines.

"This centre is a statement of our commitment to our wide customer base," adds Abate. "As our business grows, we need to respond to increasing service demands from our customers in the general industrial sectors, research and development labs, chemical process industries and the semiconductor industry. This move-up will allow us to do just that and we look forward to providing even better service in 2014 and beyond."

SPTS awarded `Company of the Year` by ESTnet

The ESTnet awards event honours prominent businesses and individuals in the Welsh electronics and high technology industry

Kevin Crofton, President and COO, SPTS on the left, receiving the Company of the Year Award

David Butler, VP Marketing, SPTS on the left, receiving the Exporter of the Year Award

SPTS Technologies, a supplier of advanced wafer processing solutions for the global semiconductor industry and related markets, was named Exporter and Company of the Year at the annual ESTnet Awards.

The event honours prominent businesses and individuals in the Welsh electronics and high technology industry.

The ESTnet is a network of technology enterprises, created to form strong business relationships, exchange knowledge and share ideas.

Edwina Hart, the Minister for Economy, Science and Transport was at the gala dinner in the Swalec Stadium in Cardiff, together with representatives of the top technology firms in Wales.

SPTS also came close to a third award; Matt Hill, a test

engineer who started with the company as an apprentice, reached the final three in the "young engineer of the year" category.

Avril Lewis, managing director of the ESTnet, the network representing electronic and software technologies businesses in Wales said, "There is a real wealth of talent in the industry in Wales and the ESTnet Awards programme further raised the profile of the sector and celebrated its key achievements. We are extremely proud of SPTS, a company that has the drive, passion and the vision to make their business a success. It's great to unearth new innovative and enabling technologies that help represent the diversity of our industry."

"We are proud to be recognised by the ESTnet award judges this year," sid an enthusiastic Kevin Crofton, president and chief operating officer. "The global microelectronics manufacturing industry is dynamic and demanding, and we have worked hard to maintain our market-leading position through constant technological innovation, while earning extraordinary customer loyalty. It was an absolute pleasure receiving the awards on behalf of our employees."

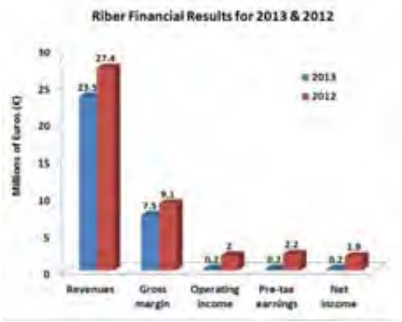
SPTS Technologies designs, manufactures, sells, and supports many markets including LEDs, high speed RF on GaAs, and power management device markets.

Riber revenues plummet 14 percent

Although seventeen MBE systems were sold to research customers in 2013, no production machines were sold in the same period

MBE tool manufacturer, Riber has released its full-year earnings for 2013.

Revenues came to €23.5 million for 2013, compared with €27.4 million in 2012. During the past year, Riber further strengthened its positions on research markets in order to limit the significant downturn affecting industrial markets with their current excess capacity.



MBE system sales (€16.9 million) were down 13 percent on 2012 (€19.4 million). Seventeen MBE systems were sold to research customers (versus 15 in 2012), partly offsetting the fact that no production machines were sold in 2013 (2 were sold in 2012).

Sales of services and accessories (€5.3 million) and cells and sources (€1.3 million) were down 18 percent overall, primarily due to the weak level of demand in 2013 from industrial customers. Sales of cells for the new markets (OLED and solar) remained sluggish, waiting for the next waves of capacity investments in South Korea. This decrease was limited by the development of sales of MBE effusion sources to R&D customers.

CHANGE IN PROFITABILITY

Factoring in the change in revenues, the gross margin came to €7.5 million in 2013 (€9.1 million in 2012), representing 32.2 percent of revenues. More specifically, the 1-point drop in the margin rate reflects the provisioning for inventories, with a net charge of €0.2 million for 2013, compared with a €0.6 million reversal in 2012.

Operating expenses were down year-on-year, notably benefiting from the policy rolled out by Riber at the beginning of 2013 to reduce its fixed costs.

In this context, consolidated net income came to €0.2 million in 2013 (representing 1.0 percent of revenues), compared with €1.9 million in 2012 (representing 7.0 percent of revenues).

Cash represented €1.7 million at December 31st, 2013, down €3.6 million in relation to December 31st, 2012, notably factoring in the high level of billing at the very end of the year and the ramping up of innovation efforts during the year. Despite a lower level of business, the company generated €1.2 million in cash flow from operations in 2013.

In view of the results for 2013 and the requirements for financing innovation, the Management Board will not be submitting a proposal for a dividend at the general meeting on June 3rd, 2014.

OUTLOOK

At the end of February 2014, the order book represented €7.4 million (€7.0 million at end-2013), with six research systems to be delivered from the second quarter of 2014 and significant levels of orders for services and accessories. The company is currently seeing an increase in the deal flow for the R&D MBE market.

In 2014, Riber is concentrating its efforts on promoting its new Compact 21 DZ R&D MBE system and extending its range of MBE effusion sources and continuing gains in market share. The firm also aims to develop thin-layer complex material depositing equipment, particularly for the buoyant OLED flat screen sector. Over the longer term, the firm aims to incorporate MBE within the silicon manufacturing chain (III-V on silicon materials, etc.).

Riber's technological expertise, its presence in South Korea and its research partnerships represent strong assets to support these developments.

The 2014 first-quarter revenues will e announced on April 28th after close of trading.

SemiTEq announces next generation of PVD and PECVD Systems

SemiTEq targets intensive R&D and small-scale production for up to 8” wafers

Russian MBE manufacturer SemiTEq has announced its next generation of PVD and PECVD Systems on the technological platform STE ICP for ICP plasma etching (STE ICP200E) and PECVD (STE ICP200D).

Both systems are designed for intensive R&D as well as small-scale production for up to 8” wafers.

The platform has an aluminium process chamber and a new design of load lock chamber, configured for installation through the clean room wall. The new table design provides advanced helium cooling for long etching processes and precision heating with thermal stabilisation for PECVD, controlled by software that allows for flexible programming of the process.

SemiTEq JSC core competences are in the development and production of MBE Systems for a wide range of III-V, wide band gap II-VI and III-nitride compound semiconductor growth. Key system components have a patented design.

MBE Systems and Wafer Processing Equipment product lines ensure the quality of epiwafer growth and its further processing under R&D as well as pilot production.

SemiTEq is the sole Russian MBE manufacturer.

SemiTEq ICP 200D

Keithley power supplies allow safe breakdown testing up to 10kV

Silicon carbide and gallium nitride devices can be tested for high voltage breakdown

Keithley Instruments has introduced two high voltage power supplies optimised for high voltage device and materials testing and high energy physics and materials science research.

The Model 2290-5 5kV Power Supply and Model 2290-10 10kV Power Supply are well suited for high voltage breakdown testing of power semiconductor components.

This includes devices made of current- and next-generation wide-bandgap materials like SiC and GaN, designed for use in “green,” energy-efficient power generation and transmission systems and hybrid and all-electric vehicles.

New Keithley Power Supplies Allow Safe Breakdown Testing at up to 10kV

Other options on the market for sourcing 10kV lack many capabilities built into Series 2290 Power Supplies.

For example, some don’t include a communication interface as standard equipment, don’t offer an available protection module, or produce significantly higher output ripple than the Series 2290 Power Supplies.

One popular 10kV sourcing solution requires purchasing a complete chassis-based semiconductor test system, then adding a voltage expander, which means it costs twelve times more than the Model 2290-10. This solution, designed for characterisation of power components, also can’t address the high voltage sourcing requirements of researchers in the basic sciences.

The Series 2290 Power Supplies are stand-alone voltage sourcing instruments that make it economical to create a high voltage test solution.

For materials researchers and semiconductor device developers involved in creating and characterising very high voltage materials and devices, the Series 2290’s maximum voltage output levels of either 5kV or 10kV. The system’s complement Keithley’s Model 2657A High Power System SourceMeter Source Measure Unit (SMU) Instrument, which provides source voltages up to 3kV.

Series 2290 Power Supplies can also be used in conjunction with test systems that include a Keithley Model 4200-SCS Parameter Analyser and/or Parametric Curve Tracer configurations for more complex applications that require

testing at up to 10kV.

Low Noise Performance

When making leakage current or high resistivity measurements with sensitive measurement instruments, a power supply with low output noise is essential. Both Series 2290 power supplies' extremely low noise performance allows sensitive instruments to measure current accurately down to picoamp levels.

The Model 2290-10's maximum output ripple is less than 1VRMS; the Model 2290-5's is just 100mVRMS. Two selectable internal filters in the Model 2290-5 allow reducing its output ripple to only 3mVRMS, one of the lowest noise outputs in the industry.

Enhanced Safety for Both Users and Sensitive Instruments

To prevent overvoltage damage to lower voltage instrumentation configured into the same test system as a Series 2290 Power Supply, Keithley has also introduced the Model 2290-PM-200 10kV Protection Module.

When low voltage instruments, such as many of Keithley's SMU instruments, are used in a high voltage test circuit with a Series 2290 power supply to make accurate leakage current measurements, the protection module safely clamps the voltage across the sensitive instrument to a maximum value of 200V.

This is even if the device under test (DUT) breaks down and effectively becomes a short. The power supplies, the protection module, sensitive instrumentation, and Keithley software and accessories bring together all the elements needed to create a safe, high voltage test environment.

Both Series 2290 power supplies have a built-in interlock circuit to disable the output voltage if a high voltage test fixture's access door is not closed, a critical feature not available in all competing products. In addition, they have low voltage analogue outputs to allow for safe monitoring of the high voltage and the output current.

Keithley has developed LabVIEW and IVI drivers for the Series 2290 to speed and simplify test system development. The IEEE-488 interface provided standard in the Series 2290 simplifies creating automated high voltage test systems and enhances safety by allowing the high voltage instrumentation to be controlled remotely.

Low Current Output Capabilities

In addition to their high voltage outputs, the Model 2290-5 can output up to 5mA of current (25W) and the Model 2290-10 can output up to one milliamp (10W). Both offer one micro-amp current measurement resolution. The front panels of these instruments provide voltage and current output displays, as well as a third display that shows the user's choice of four settings: output voltage, voltage limit, current limit, or current trip.

Applications

In addition to high voltage breakdown testing, applications for Series 2290 Power Supplies include high energy basic science research, including voltage component and materials testing, insulation testing, and high voltage resistivity measurements. Physicists and material scientists will find them valuable for applications that involve studying radiation properties and effects, studying and using particle beams, and studying material structures.

Pricing and Availability

The new power supplies are immediately available from Keithley sales partners at these US list prices:

Model 2290-10 10kV Power Supply: $4900
Model 2290-5 5kV Power Supply: $3890
Model 2290-PM-200 10kV Protection Module: $1200

Samco to distribute VPE`s MOCVD tools

Regions where Samco will distribute the reactors include the Far East and Europe. The systems are used in GaN and solar cell production

Valence Process Equipment (VPE) of Branchburg New Jersey has signed an agreement with Samco Inc., based in Kyoto, Japan, to distribute VPE's MOCVD equipment.

The agreement gives Samco exclusive distribution rights in Japan as well as non-exclusive rights to sell the products in a number of other countries including China, South Korea and Europe.

VPE is a technology company that has developed a novel MOCVD reactor for GaN based semiconductor devices including High Brightness LED's for Solid State Lighting.

The unique patented design of the VPE system is claimed to reduces consumption of expensive gases and metal-organic precursors by up to 40 percent in comparison with competing products. VPE's initial product was the GaN-500 reactor, announced in 2011, with a current capacity of 59 x 2" or 18 x 4" wafers. VPE has recently released the GaN-550 MOCVD reactor with a capacity of 72 x 2" or 20 x 4" wafers.

Valence GaN_500 Reactor

Samco is a provider of dry etch and plasma CVD systems to the global Compound Semiconductor Industry.

Recently, Samco has placed a focus on selling next-generation production equipment for GaN power devices that are a cornerstone of "green electronics" and have a large impact on energy efficiency. The addition of MOCVD strengthens Samco's product line-up as MOCVD, plasma-CVD, dry etching and surface treatment systems can be bundled to provide a "one stop solution" for customers involved in GaN semiconductor applications.

As part of the agreement Samco will purchase and install a GaN-550 MOCVD system in its facility in Kyoto for customer demonstrations. Installation is planned for July 2014 and the system will be used to develop novel power device epitaxial structures on large diameter wafers in collaboration with a key customer.

VPE CEO and Founder, Frank Campanale, comments, "We are delighted to embark on this partnership with a highly respected and capable company like Samco. Our MOCVD system complements Samco's existing product range and creates a unique suite of products for the GaN semiconductor community".

Altatech wins CVD system order from U.S. university

The tool will be used in the production of advanced LEDs and solar cells and silicon based devices

Altatech, a subsidiary of Soitec, has received an order from the University of Washington in Seattle for an AltaCVD system.

The tool offers a combination of capabilities that allows users to develop new process materials with higher added value.

Altatech's CVD system will be installed at the University's Washington Nanofabrication Facility (WNF), where it will be used by both internal and external researchers in fabricating a broad range of semiconductor-based devices.

These will include advanced LEDs, solar cells, CMOS transistors, MEMS and ICs built with the latest in through-silicon-via (TSV) technology,

Altatech's pulsed CVD systems are currently used n R&D iand pilot production facilities throughout Europe. However, the University of Washington's order represents the first such system to be delivered to a North American university R&D and pilot production facility.

The university's acquisition of the AltaCVD system, along with recent installations of an advanced deep reactive ion etcher (DRIE) and a plasma-enhanced CVD (PECVD) tool, provides the capability to assemble an electroplated TSV fill process.

Commenting on the tool's capabilities, Michael Khbeis, acting director of the WNF, claims, "The AltaCVD system provides a unique capability that enables researchers to deposit conformal metal films for TSV applications as well as metal oxides and nitrides for high-k dielectrics and piezoelectric materials."

"The higher deposition rate enabled by pulsed CVD makes ALD (atomic layer deposition) films a tractable solution for scale-up paths toward high-volume manufacturing for our researchers and industrial clients. This ensures a viable pathway from academia to real economic impact in our region," he adds.

"Extending the use of our CVD systems into this acclaimed user facility in North America continues to demonstrate the widely recognised advantages of our pulsed deposition technology," says Jean-Luc Delcarri, general manager of Soitec's Altatech subsidiary. "We are very pleased to add the University of Washington to the growing list of our CVD equipment adopters."

Altatech will support its AltaCVD installation at the University of Washington from its U.S.-based business and service operation centre.

The AltaCVD system uses pulsed deposition technology to offer a unique combination of capabilities for developing new materials. It can perform ALD for exceptional 3D coverage at deposition rates matching those of more conventional CVD techniques.

This allows superior stoichiometry control while creating highly conformal thin and thick films, which cannot be achieved using many of today's existing technologies.
Altatech's system design combines a unique vaporiser technology, gas/liquid panel integration, dual-channel showerhead and chamber design. The combination of Altatech's proprietary reactor design and precursor introduction path with pulsed liquid injection and vaporisation enables nanoscale control of film thickness, uniformity, composition and stoichiometry in complex materials.

IQE delivers 200mm GaN on Silicon wafers to Singapore MIT

The wafers will be used in the next generation CMOS program

IQE has delivered the first 200mm (8") GaN on silicon wafers into the Singapore-MIT Low Energy Electronic Systems (SMART-LEES) program.

Conventional CMOS is now rapidly reaching fundamental limits of silicon performance despite the ever decreasing transistor linewidths and highly complex architectures being deployed by leading semiconductor companies globally.

This has led to many leading foundries and IDMs actively developing Compound Semiconductor on Silicon (CSoS) technologies in order to exploit the advantageous electronic, optical and power handling properties of compound semiconductors, whilst continuing to use the scale and cost structure of existing silicon semiconductor fabs.

The SMART-LEES program in Singapore is a significant programme, developing, among other technologies, a comprehensive array of CSoS technologies to facilitate complete monolithic integration of CMOS and compound semiconductor circuits, in a way that allows the processing of the wafers through conventional 200mm CMOS processing lines.

What's more, design libraries will be developed to allow widespread adoption of these technologies across multiple end markets.

IQE has developed and delivered 200mm GaN on silicon High Electron Mobility (HEMT) wafers, which have been delivered to this program to enable the realisation of a new generation of RF device architectures, integrated with highly efficient power control circuitry.

It is expected that further collaboration will quickly lead to a wide variety of other compound semiconductor combinations to be realised as part of the full array of CSoS technologies.

Project leader, Gene Fitzgerald, Merton C Fleming Professor of Materials Science at MIT comments, "It has been clear for some time that conventional CMOS is no longer capable of continuing Moore's law. The ever increasing capital intensity of narrowing linewidths, coupled with the rapidly reducing performance benefit, means a new paradigm needs to be introduced."

He continues, " Compound semiconductors fully integrated on a Silicon platform is a highly optimal solution, taking advantage of both the greatly superior performance of compound Semiconductors in many applications, coupled with the cost benefits of the existing silicon fab infrastructure. Our program fully integrates III-V devices into the silicon design platform, resulting in the ability to develop fundamentally new circuit designs for a wide-range of applications. We are very happy to be working together with IQE, the leading compound semiconductor materials company to realise the creation of next generation CMOS platforms."

Drew Nelson, President and CEO of IQE adds, "It is a great privilege to be working with such a highly talented team within the SMART alliance, on technologies which will drive a new phase of growth in the semiconductor Industry. Compound semiconductors have always been the next obvious choice to carry forward the silicon industry, and we are very excited about being a major part of the next revolution in fully integrated CMOS technology, bringing the next leap in performance across a great range of technologies."

Midsummer launches R&D platform for CIGS and CZT solar cells

The tool can also be used for a variety of applications where a sputtered material stack in an unbroken vacuum chain is required

Swedish firm Midsummer, a supplier of equipment manufacturing of CIGS thin film flexible solar cells, has launched the UNO, a low cost versatile research and development platform for thin film deposition specifically developed for universities and research facilities.

UNO tool

The cost effective UNO tool derives from the production of CIGS solar cells. With its generic design and optional configurations, UNO is the ideal solution for a range of thin film research applications. It has a high throughput, flexibility, stability and ability to design complex test series.

"There has been a lot of interest from universities and institutes for a lower cost version of our commercial DUO production tool for research and development," says Sven Lindström, CEO, Midsummer. "We are happy to announce the launch of the UNO in response to these requests, and hope that a research tool like this will contribute to accelerate the development of cost-effective and efficient thin film CIGS and CZTS solar cells on a global scale."

The UNO is a platform for CIGS and CZTS (copper, zinc, tin and sulphide) solar cell research. In addition, it can be used for a multitude of applications where a sputtered material stack in an unbroken vacuum chain is required (thin film batteries, fuel cells, small display screens etc.).

The UNO can have up to thirteen sputtering cathodes and warm the substrate up to 750°C (1,400°F). It can load up to 300 substrates and run automatic test series, where each substrate has different parameter settings. It can also be supplemented with co-evaporation, analytical tools, database and various options.

The UNO has many of the features and design of the DUO, including a small footprint. The biggest difference between the two tools is that the UNO has only one main vacuum chamber and that sputtering takes place in only one process station at a time, which is suitable for R&D.

Another R&D feature is that the UNO can use both glass and stainless steel substrates and can be equipped with more in-site measurement stations. The UNO is a pure R&D tool and not a low cost production tool. The price of the UNO starts at under $1 million, but depends on configuration.

Midsummer's commercial production line is the DUO, a compact CIGS turn-key system with a 5 MW annual production capacity. Midsummer's CIGS cells looks like crystalline silicon solar cells, but are made on stainless steel substrates. This makes the cells suitable not only for regular solar panels, but also for flexible, light weight panels that can be used

on membrane roofs, landfills or other structures where the traditional glass modules cannot be applied.

"We firmly believe that thin film CIGS solar cells are the solar cells of the future," concludes Sven Lindström, CEO, Midsummer. "They are increasingly efficient and have many advantages over traditional silicon-based solar cells. They are durable, can withstand vibrations, can be curved and bent, and can be manufactured cost-efficiently in small volumes."

Thin film CIGS solar panels are thinner and lighter than traditional silicon solar cells made of glass. They are also non-toxic (no cadmium) and can be made frameless, thus ideal for buildings and moving vehicles in cities. They are flexible and can be bent.

IQE revenues up 44 percent thanks to wireless

The robust wireless business and diversification strategy drives strong rises in revenues, profit and earnings

IQE has announced its final results for the year ended 31st December 2013.

The firm achieved a new Group record of £126.8 million, up from £88.0 million in 2012.

This includes £30.9 million revenues from Kopin Wireless, acquired in January 2013. However, the company was affected by adverse H2 currency impact as sterling appreciated 3 percent against the US dollar.

H2 wireless sales were up 3 percent over H1 in constant currency and H2 photonic sales were up 12 percent over H1 (in constant currency). The adjusted PBT was up 51 percent to £13.0 million from £8.6 million (Reported PBT £5.2 million).

The adjusted fully diluted EPS increased 43 percent to 2.00p from 1.40p (Reported fully diluted EPS 0.89p). Cash inflow from operations before exceptional items was up 346 percent from £4.7 million to £16.2 million.

Cash conversion before exceptional items was 111 percent up from 51 percent. Net debt was £34.4 million (opening net debt £15.5 million increased primarily due to £25 million of debt to part fund the Kopin acquisition.

Drew Nelson, IQE Chief Executive, made the following statement:

"IQE's core wireless division has again delivered a robust performance, with continued growth despite a significant downstream inventory correction in the major chip companies due to softness in the high end smartphone market. As a direct result of our customer risk mitigation strategy, which we have executed over the last 18 months and completed with the acquisition of Kopin Wireless, we are much less sensitive to market share shifts between the major chip supply companies.

"Concerns in the UK over the last year that silicon CMOS would significantly damage the Compound Semiconductor industry have proved unfounded and are not reflected in our financial performance nor in our customers' expectation of future long term demand drivers.

"Wireless remains an attractive market for us over the coming years with demand continuing to be driven by the proliferation of wireless applications and the need for sophisticated GaAs chips to deal with the explosive growth in data traffic. Beyond this, the next waves of innovation which will drive handset replacement cycles are likely to include lasers and sensors using compound semiconductor technology, for gaming, 3D image capture, gesture recognition, and sensing for a variety of applications including healthcare monitoring devices.

"Our business diversification strategy also gained strong traction, and we achieved a number of significant technical and commercial milestones during 2013 which reflect the strong progress made in our other key markets including photonic sensors and lasers, advanced solar (CPV), power semiconductors, infrared, LED and advanced electronics.

"Our integration remains firmly on track, and we expect to realise significant reductions in our financial overheads, whilst benefiting greatly from the operational and technical synergies we are delivering.

"IQE is at the forefront of the enabling technologies that are at the very heart of many of the twenty-first century trends and products. We are confident that the Group is well positioned for continued growth in earnings and cash flow in 2014 and beyond."

NT-MDT launches AFM with automated, multiple tip exchange

Atomic Force Microscopy (AFM) is expanding rapidly into all venues including semiconductor characterisation

NT-MDT has announced Titanium, what the firm says is the first AFM with a self-aligning, multiple probe cartridge for fast, automated tip exchange.

Titanium's unique Revolution Cartridge simplifies one of the most challenging steps in AFM workflow: tip exchange and alignment. Revolution holds thirty eight tips. As each new probe moves into position, Titanium automatically centres and aligns the probe and laser, dramatically cutting downtime for tip exchange as well as opening AFM to less sophisticated users and more routine applications.

Picture: Titanium 38 Probe Revolution Cartridge NT-MDT's Titanium feature a 38-probe Revolution Cartridge for multi-probe automated cantilever replacement

Real-time detection of cantilever deflection allows Titanium to collect topographic, mechanical and electrical properties in a single pass, with high quality and spatial resolution. Its robust, stable engineering guarantee exceptionally low drift (0.2nm/min) and low noise level (25fm/ÖHz).

Titanium also offers the new HybriD Mode (HD-AFM Mode), a new high resolution modality especially well-suited to nanomechanical testing.

Other options include a standard AFM head for traditional probes, an AFM head for liquid studies, and an STM head for scanning tunneling and spectroscopy. A nanoindentor measuring head and a heating stage are also available. These solutions provide a robust growth path and make Titanium the ideal instrument for multi-user facilities.

NT-MDT service stands behind Titanium, offering a triple warranty that provides free cantilevers (under regular usage) for three years.

IPG announces configurable fibre laser workstation

The firm's UV laser systems are suited for fabricating complex 2-D and 3-D structures such as micron-scale devices. Heat-free laser ablation facilitates exact tolerances without collateral damage to the material

IPG Photonics Corporation has introduced the IX-200-F, an advanced fibre laser micromachining system for general purpose, R&D and batch-scale production applications.

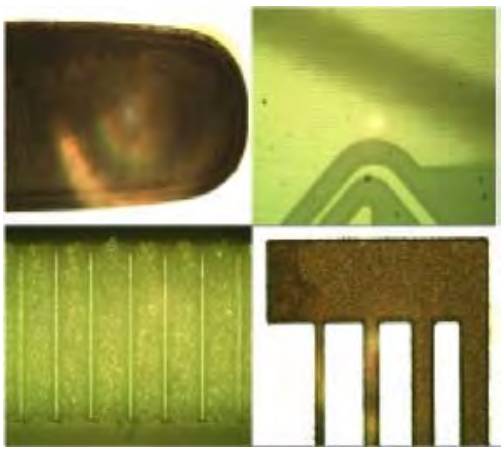
The multi-functional system can easily be configured with different combinations of fibre lasers and beam delivery systems to address high-precision, cutting, drilling and patterning micromachining applications. It represents the optimum combination of IPG's fibre laser and materials micro-processing workstation technologies.

IPG's IX-200-F is a fully enclosed and interlocked CDRH Class 1 system, configurable with a wide range of IPG fibre lasers and fully integrated with the system operating hardware and software. The system core consists of special structural design granite to minimise the effects of vibration and thermal drift on the overall accuracy of the product.

The IX-200-F features a high-resolution, high-performance microscope vision system which provides a continuous zoom range from 38X to 880X for sub-micron automated part alignment and inspection. System software includes macro-building tools for fast programming and generation of automated processes for complex feature machining. Additional utilities allow complex pattern input from standard CSV and DXF files.

The selection of IPG Fibre lasers currently supported on the IX-200-F includes pulsed IR to over 500 watts and pulsed green up to 50 watts as well as UV lasers. Users may select ablation or thermal cutting and scanning or fixed beam delivery configurations.

The IX-200-F includes precision, multi-axis part-handling and vision systems for accurate machined feature placement and process control and fully-integrated software enabling both ease of use and highly complex machining functions.



T*op (L-R): FR-4, ITO ; Bottom (L-R): Al2O3, Copper*

Applications for IPG's IX-200-F include cutting of ceramics, metals, polymers and semiconductor materials and patterning of ITO and other thin-films. Drilling applications include hole diameters down to 15 microns in 300 micron thick ceramics, with placement accuracies of better than

5 microns, at rates of 100 holes per second. The advanced world class applications laboratories of IPG Microsystems located in Manchester, NH USA, provide demonstrations and proof of concept application studies for domestic and international customers.

"The IX-200-F combines IPG's world-leading fibre lasers and the industry-proven IX-200 precision workstation design into a flexible product that provides users a highly cost-effective laser processing tool," states Jeffrey Sercel, President of IPG Microsystems.

"The range of configurable options that can be either factory installed or field installed at a later date, enables users to purchase the capability they need today and preserve the value of the capital investment through future upgrades as application requirements evolve."

Martini Tech offers GaN MOCVD deposition for LEDs

The Tokyo based firm is offering gallium nitride MOCVD for deposition on sapphire substrates

Martini Tech has started to offer its customers a new GaN deposition service on sapphire substrates by MOCVD for LED applications.

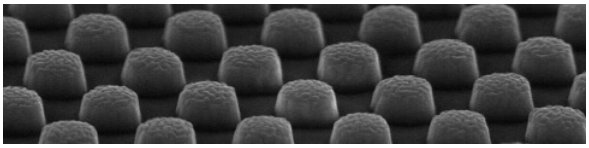


Image of GaN MOCVD on sapphire substrate

LEDs are becoming increasingly popular in various fields of the electronics industry: they can be used inside digital clocks, for street illumination applications, to send information and in large-size television screens and computer monitors.

LEDs are similar to incandescent light bulbs but they differ from them as they do not have a filament and therefore they do not get particularly hot and do not become unusable after a certain period of time due to filament burn out.

Different from incandescent light bulbs, LEDs are illuminated uniquely by the movement of the electrons in a semiconductor material.

Such important characteristics, coupled with electricity consumption which is lower than that of incandescent light bulbs make them viable as their potential replacement.

The widespread adoption of LEDs has so far being hindered by a series of factors, the main ones being the relatively high price and lower light output compared with traditional incandescent light bulbs.

GaN deposition is one of the most promising techniques to improve the light output of LEDs and involves the deposition of a thin GaN epitaxial layer on a patterned sapphire substrate (PSS).

The service offered includes the deposition by MOCVD of undoped GaN and of *n*- or *p*- doped GaN for high-quality highly-ordered crystalline layers up to 5μm of thickness.

Source: Newswire Today and LINK

SiO2 ded GaN for high-quality highly-ordered crystalline layers up to 5μm of thickness.Source: Newswire Today and LINK

Compound Semiconductor conference hits a new high

35 presentations equipped delegates with a comprehensive overview of the compound semiconductor industry

Around 300 delegates and over 30 sponsors descended on Frankfurt for the fourth CS International Conference, which was held at the Sheraton Airport Hotel this week.

This must-attend event for the leaders of the compound semiconductor industry set a new standard for its number of presentations.

The conference covered all aspects of the industry, with presentations grouped into six key themes:

Power Electronics
LEDs
Integration of CMOS and III-Vs
Wide Bandgap RF Devices
Front-ends for Mobile Devices
Lasers, PICs & PV

Presentations on these topics highlighted the growing penetration of compound semiconductors into the silicon industry, and the use of silicon in the making of III-V chips. Leading developers of next-generation CMOS, such as IBM and Imec, are pioneering approaches to integrate high-mobility materials, for example InGaAs, into the channels of transistors in microprocessors, while silicon substrates are viewed as a low-cost platform for making LEDs, as well also power and RF electronics based on GaN.

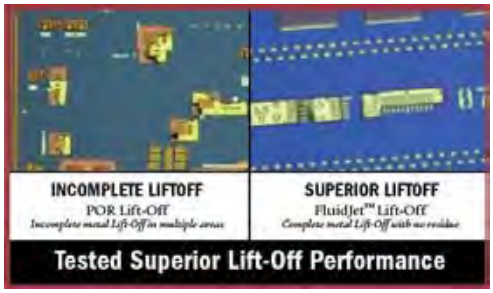
Meanwhile, power amplifiers that are based on silicon are starting to go head-to-head with those made from GaAs for deployment in the latest smartphones. It appears that devices based on CMOS will gain market share, but GaAs will dominate the market for many years to come.

A more detailed report of the presentations at CS International Conference will appear in the April /May edition of *Compound Semiconductor* magazine. This issue will also contain details of the winners of the coveted CS Industry Awards.

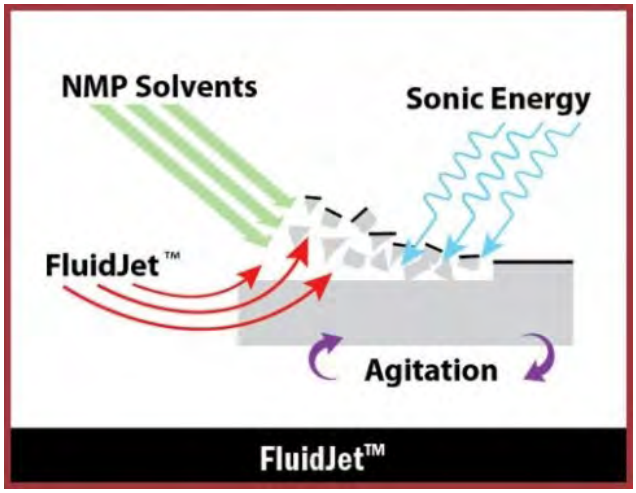
For more information about CS International Conference, and opportunities available for the 2015 event, contact Stephen Whitehurst: stephen.whitehurst@angelbc.com Tel 0044 (0)2476 718 970. www.cs-international.net

MEI›s GaAs BiFET tool set to lift off

The FluidJet metal liftoff system is claimed to eliminate device damage, while using 80 percent less chemical than current single wafer processing solutions



MEI has revealed its FluidJet batch wet processing system for metal liftoff in MEMS manufacturing, delivering higher yielding, more cost effective metal liftoff processing.



MEI says its FluidJet batch wet processing system for metal liftoff achieves no metal re-deposition on either the front side or back side of the wafer, eliminates device damage, while using 80 percent less chemical than current single wafer processing solutions.

FluidJet also enables efficient, easily obtained gold and metal reclaim, reducing waste and downtime. FluidJet could also save manufacturing floor space by reducing the wet process footprint requirement by at least 60 percent over comparable throughput single wafer spray tools.

“By adopting the FluidJet metal liftoff system, semiconductor manufacturers will increase yield while reducing downtime and chemical costs and disposal,” says Dan Cappello, President and CEO, MEI LLC. “FluidJet cleans the surface gently improving metal liftoff performance at a lower cost. Side by side “split lot” comparison data demonstrates superior performance on liftoff and resist strip layers while also reducing defects.”
MEI says its FluidJet metal liftoff system is unlike conventional single wafer metal liftoff systems. Conventional metal liftoff solutions rely on high-pressure sprays that produce metal debris that can scratch or tear fine metal features. Metal debris can also redeposit, causing shorts.

The FluidJet batch immersion system’s gentle removal and self cleaning tanks enable lifted metals to be more easily and completely reclaimed. Strainer baskets are emptied in minutes and sized to easily hold several thousand wafers worth of lifted metal.
MEI’s FluidJet targets semiconductor and MEMS processing applications where Metal Liftoff is required to create GaAs BiFET device structures for mobile communications

II-VI to speed up laser optic production with Veeco IBD tool

The SPECTOR-HT system is claimed to offer higher depostion rates than other tools

II-VI Incorporated has ordered the SPECTOR-HT Ion Beam Deposition (IBD) System and added Veeco’s new Quest Optical Monitor, for use in its high-volume production of laser optics.

Veeco says its SPECTOR-HT IBD System produces high quality optical thin films with improved levels of productivity and throughput.

SPECTOR-HT IBD reactor

The Quest Optical Monitor provides up to ten times improvement in layer thickness accuracy compared to previous generations for precise manufacturing control.

“Veeco’s SPECTOR-HT IBD System allows us to deliver high quality laser optics faster by achieving superior deposition rates while maintaining exceptional film qualities,” says Mark West, General Manager, II-VI Infrared. “The Veeco Quest Optical Monitor upgrade is an incredible breakthrough. It ensures we will have a repeatable, highly productive operation using the latest technology, enabling us to produce the highest quality laser optics.”

Headquartered in Saxonburg, Pennsylvania, II-VI specialises in engineered materials and optoelectronic components. Veeco is an focuses on MOCVD, MBE, Ion Beam and other advanced thin film process technologies.

“II-VI is an optical coating leader and their endorsement of the SPECTOR-HT is clear indication of its exceptional value,” continues Jim Northup, Vice President and General Manager of Veeco MBE, Optical Systems and Ion Sources. “As the optics industry seeks faster deposition rates and more repeatable

processes, Veeco's SPECTOR-HT IBD System, coupled with the new Quest Optical Monitor, achieves unprecedented levels of productivity by offering the highest throughput for optical thin film manufacturers."

IQE delivers first 150mm VCSEL epiwafers

The high volume production of the wafers will be used in a variety of applications. These will include the mobile, defence and military, computing and medical sectors

IQE says it has delivered the world's first 150mm (6") VCSEL epi wafer process for high volume, low cost applications.

Markets for VCSELs are proliferating rapidly as this advanced laser is becoming the device of choice for many high volume applications including:

• *Gesture recognition, for gaming and non-contact navigation (e.g TV, smartphone, tablet)*

• *Depth imaging for 3D vision , driving next wave of handset innovation for must have new phones*

• *Low energy optical storage and fast switching in high capacity data centres, servers and ultra-high speed computing*

• *High speed datacomms, including Active Optical Cables (AOC)*

• *UltraHigh Density magnetic Storage using Heat Assisted Magnetic Recording (HAMR)*

• *Illumination for IR cameras for security, safety, night vision*

• *Industrial heating including paint curing and commercial print shops*

• *Cosmetics and healthcare including hair removal, antiwrinkle, blemish reduction*

A number of these applications require multi-element array configurations which use greater surface areas and therefore more epiwafer material. They also offer higher optical power output compared with discrete devices.

Many of these markets are price elastic, and by moving to 150mm wafer sizes, compatible with existing well established, state of the art 150mm RF GaAs wafer processing lines, high performance VCSELs can be manufactured in large volume using fabrication and testing techniques similar to that of LEDs.

This combination will provide a high volume manufacturing technology and capability to help drive down the cost of VCSEL based photonics products for deployment in mass market, consumer applications.

The improved cost structure will allow designers to utilise the operational and performance advantages of laser devices to further develop advanced sensing applications which are expected to drive the next wave of innovation in consumer products such as cell phones, tablets and other handheld devices.

Initial engineering evaluation and product qualification wafers have already been delivered and initial performances have replicated those of existing smaller wafer sizes. Production is expected to ramp over the coming year.

Drew Nelson, IQE CEO, says, "VCSEL enabled products such as gesture recognition and 'time of flight' sensing are expected to ramp significantly over the coming period as they become incorporated into next generation handset and mobile communication devices, as well as a myriad of other high volume applications."

"By introducing our new 150mm VCSEL epiwafer process, which is compatible with existing high volume RF GaAs chip processing lines, we are enabling a new low cost manufacturing route for high performance laser devices.IQE has built a powerful technology platform for VCSELs, and recent announcements on record low power consumption VCSELs for data centres and record high speed data transmission with IBM for datacentres, servers and supercomputers are testament to the strength and depth of this platform," he adds.

Rubicon announces pricing of public offering of common stock

The provider of sapphire substrates and products to the LED, semiconductor and optical markets will sell stockholders at a price to the public of $13.00 per share

Rubicon Technology, Inc. has announced the pricing of an underwritten public offering of 2,500,000 shares of its common stock.

The offering is expected to close on March 24th, 2014, subject to satisfaction of customary closing conditions. In addition, Rubicon has granted the underwriters a thirty day option to purchase up to an additional 375,000 shares of its common stock to cover over-allotments, if any.

Canaccord Genuity Inc. is acting as sole book-running manager for the offering and D.A. Davidson & Co. is acting as co-manager for the offering. Rubicon will not receive any proceeds from the sale of common stock by selling stockholders.

The offering is being made pursuant to an effective shelf registration statement previously filed with the Securities and Exchange Commission (SEC). A prospectus supplement and accompanying prospectus describing the terms of the offering will be filed with the SEC.

EVG establishes China headquarters in Shanghai

The new subsidiary aims to enhance service and support for the rapidly expanding micro- and nano-electronic manufacturing customer base in region

The new subsidiary aims to enhance service and support for the rapidly expanding micro- and nano-electronic manufacturing customer base in region

EV Group (EVG), a supplier of wafer bonding and lithography equipment for the compound semiconductor, MEMS and nanotechnology markets, has opened a new, wholly owned subsidiary in Shanghai.

This centre is called EV Group China Ltd. and will serve as regional headquarters for all of EVG's operations in the People's Republic of China.

The new subsidiary, which houses a local service centre and spare parts management facility will support the company's ongoing efforts to improve service and response times to local customers.

As China continues to increase its technology development efforts to become a leading manufacturing region for the semiconductor, compound semiconductor, power device, advanced packaging, LED and MEMS industries, EVG has expanded its operations in order to be more effective and efficient in meeting the needs of its growing customer base in the region.

EV Group China Ltd. is an integral part of EVG's worldwide customer support network, serving as the first point of contact for all service and customer support issues.

"The opening of our new EV Group China subsidiary affords us a great opportunity to continue to deliver on our commitment to provide on-demand, stellar service that our customers have come to expect from EVG. The significant growth in business that we've seen in China, coupled with the continued huge market potential in this region, makes establishing a new subsidiary in China an effective way to continue to build upon our presence here and strengthen support for our local customers and partners," says Hermann Waltl, executive sales and customer support director at EV Group.

EVG has had an active presence in China for more than a decade. Success in this region has allowed order intake from Chinese customers to multiply over the past several years. EVG has now established five wholly owned subsidiaries across the globe.

MKS to acquire Brooks Automation division for vacuum gauges

The firm is to buy the Granville-Phillips subsidiary

MKS Instruments, a provider of technologies that enable advanced processes and improve productivity, has agreed to purchase the assets of Granville-Phillips, a division of Brooks Automation, Inc. for $87 million in cash.
Granville-Phillips is a global provider of vacuum measurement and control instruments to the semiconductor, thin film and general industrial markets, with sales of approximately $30 million in 2013.

Granville-Phillips was founded in 1954, and operated as an independent company until its acquisition by Helix Technology in 1998. It became part of Brooks Automation through the merger of Helix and Brooks in 2005.

"We are very pleased to announce this acquisition," comments Gerald G. Colella, Chief Executive Officer and President of MKS Instruments.

"Granville-Phillips is an ideal complement to our vacuum gauge business, and is a business that we highly respect and know well. While we are the leader in direct pressure measurement, they are a well-regarded leader in indirect vacuum gauges, with a premium brand and an excellent reputation for quality, reliability and performance. The acquisition is well aligned with our stated strategy to grow our core semiconductor business, while diversifying into other high growth advanced markets."

Jack Abrams, Senior Vice President Global Sales, comments, "We believe we have numerous opportunities to grow the Granville-Phillips business, leveraging our existing sales channels and expanding our product portfolio. We believe we can offer a broad range of advanced vacuum gauges that will be highly responsive to the needs of customers in our served markets.

"We see the potential for both revenue and cost synergies as we integrate Granville-Phillips into MKS," continues Colella. "Their profitability and cash flow metrics are aligned with our own operating model, and we expect the acquisition to be accretive to our earnings in 2014. Going forward, with the revenue growth potential that we believe we can achieve with this business, as well as operating synergies to be realized over the next few years, we expect this acquisition to meet or exceed our target return thresholds."

The acquisition is subject to regulatory approvals and other customary closing conditions and is expected to close in the second quarter of 2014.

Meaglow's Plasma tool advances semiconductor manufacturing

As computer chips become smaller and smaller, advanced production techniques, such as Atomic Layer Deposition (ALD) have become more important for depositing thin layers of material.

Meaglow Ltd. says it has made a breakthrough in semiconductor production.

As computer chips become smaller and smaller, advanced production techniques, such as Atomic Layer Deposition (ALD) have become more important for depositing thin layers of material.]

Unfortunately the ALD of some materials has been prone to contamination from the plasma sources used. Meaglow has developed a hollow cathode plasma source which has reduced oxygen contamination by orders of magnitude, allowing the reproducible deposition of semiconductor materials with improved quality.

The breakthrough has been shown in a recent publication of oxygen reduction figures for the hollow cathode plasma source supplied last year to the group of Professor Necmi Biyikli, of the Institute of Materials Science and Nanotechnology, at Bilkent University in Turkey. The plasma source was used to upgrade their existing Atomic Layer Deposition (ALD) system by replacing an inductively coupled plasma source. The publication in the Journal of Materials Chemistry C (*J. Mater. Chem. C 2 (2014) 2123*) shows a reduction in oxygen content of orders of magnitude compared to previous results. There is also a marked improvement in material quality. These results render the older inductively coupled plasma sources obsolete for many applications.

fit existing systems or can be integrated with equipment manufacturers. It can also be utilized in a number of different applications including MBE, and LPMOCVD among others. Interested parties should email info@meaglow.com.

Meaglow develops hollow cathode plasma source

Hollow cathode plasma source could reduce oxygen contamination

Meaglow has announced a breakthrough in semiconductor production. As computer chips become smaller and smaller, advanced production techniques, such as Atomic Layer Deposition (ALD) have become more important for depositing thin layers of material. Unfortunately the ALD of some materials has been prone to contamination from the plasma sources used.

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Meaglow is seeking other customers interested in improving the material quality of their ALD and other plasma grown nitride layers. The hollow cathode plasma technology is also scalable to large deposition areas. The Plasma source can be used to retrofit existing systems or can be integrated with equipment manufacturers. It can also be utilized in a number of different applications including MBE, and LPMOCVD among others.

IPG Photonics buys Veeco MBE reactor

The tool will be used for III-V laser production

IPG Photonics Corporation has purchased an additional Veeco GEN2000 production MBE system to add to its fleet of Veeco MBE systems.

GEN2000 MBE tool

Located in Oxford, Massachusetts, IPG will use the GEN2000 for high-volume manufacturing of laser diodes for fibre lasers. IPG Photonics Corporation is a manufacturer of high-power fibre lasers and amplifiers and now utilises multiple Veeco MBE

systems in its laser production operations.

“Veeco’s GEN2000 is the perfect complement to our existing set of Veeco MBE systems because of its superior throughput and low production costs,” says Alex Ovtchinnikov, Senior Vice President, Components at IPG Photonics. “Having the ability to transfer production methods from our other Veeco MBE systems means we can ramp laser diode production quickly and reliably to meet increasing demand for our fibre lasers.”

With their excellent performance, low power consumption and favourable ownership costs, fibre lasers are becoming the cutting and welding method of choice for materials processing applications, particularly in the automotive industry, according to a report on the laser cutting market from Markets and Markets. As the technology continues to advance, fibre lasers are gaining adoption in other industries including semiconductor processing, 3-D printing and smartphone manufacturing.

“IPG is the clear leader in fibre laser production and has been utilising our production MBE systems for years,” says Jim Northup, Vice President, General Manager for Veeco’s MBE Operations. “The GEN2000 delivers the highest throughput and lowest cost of ownership MBE technology in the industry, making it the ideal system to manufacture IPG’s high performance laser diodes.”

The GEN2000 MBE cluster tool offers 7 x 6” epiwafer growth of devices such as lasers, multi-junction solar cells, and pseudomorphic high-electron-mobility transistors (pHEMTs). Veeco says it allows for growth of different materials in connected modules.

Yole: Apple and GTAT investing over $1 billion in sapphire

The market analyst says that sapphire substrates will retain over 90 percent of the LED market through 2020, far higher than alternatives GaN and silicon

The sapphire industry recently ended an eighteen month period of depressed pricing and achieved US$936 million in revenue for wafer products.

Recovery was helped by an increase in LED demand due to growing adoption in general lighting and a resilient LCD backlight market.

This is according to the “Sapphire Applications and Market: From LED to Consumer Electronics” report from Yole Développement.

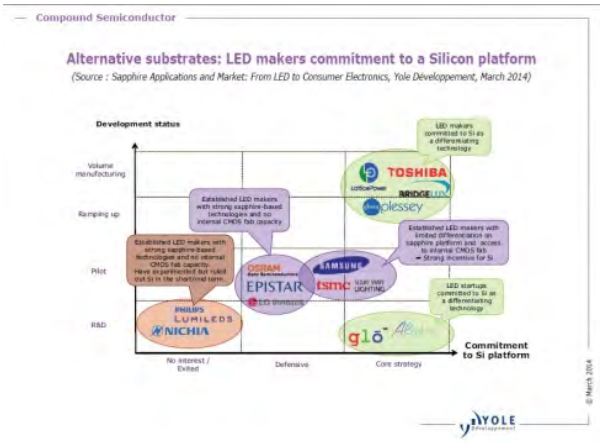
“But the saving grace was new consumer electronic (CE) applications: camera lens and fingerprint reader covers, mostly driven by Apple in 2013” explains Eric Virey, Senior Analyst at Yole Développement.

Overall, the growth in wafer demand will be enough to justify a capacity increase toward the end of 2014. For the longer term, Yole analysed opportunities of alternative LED substrates (GaN and silicon) but concluded that sapphire will retain over 90 percent of the market through 2020.

Yole says Apple and GTAT are investing more than US$1 billion in sapphire manufacturing.

After almost two years of losses, core prices increased by more than 50 percent in 2013; tier-1 sapphire vendors are finally selling at prices close to breakeven costs.

After a short pause, Yole expects the uptrend to resume through Q2 and Q3. But leading vendors’ interests are not to increase prices above levels that would allow tier-2 competitors to generate a profit as well.



”We therefore expect prices to stabilise by the end of the year. Due to strong competition, finishing companies didn’t pass the higher material costs on to their customers. Wafer prices remained stable in 2013 but will go up slightly in Q2-2014. For PSS, which now dominates with 85 percent penetration rate, prices could increase faster as supply currently falls short of demand in Taiwan”, says Virey.

This,Yole estimates, will continue until leading suppliers increase capacity and emerging players in China ramp up and enter the supply chain later in 2014. Overall, sapphire prices should stabilise by the end of 2014 and start decreasing again in late 2015 as the industry keeps improving its cost structure.

And Apple could completely transform the industry in 2014.

Sapphire has been used for years in various luxury cell phones.

In 2013 Yole indicated that adoption in more accessible models could start in 2014. This just happened with the introduction by Gionee of the first ‘non-luxury’ (less than $1000) smartphone to feature a sapphire display cover. If adopted by leading cell phone OEMs for their flagship models, total sapphire demand could double by the end of 2014 and by twenty times by the end of the decade.

On November 4th 2013, GTAT and Apple announced a partnership to set up a large sapphire manufacturing plant in Mesa, Arizona. Yole Développement thoroughly analysed the deal and reached the conclusion that exiting 2014, the plant could reach a capacity equivalent of more than twice the current worldwide capacity.

What for?

Demand for home buttons and camera lens covers are expected to increase in 2014 and 2015, but even with aggressive forecasts for smart watches (and assuming that Apple uses sapphire for its own model which Yole Développement's analysts don't believe it will), the company could still tap into the existing supply chain to procure the sapphire it needs.

It's therefore difficult to justify this US$1 billion investment unless new applications requiring a lot of sapphire are coming to market. From our analysis, Yole considers cell phone display covers to be the most likely outlet for this capacity.

Yole modelled the Mesa operations and believe that the plant will make sapphire slabs that will then be sliced and polished by Apple subcontractors in China. The simulated slab cost of $6.40 per part would enable a US$17 cost per finished display cover, with a path for less than $13 ASP in the midterm. The plant could deliver an equivalent of forty-two million display covers in 2014 and more than eighty-five million in 2015.

Optelian makes GaAs wafer supply agreement with CST

Under this foundry agreement, CST will supply to Versawave fully processed GaAs wafers with an optical coating, as designed and specified by Versawave

Optelian and Compound Semiconductor Technologies (CST) will supply GaAs wafers to Optelian's Versawave Division as a key component of Versawave's high-speed optical modulator technology.

"We are delighted to be working with a world-class partner like Compound Semiconductor Technologies," states David Weymouth, Optelian's CEO. "Their Class 50 clean room environment, combined with full ISO compliance, enables Optelian to maintain our exceptionally high manufacturing standards."

In conjunction with this agreement, Optelian has also ramped up Versawave facilities at its corporate and manufacturing headquarters in Ottawa. The wafers supplied by CST will be integrated into Versawave opto-electrical modules by Optelian's manufacturing team.

"Quality is a core aspect of the culture here at Optelian," says Dennis Isotti, Vice President of Operations. Optelian is TL-9000 certified, which is a catalyst that helps create an environment of continuous improvement for the organisation. We are proud of our North American manufacturing capabilities and have the expertise to ramp up production of Versawave modules to orders of magnitude above the current production capacity."

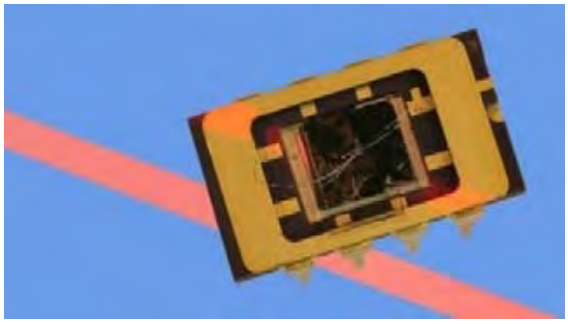
Versawave module production will be transferred into a newly built custom clean room space where process and operations will be fully integrated into Optelian's production and quality control systems. Manufacturing is capable of 24/7 production, resulting in shorter lead times while ensuring on-time customer delivery and quality.

"Moving R&D and Operations under the same roof will not only make us more efficient, but also more agile," comments Simon Benwell, Director of Advanced Optical Components, at Optelian's Versawave Division. "By having R&D work in conjunction with the production teams, our NPI times will reduce significantly while our production capacity will drastically increase. These are both essential for our new products coming onto the market in 2014 and beyond."

Novel Devices

Magic molybdenite creates solar cells and LEDs

Electronic components made up of a layer of molybdenite superposed on a layer of silicon can produce light due to the the special properties of molybdenite

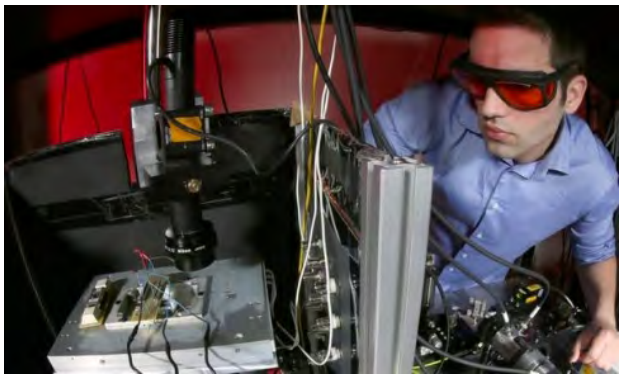


After using it to develop a computer chip, Flash memory device and photographic sensor, EPFL scientists have once again tapped into the electronic potential of molybdenite (MoS2) by creating diodes that can emit light or absorb it to produce electricity.

Molybdenite has a few surprises still up its sleeve.

EPFL professor Andras Kis and his team in the Laboratory of Nanoscale Electronics and Structures (LANES) is continuing his study of this promising semiconductor. In research recently published in the journal *ACS Nano,* they have demonstrated the possibility of creating lLEDs and solar cells.

The scientists built several prototypes of diodes - electronic components in which voltage flows in only one direction - made up of a layer of molybdenite superposed on a layer of silicon. At the interface, each electron emitted by the MoS2 combines with a "hole" - a space left vacant by an electron - in the silicon. The two elements lose their respective energies, which then transforms into photons. "This light production is caused by the specific properties of molybdenite," explains Kis. "Other semiconductors would tend to transform this energy into heat."



Working in tandem

Even better, by inversing the device, electricity can be produced from light. The principle is the same: when a photon reaches the molybdenite, it ejects an electron, thus creating a "hole" and generating voltage.

"The diode works like a solar cell," says Kis. "Our tests showed an efficiency of more than 4 percent. Molybdenite and silicon are truly working in tandem here. The MoS2 is more efficient in the visible wavelengths of the spectrum, and silicon works more in the infrared range, thus the two working together cover the largest possible spectral range."

The scientists want to study the possibility of building electroluminescent diodes and bulbs. This discovery could, above all, reduce the dissipation of energy in electronic devices such as microprocessors, by replacing copper wires used for transmitting data with light-emitters.

Probing the sound of a GaAs quantum dot

New research has suggested that using interactions between sound waves and electrons reveal information about the environment of the electron. This discovery could have potential applications in quantum computing technology

Physicists at the University of Sydney have discovered a method of using microwaves to probe the sounds of a GaAs quantum dot, a promising platform for building a quantum computer.

The findings have been published *in Nature Communications*.

A quantum dot consists of a small number of electrons trapped in zero dimensions inside a solid. The quantum mechanical properties of these electrons can be used to store and manipulate quantum data for revolutionary applications in computing, communication, sensing and bio-medical diagnostic applications.

James Colless and Xanthe Croot from the University's School of Physics, discovered a way to study what happens when electrons in GaAs quantum dots interact with sound waves of the solid they are trapped in.

"The possibility of computing using quantum logic, rather than the classical logic on which today's machines are based, has changed the boundary between hard and easy problems. Previously it was thought that certain tasks - exactly modelling a complex molecule to construct new medicines or computing certain mathematical functions - were simply too hard for any computer, no matter how big," says David Reilly, from the Centre of Excellence for Engineered Quantum Systems (EQuS) and the University's School of Physics.

"The rules of the game have now changed. We now know that quantum mechanics allows certain interesting problems to be computed with ease, so long as you can build a machine that operates according to quantum mechanics - a daunting task!"

"Our work is a further step towards understanding the issues that enable or disable quantum machines. Sound waves in solids are a key mechanism that can lead to quantum devices interacting with their environment," Reilly explains.

These sounds waves are called phonons, and are similar to the waves one can make in a stretched slinky. The 'slinky chain', in this case, is formed by the atoms which make up the solid. It turns out that interactions between sound waves and electrons reveal information about the environment of the electron - akin to detecting the size and shape of a room by listening to a singer's voice in that room.

The absence of inversion symmetry in the zinc-blende crystal structure of GaAs, results in a strong piezoelectric interaction between lattice acoustic phonons and qubit states with an electric dipole, a potential source of decoherence during charge-sensitive operations. To combat this, the scientists generated phonons in a GaAs double quantum dot, configured as a single- or two-electron charge qubit, and driven by the application of microwaves via surface gates.

The interaction between quantum dots and the solids in which they form is a double-edged sword for the purpose of quantum computing. On one hand, sound vibrations have been used to 'shuttle' electrons from place to place in quantum circuits - almost like a wave might pick up a surfer and take them into the beach.

"However, there are other contexts where sound interacting with electrons can cause huge problems: in particular, when you are performing a quantum algorithm and only want the electron to interact with certain parameters that the experimenter controls," explains Xanthe Croot.

Unwanted sound can significantly limit the time you have to perform the algorithm before the electron loses all the information it was storing. Understanding how the size and geometry of the quantum circuit affects these interactions is therefore extremely important.

In quantum computing, different configurations of electrons within the dot represent something similar to the 0 and 1 (or on and off) states in classical computing. The 1 and the 0 states have different energies: if you apply microwaves with exactly this energy difference you can change the state from 0 to 1 and vice versa.

"We found that if you apply microwaves with energy slightly higher than the electron energy difference, the system creates

sound of a very specific frequency. It is almost like the electron saying, if you hit me too hard I'll scream," says Croot.

"Changing the microwave energy will change the frequency of the sound that the system creates in the solid. The results show that some frequencies of sound interact very strongly with the system, while others less so. There are hints in the data that the geometry of the quantum dot plays a key role in determining which frequencies will interact strongly."

This collaboration brought together experimentalists and theorists at the EQuS, University of Sydney, University of Queensland and materials scientists

The research is described in detail in the paper, "Raman phonon emission in a driven double quantum dot," by J.I. Colless *et al* in *Nature Communications,* 5, Article number: 3716. doi:10.1038/ncomms4716

Antimonides surf the invisible wave

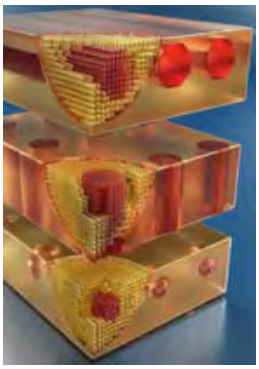
Researchers have created a semiconductor incorporating erbium antinonide, that manipulates light in the invisible infrared/terahertz range, paving the way for new and enhanced applications

Promising to address an array of applications, from energy efficiency to telecommunications to enhanced imaging, researchers at UC Santa Barbara say they have created a compound semiconductor of nearly perfect quality.

The material comprises embedded nanostructures containing ordered lines of atoms that can manipulate light energy in the mid-infrared range.

More efficient solar cells, less risky and higher resolution biological imaging, and the ability to transmit massive amounts of data at higher speeds are only a few applications that this unique semiconductor will be able to support.

"This is a new and exciting field," says Hong Lu, researcher in UCSB's Department of Materials and Department of Electrical and Computer Engineering, and lead author of a study that appears as a cover story of the March issue in the journal *Nano Letters*, a publication of the American Chemical Society.



Artist's concept of nanometre-size metallic wires and metallic particles embedded in semiconductors, as grown by Hong Lu (Credit: Peter Allen, UCSB}

Key to this technology is the use of erbium, a rare earth metal that has the ability to absorb light in the visible as well as infrared wavelength - which is longer and lower frequency wavelength to which the human eye is accustomed - and has been used for years to enhance the performance of silicon in the production of fibre optics.

Pairing erbium with the element antimony, the researchers embedded the resulting compound - erbium antimonide (ErSb) - as semi-metallic nanostructures within the semiconducting matrix of gallium antimonide (GaSb).

ErSb, according to Lu, is an ideal material to match with GaSb because of its structural compatibility with its surrounding material, allowed the researchers to embed the nanostructures without interrupting the atomic lattice structure of the semiconducting matrix. The less flawed the crystal lattice structure of a semiconductor is, the more reliable and better performing the device in which it is used will be.

"The nanostructures are coherently embedded, without introducing noticeable defects, through the growth process by molecular beam epitaxy," notes Lu. "Secondly, we can control the size, the shape and the orientation of the nanostructures."

Epitaxy is a process where layers of material are deposited atom by atom, or molecule by molecule, one on top of the other with a specific orientation.

"It's really a new kind of heterostructure," says Arthur Gossard, professor in the Materials Department and in the Department of Electrical and Computer Engineering.

Semiconductors incorporating different materials have been studied for years. But a technology UCSB professor and Nobel laureate Herbert Kroemer pioneered was a single crystal heterostructured semiconductor/metal which was rather different.

The nanostructures allow the compound semiconductor to absorb a wider spectrum of light due to a phenomenon called surface plasmon resonance, explains Lu, and that the effect has potential applications in broad research fields, such as solar cells, medical applications to fight cancer, and in the new field of plasmonics.

Optics and electronics operate on vastly different scales, with electron confinement being possible in spaces far smaller than light waves. Therefore, it has been an ongoing challenge for engineers to create a circuit that can take advantage of the speed and data capacity of photons and the compactness of electronics for information processing.

The highly sought bridge between optics and electronics may be found with this compound semiconductor using surface plasmons, electron oscillations at the surface of a metal excited by light.

When light (in this case, infrared) hits the surface of this semiconductor, electrons in the nanostructures begin to resonate. This means that they move away from their equilibrium positions and oscillate at the same frequency as the infrared light .

This preserves the optical information but shrinks it to a scale that would be compatible with electronic devices.

In the realm of imaging, embedded nanowires of ErSb offer a strong broadband polarisation effect, according to Lu, filtering and defining images with infrared and even longer-wavelength terahertz light signatures.

This effect can be used to image a variety of materials, including the human body, without the risk posed by the higher energies that emanate from X-rays, for instance.

Chemicals such as those found in explosives and some illegal narcotics have unique absorption features in this spectrum region. The researchers have already applied for a patent for these embedded nanowires as a broadband light polariser.

“For infrared imaging, if you can do it with controllable polarisations, there’s information there,” says Gossard.

While infrared and terahertz wavelengths offer much in the way of the kind of information they can provide, the development of instruments that can take full advantage of their range of frequencies is still an emerging field.

Lu credits this latest breakthrough to the collaborative nature of the research on the UCSB campus, which allowed her to merge her materials expertise with the skills of researchers who specialise in infrared and terahertz technology.

“It’s amazing here,” she says. “We basically collaborated and discovered all these interesting features and properties of the material together.”

“One of the most exciting things about this for me is that this was a ‘grassroots’ collaboration,” says Mark Sherwin, professor of physics, director of the Institute for Terahertz Science and Technology at UCSB, and one of the paper’s co-authors.

The idea for the direction of the research came from the junior researchers in the group, he continues, grad students and undergrads from different laboratories and research groups working on different aspects of the project, all of whom decided to combine their efforts and their expertise into one study. “I think what’s really special about UCSB is that we can have an environment like that.”

Since the paper was written, the researchers have gone into industry, into companies such as Intel and Agilent, or pursued careers in academia.

Researchers on campus are also exploring the possibilities of this technology in the field of thermoelectrics, which studies how temperature differences of a material can create electric voltage or how differences in electric voltages in a material can create temperature differences.

UCSB researchers John Bowers (solid state photonics) and Christopher Palmstrom (heteroepitaxial growth of novel materials) are investigating the potential of this new semiconductor.

The research has been described in detail in the publication, “Self-Assembled ErSb Nanostructures with Optical Applications in Infrared and Terahertz,” by Hong Lu *et al* in *Nano Letters*, 2014, 14 (3), pp 1107–1112. DOI: 10.1021/nl402436g

Nanoparticles create skinny solar cells

Nanostructures on top of an active solar material might be able to capture the light and increase efficiency

Nanostructures could enable more light to be directed into the active layer of solar cells, increasing their efficiency.

Martina Schmid at Helmholtz Zentrum Berlin (HZB), has now measured how irregularly distributed silver particles influence the absorption of light. She demonstrated that nanoparticles interact with one another via their electromagnetic near-fields, so that local “hot spots” arise where light is concentrated especially strongly.

The work has been described in *Europhysics News*, the magazine of the European Physical Society, and points the way for improved designs of these kinds of nanostructures.

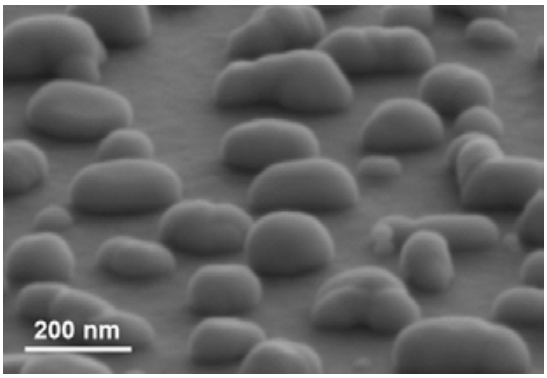
It is desirable, even with thin-film solar cells, to utilise less material and so save on fabrication costs. For example, chalcopyrite cells (i.e. copper-indium-gallium-diselenide, or ‘CIGS’ cells) in part consist of rare-earth elements like indium and gallium.

If the active layer is made too thin, however, it absorbs too little light and the efficiency level drops. Nanostructures on top of the active material might be able to capture the light and thus increase the efficiency. This idea is being pursued by Martina Schmid, who heads the NanooptiX group of junior scientists at HZB and holds a junior professorship at Freie Universität Berlin.

“Our objective is to optimise nanostructures so they selectively direct certain wavelengths of the solar spectrum into the cells,” she says.

Irregularly distributed nanoparticles

One option to achieve this is to construct simple nanostructures from metallic particles that self-organise by heat-treatment of a thin metallic film. Schmid initially coated a glass substrate with a 20nm film of silver, which she subsequently subjected to heat treatment. Irregular silver particles are formed in this way having diameters of around 100nm.



The silver nanoparticles are irregularly shaped and randomly distributed over the surface, as shown by the scanning electron microscope image (Image: HZB)

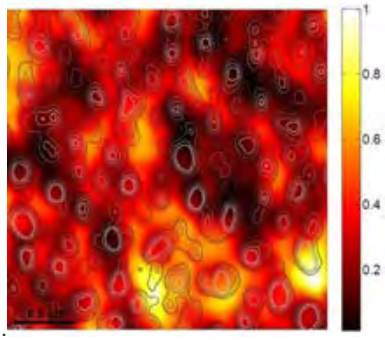
Traversing the sample with the "light pick"

In collaboration with colleagues at the California Institute of Technology (CalTech), Schmid investigated how these types of randomly distributed nanoparticles influence the incidence of light on a cell below. They used a particularly sensitive method known as scanning near-field optical microscopy (SNOM). In this technique, an extremely tiny point scans the sample, determining the topography as with atomic force microscopy.

However, it also simultaneously illuminates the sample through an even smaller aperture in the probe point to create optical excitations (plasmons) in the nanoparticles. These optical excitations can either couple the light into the solar cell as desired - or instead transform the light into heat, whereby it is lost to the solar cell.

It's all about neighbourhood; interactions determine the light scattering

Measurements showed that there can be strong interactions between densely situated, irregularly distributed nanoparticles leading to local "hot spots"



The topography of the sample surface can be seen here (white lines around the nano-particles) as well as the local optical excitations. The image displays several "hot spots" (yellow) that arise through interactions of the nanoparticles with the light and also with one another (Image: HZB/CalTech)

"Whereas the darker regions tend to absorb light and transform it into heat, the hot spots show where nanoparticles strongly interact via their electromagnetic near-fields. In these regions of enhanced fields, energy transformation in the solar cell could potentially be enhanced," Schmid explains.

In the end, areas of stronger fields but also of comparatively weaker ones arise. However, it is difficult to establish a clear relationship between the occurrence of these hot spots and specific nanoparticles.

"The particles mutually affect one another through their electromagnetic near-fields, which are notably more complex than suspected until now. We need to ascertain how we can intentionally create the desired field distributions," says Schmid. She will investigate these questions further at HZB and at the Freie Universität Berlin together with the research group headed by Paul Fumagalli.

More details of this work have been published in the paper, "Scanning near-field optical microscopy on dense random assemblies of metal nanoparticles," by M. Schmid *et al* in *Journal of Optics*, 15, 125001 (2013).

doi:10.1088/2040-8978/15/12/125001.

Boosting the activity of GeS nanostructures

A new development could pave the way to lower cost and safer optoelectronics, solar energy conversion and faster computer circuitry

Chinese researchers have found a convenient way to selectively prepare germanium sulphide nanostructures, including nanosheets and nanowires that are more active than their bulk counterparts.

Germanium monosulphide (GeS) is emerging as one of the most important "IV–VI" semiconductor materials with potential in optoelectronics applications for telecommunications and computing, and as an absorber of light for use in solar energy conversion.

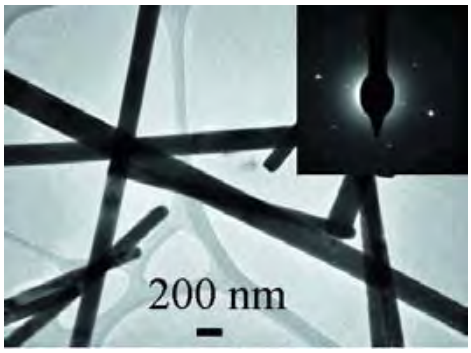
One important property is its much lower toxicity and environmental impact when compared to other semiconductors made with cadmium, lead and mercury. It is less costly than other materials made with rare and noble metal elements.

Indeed, glassy GeS has been used in lasers, fibre optic devices and infrared lenses as well as rewritable optical discs and non-volatile memory devices for several years. It is also used extensively as a solid electrolyte in conductive bridging random access memory (RAM) devices.

The repertoire of this material might be extended much further with the extra control that its use as nanostructured systems might allow. Liang Shi and Yumei Dai of the University of Science and Technology of China, in Hefei, point out that research in this area has lagged behind that with other IV-VI semiconductors.

They hope to change that and have focused on how nanosheets and nanowires of GeS might be readily formed. They have used X-ray powder diffraction, transmission electron microscopy (TEM), energy-dispersive X-ray spectrometry and scanning electron microscopy to investigate the structure, morphology, composition and optical absorption properties of

their samples.



GeS nanowires (main image) and micrograph showing crytallinity (inset)

The team used simple "wet" chemistry to synthesis their products using germanium dichloride-dioxane complex, thiourea and oleylamine (OLA) as starting materials. The ingredients were mixed in a sealed reaction flask, blasted with ultrasound to exclude air and then stirred and heated.

The team was able to make nanosheets of GeS this way if the process was carried out for several hours at 593 Kelvin. At higher temperature, 613 Kelvin, they found that the sheets wind up into nanowires. The precise heating time and temperature allowed them to control the structure of the final product. The team suggests that the rolling up of the nanosheets into nanowires is driven by the surface tension between the sheet and the OLA molecules during the heating.

Having proven the structural integrity of their GeS nanowires and nanosheets, the team built several test devices - a photoresponsive unit - which they used to evaluate the optical and electronic properties of the products. The team says that they have demonstrated "outstanding photoresponsive behaviour". This "indicates the potential use of as-synthesised GeS nanosheets and nanowires in solar energy conversion systems, such as the fabrication of photovoltaic devices".

This work is described in the paper, "Synthesis, formation mechanism and photoelectric properties of GeS nanosheets and nanowires," by L. Shi and Y. Dai in *Journal of Applied Crystallography (2014),* 47, 527-531 doi:10.1107/S1600576713034535

This article was adapted by a story written by Jonathan Agbenyega, Business development manager, at the International Union of Crystallography.

Polymer cools down LEDs at 200 degrees C

A novel thermal interface material could be used to draw heat away from high-brightness LEDs and other semiconductor devices

Polymer materials are usually thermal insulators.

But by harnessing an electropolymerisation process to produce aligned arrays of polymer nanofibres, researchers have developed a thermal interface material able to conduct heat twenty times better than the original polymer. The modified material can reliably operate at temperatures of up to 200 degrees Celsius.

The new thermal interface material could be used to draw heat away from electronic devices in servers, automobiles, high-brightness LEDs and certain mobile devices. The material is fabricated on heat sinks and heat spreaders and adheres well to devices, potentially avoiding the reliability challenges caused by differential expansion in other thermally-conducting materials.

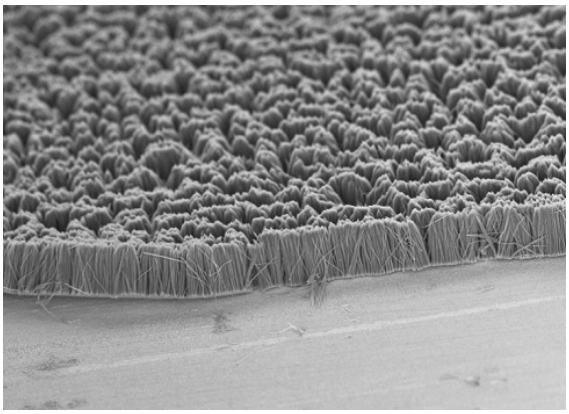
"Thermal management schemes can get more complicated as devices get smaller," notes Baratunde Cola, an assistant professor in the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology. "A material like this, which could also offer higher reliability, could be attractive for addressing thermal management issues. This material could ultimately allow us to design electronic systems in different ways."

The research was reported March 30th in the online publication *Nature Nanotechnology*. The project involved researchers from the Georgia Institute of Technology, University of Texas at Austin, and the Raytheon Company. Virendra Singh, a research scientist in the Woodruff School, and Thomas Bougher, a Ph.D. student in the Woodruff School, are the paper's co-first authors.

Amorphous polymer materials are poor thermal conductors because their disordered state limits the transfer of heat-conducting phonons. That transfer can be improved by creating aligned crystalline structures in the polymers, but those structures - formed through a fibre drawing processes - can leave the material brittle and easily fractured as devices expand and contract during heating and cooling cycles.

According to Cola, the new interface material is produced from a conjugated polymer, polythiophene, in which aligned polymer chains in nanofibres facilitate the transfer of phonons - but without the brittleness associated with crystalline structures. Formation of the nanofibres produces an amorphous material with thermal conductivity of up to 4.4 watts per metre Kelvin at room temperature.

The material has been tested up to 200 0C, a temperature that could make it useful for applications in vehicles. Solder materials have been used for thermal interfaces between chips and heat sinks, but may not be reliable when operated close to their reflow temperatures.

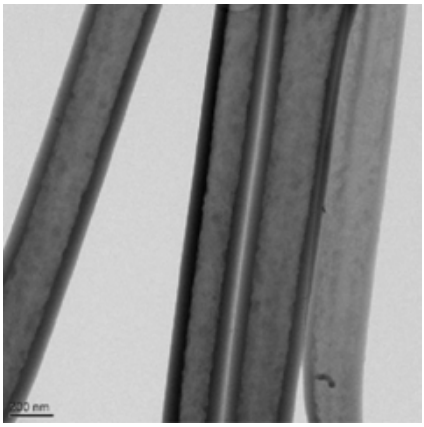


Scanning electron microscope image shows vertical polythiophene nanofibre arrays grown on a metal substrate. The arrays contained either solid fibres or hollow tubes, depending on the diameter of the pores used to grow them. (Credit: Virendra Singh)

"Polymers aren't typically thought of for these applications because they normally degrade at such a low temperature," Cola explains. "But these conjugated polymers are already used in solar cells and electronic devices, and can also work as thermal materials. We are taking advantage of the fact that they have a higher thermal stability because the bonding is stronger than in typical polymers."

The structures are grown in a multi-step process that begins with an alumina template containing tiny pores covered by an electrolyte containing monomer precursors. When an electrical potential is applied to the template, electrodes at the base of each pore attract the monomers and begin forming hollow nanofibres.

The amount of current applied and the growth time control the length of the fibres and the thickness of their walls, while the pore size controls the diameter. Fibre diameters range from 18 to 300 nm, depending on the pore template.



Transmission electron microscope image shows four polymer nanofibres with hollow structure. The thickness of the walls of the tubes ranged from 40 to 80 nm, depending on the amount of current applied and the growth time. (Credit: Ye Cai)

After formation of the monomer chains, the nanofibres are cross-linked with an electropolymerisation process, and the template removed. The resulting structure can be attached to electronic devices through the application of a liquid such as water or a solvent, which spreads the fibres and creates adhesion through capillary action and van der Waals forces.

"With the electrochemical polymerisation processing approach that we took, we were able to align the chains of the polymer, and the template appears to prevent the chains from folding into crystals so the material remained amorphous," Cola explains. "Even though our material is amorphous from a crystalline standpoint, the polymer chains are highly aligned - about 40 percent in some of our samples."

Though the technique still requires further development and is not fully understood theoretically, Cola believes it could be scaled up for manufacturing and commercialisation. The new material could allow reliable thermal interfaces as thin as three microns - compared to as much as 50 to 75 µm with conventional materials.

"There are some challenges with our solution, but the process is inherently scalable in a fashion similar to electroplating," he says. "This material is well known for its other applications, but ours is a different use."

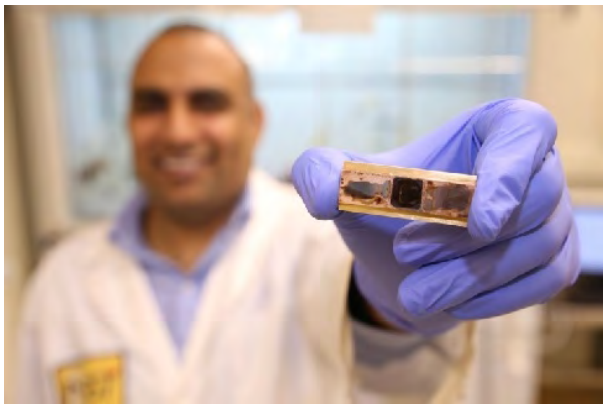
Engineers have been searching for an improved thermal interface material that could help remove heat from electronic devices. The problem of removing heat has worsened as devices have gotten both smaller and more powerful.

Rather than pursue materials because of their high thermal conductivity, Cola and his collaborators investigated materials that could provide higher levels of contact in the interface. That's because in some of the best thermal interface materials, less than one percent of the material was actually making contact.

"I stopped thinking so much about the thermal conductivity of the materials and started thinking about what kinds of materials make really good contact in an interface," Cola comments. He decided to pursue polythiophene materials after reading a paper describing a "gecko foot" application in which the material provided an estimated 80 percent contact.

Samples of the material have been tested to 200 0C through eighty thermal cycles without any detectable difference in performance. While further work will be necessary to understand the mechanism, Cola believes the robustness results from adhesion of the polymer rather than a bonding.

"We can have contact without a permanent bond being formed," he adds. "It's not permanent, so it has a built-in stress accommodation. It slides along and lets the stress from thermal cycling relax out."



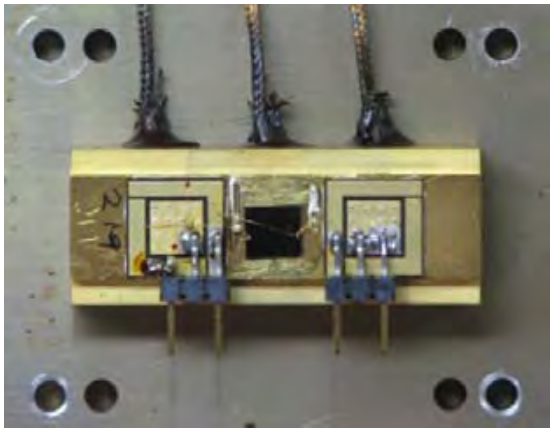
Research scientist Virendra Singh holds a test sample used to measure thermal conductance and thermal cycle reliability in a new polymer material developed to remove heat from electronic devices. (Georgia Tech Photo: Candler Hobbs)

A patent application has been filed on the material. Cola has formed a startup company, Carbice Nanotechnologies, to commercialise thermal interface technologies. It is a member of Georgia Tech's VentureLab program.

The research has been described in the paper, "High thermal conductivity of chain-oriented amorphous polythiophene," by Virendra Singh, *et al*. in *Nature Nanotechnology, 2014*. doi:10.1038/nnano.2014.44

http://www.dx.doi.org/10.1038/nnano.2014.44

This research was supported by the National Science Foundation (NSF) through award CBET-113071, a seed grant from the Georgia Tech Centre for Organic Photonics and Electronics and an NSF-IGERT graduate fellowship. Any conclusions or opinions are those of the authors and do not necessarily represent the official views of the NSF.



This image shows testing of a polythiophene nanofibre array grown on a copper heat sink and dried in contact with a SiC RF device simulator. (Credit: Daniel P. Resler)

POET Technologies applies for quantum computing patents

The innovator of III-V devices has also taken on ex Fairchild executive Daniel DeSimone as VP of Product Development at the POET laboratories

POET Technologies, the developer of the planar opto-electronic technology (POET) platform for monolithic fabrication of integrated circuit devices containing both electronic and optical elements on a single semiconductor wafer, has added to its key staff.

The firm has taken on Daniel DeSimone at the POET laboratories as Vice President, Product Development.

POET Technologies is also set to rapidly expand its intellectual property (IP) assets.

The company has filed new IP portfolio protection documents with the U.S. Patent and Trademark office (USPTO) and in other key jurisdictions to support strategic applications in POET-based quantum computing.

DeSimone was most recently Senior Manager, Test and Wafer Sort Engineering, at Fairchild Semiconductor. Under his leadership, the Fairchild team achieved significant increases in quality and yield during wafer production in several 0.5 and 0.35 micron CMOS/BiCMOS/BiPolar technologies.

In addition to manufacturing experience, DeSimone brings to the company two distinct experiences. The first is a strategic product roadmap definition - addressing server and storage vertical markets. The second is broad integrated circuit development encompassing analogue mixed signal through large digital application specific integrated circuits.

Peter Copetti, Executive Chairman and interim CEO, notes, "Over the last few months, the company has moved dramatically from proof-of-principle through lab device demonstration, full third-party validation with a commercial foundry and working with select potential partners on technical design kits."

He adds, "We are entering a new parallel stage - increasing quality and design robustness for manufacturability as part of commercialisation of our game changing IP - and Mr. DeSimone's combined experience is exactly what we need to assist the team in moving to the next level."

POET-Based Quantum Computing IP

The company is also announcing a key expansion of its IP asset base. The firm already has a large inventory of key and ancillary patents protecting its unique platform for monolithic fabrication of integrated circuit devices containing both electronic and optical elements on a single semiconductor wafer. Details of the existing portfolio are available through USPTO.

In addition to this portfolio, the company recently filed for

protection a number of new IP classes with USPTO, as well as in Canada, Japan, Korea, and other key jurisdictions.

"The commercialisation process of the Company's POET platform has historically yielded intellectual assets with future commercial development potential meriting IP protection," says Copetti. "While the company has focused assets and effort on near-term commercialization goals, our labs are generating future IP as well."

The new portfolio includes:

Closed Loop Rectangular Resonators in POET & Thyristor Memory
(OPE-069; 14/238,649; PCT/US12/51265; EPO 12824167.6)
Fiber Optic Coupling Array
(OPE-070; 14/104,230; PCT/US13/74658)
Quantum Dot Lasers in POET for 1310-1550 nm Operation
(OPE-072; 13/921,311)
Universal Memory Cell in POET for DRAM, SRAM and NVRAM Applications
(OPE-073; 13/951,578)
IR Imaging Structures in POET based on Quantum Dot Epitaxy
(OPE-074; 14/023,525)
Whispering Gallery Mode Resonators in the Planar OptoElectronic Technology; and Implementation of 1550 nm Optoelectronics in the Planar OptoElectronic Technology

Copetti adds, "In this latest round of patent applications, the company has filed patent protection for IP that, in the medium-to-long-term, supports theoretical quantum computing applications, such as the fabrication of quantum dot-based spin qubits and the devices needed to read and write them on the same die. With POET integrated optoelectronics, we are already ahead of the curve, and we want to stay that way."

A qubit - also known as a quantum bit – is a unit of information in quantum computing. It is the quantum analogue of a bit in a classical computing system, which would have to be in one of two states. Quantum mechanics allows a qubit to be in a superposition of both states at the same time, a property which is fundamental to quantum computing. The new patent applications are for medium-to-long-term strategic positioning, and they are complementary to the core POET intellectual assets.

Ultra-thin light detectors

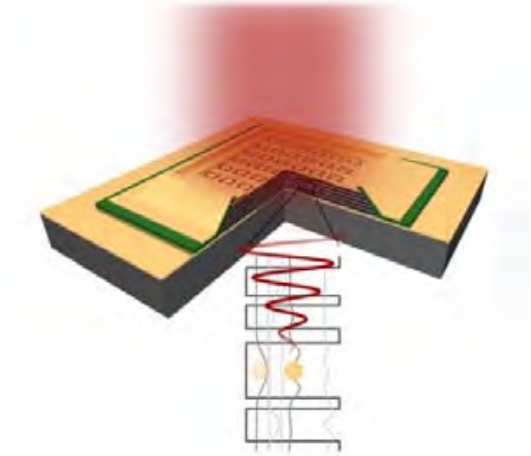
Combining an MBE grown GaAs/AlGaAs quantum cascade laser with a metamaterial opens up the possibility of integrating a light detector for terahertz radiation into a chip

A new, extremely thin kind of light detector was created at Vienna University of Technology. Two very different technologies were combined for the first time: metamaterials and quantum cascade structures.

The quantum-cascade detector is based on a conventional THz-QCL. It consists of a GaAs/Al0.15Ga0.85As heterostructure grown by MBE with the exact growth sequence: 8.0/2.7/6.6/4.1/15.5/3.0/9.2/5.5 nm, where the bold letters represent the Al0.15Ga0.85As barriers and the normal letters the GaAs wells.

Subtle interactions of electrons and light make them very valuable for technology; ultra-thin systems of semiconductor layers can turn electrical voltage into light. But they can also be used the other way around and serve as light detectors.

Until now, it has been hard to couple light into these layered semiconductor systems. Now scientists at Vienna University of Technology say they have solved this problem. They used metamaterials, which are able to manipulate light in the terahertz range due to their special microscopic structure.



Schematic of the detector: the metamaterial couples the incident light to the semiconductor, and then it can be converted into an electric signal

Customised Semiconductor Layers

"Ultra-thin layered semiconductor systems have the great advantage, that their electronic properties can be very precisely tuned", says Karl Unterrainer (TU Vienna).

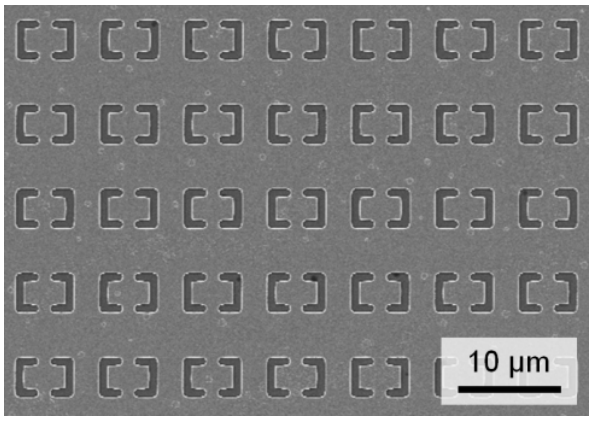
By selecting suitable materials, by tuning the thickness of the layers and the geometry of the device, the behaviour of the electrons in the system can be influenced. That way, quantum cascade lasers can be built, in which the electrons jump from layer to layer and emit a photon with each jump. Also, light detectors can be created, with a selective sensitivity to one particular wavelength.

The problem, however, is that quantum physics prohibits photons with a certain directions of oscillation (polarisation) from interacting with the electrons of the semiconductor system. Light which hits the layered surface head-on cannot influence the electron in the semiconductor. Therefore a method is required to rotate the polarisation of the incident light, so that it can be detected in the semicionductor layers.

This can be done with an unusual method - with metamaterials. A metamaterial has an ordered geometric structure with a periodicity smaller than the wavelength of the incident light.

The light is scattered according to the structure's geometry, some wavelengths may be absorbed, others reflected. The intriguing play of colours on a butterfly's wings comes from exactly this kind of effects. Metamaterials on top of a semiconductor structure are able to rotate the polarisation

of the incoming light so that it can interact with the electrons inside.



The periodic structure and the size of the resonators in the metamaterial define the wavelenth range which can be detected

The light used in the experiment has a considerably longer wavelength than visible light: It is radiation in the terahertz- or infrared regime, with a wavelength of about a tenth of a millimetre. This kind of radiation has important technological applications, for instance for next-generation computer technology, but it is difficult to work with these kind of waves.

A Detector on a Chip

The discovery made at Vienna University of Technology now opens up the possibility of integrating a light detector for terahertz radiation into a chip. “With conventional fabrication methods, large arrays of such detectors can be built”, Unterrainer explains.

They do not take up much space: Layers with a thickness in the order of magnitude of nanometres are enough to detect light – the detector is more than a thousand times thinner than the wavelength of the light which is being detected.

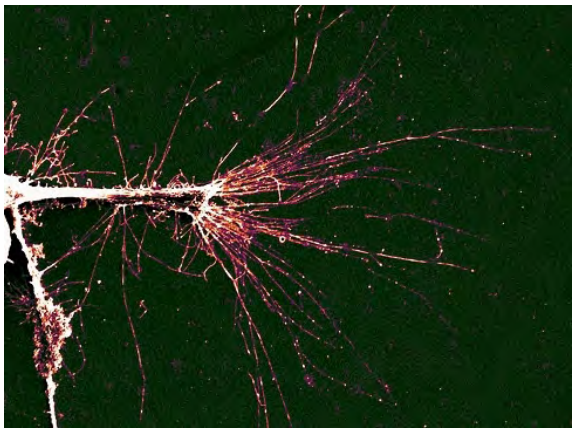
The research is published in the report, “Resonant metamaterial detectors based on THz quantum-cascade structures,” by A. Benz, *et al* in *Nature Scientific Reports,* 4, Article number: 4269. doi:10.1038/srep04269

GaN aids biomedical implantation

University researchers worked with gallium nitride because it is one of the most promising semiconductor materials for use in biomedical applicationsedical implantation

Changing the texture and surface characteristics of a semiconductor material at the nanoscale can influence the way that neural cells grow on the material.

The finding stems from a study performed by researchers at North Carolina State University, the University of North Carolina at Chapel Hill and Purdue University, and may have utility for developing future neural implants.



PC12 cell growing onto a randomly textures surface. Note how the cell is spreading out in all directions

“We wanted to know how a material’s texture and structure can influence cell adhesion and differentiation,” says Lauren Bain, lead author of a paper describing the work and a Ph.D. student in the joint biomedical engineering program at NC State and UNC-Chapel Hill. “Basically, we wanted to know if changing the physical characteristics on the surface of a semiconductor could make it easier for an implant to be integrated into neural tissue - or soft tissue generally.”

The researchers worked with GaN because it is one of the most promising semiconductor materials for use in biomedical applications. They also worked with PC12 cells, which are model cells used to mimic the behaviour of neurons in lab experiments.

In the study, the researchers grew PC12 cells on GaN squares with four different surface characteristics: some squares were smooth; some had parallel grooves (resembling an irregular corduroy pattern); some were randomly textured (resembling a nanoscale mountain range); and some were covered with nanowires (resembling a nanoscale bed of nails).

Very few PC12 cells adhered to the smooth surface. And those that did adhere grew normally, forming long, narrow extensions. More PC12 cells adhered to the squares with parallel grooves, and these cells also grew normally.

About the same number of PC12 cells adhered to the randomly textured squares as adhered to the parallel grooves. However, these cells did not grow normally. Instead of forming narrow extensions, the cells flattened and spread across the GaN surface in all directions.

More PC12 cells adhered to the nanowire squares than to any of the other surfaces, but only 50 percent of the cells grew normally. The other 50 percent spread in all directions, like the cells on the randomly textured surfaces.

“This tells us that the actual shape of the surface characteristics influences the behaviour of the cells,” Bain says. “It’s a non-chemical way of influencing the interaction between the material and the body. That’s something we can explore as we continue working to develop new biomedical technologies.”

The work is described in the paper, “Surface Topography and Chemistry Shape Cellular Behavior on Wide Band-Gap Semiconductors,” by Lauren E. Bain *et al,* in *Acta Biomaterialia.*

DOI: 10.1016/j.actbio.2014.02.038

Quantum Semi and Silvaco to advance modelling of Si-Ge-C superlattices

Si-Ge-C superlattice films enable efficient light absorption and emission across an extended wavelength range, from UV to MWIR

Quantum Semiconductor and Silvaco are to a collaborate to develop advanced TCAD models for silicon-based superlattices.

The TCAD tools and engineering support provided by Silvaco enabled Quantum Semiconductor to receive follow-on SBIR Phase 1B award funding from the National Science Foundation.

The Quantum Semi technology platform addresses some of the most challenging problems facing CMOS today.

Si-Ge-C superlattice films, which have improved optoelectronic properties, enable highly efficient light absorption and emission across an extended wavelength range, from UV to MWIR.

Through their collaboration, Quantum Semiconductor and Silvaco will incorporate new electronic band structure models of the silicon-based superlattices into Silvaco's TCAD tools which will be used to perform advanced device simulations.

"Our vision is to bring new functionality to CMOS by incorporating Si-Ge-C superlattices which allow the efficient absorption and emission of light from UV to Visible to Infrared, enabling new products for image sensing, optical communications, silicon photonics, wide-spectrum photovoltaic cells and even advanced Tunnel MOSFETS," says Carlos Augusto, CTO of Quantum Semiconductor. "

Quantum Semiconductor is very pleased to collaborate with Silvaco. To enable the adoption of these new superlattices into CMOS design and manufacturing, new models must be developed to describe their properties. With Silvaco, we can accelerate the investigation and verification of modeling and optimisation for Si-Ge-C superlattices combined with CMOS."

Silvaco's TCAD tools provide solutions for researchers working on advanced and innovative technologies and will continue to improve their solutions by collaborating with Quantum Semiconductor LLC.

"We are excited to collaborate with Quantum Semiconductor and develop new physical models allowing the use of Si-Ge-C superlattice films in our TCAD flow," adds Eric Guichard, VP of the TCAD Division at Silvaco. "We expect that this partnership will enable Silvaco to provide additional unique solutions to our customers working on the next generation of optoelectronic devices which incorporate these novel superlattice materials."

Enhancing performance of III-V nanowires

Using InGaAs on InAs stems grown on graphene could benefit solar cell and laser technology

Imagine a field of small wires-standing at attention like a tiny field of wheat-gathering the Sun's rays as the first step in solar energy conversion.

Researchers at the University of Illinois at Urbana-Champaign have achieved new levels of performance for seed-free and substrate-free arrays of nanowires from class of materials called III-V directly on graphene.

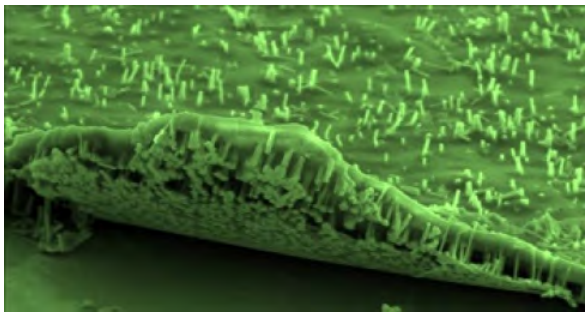
These compound semiconductors hold particular promise for applications involving light, such as solar cells or lasers.

A dense array of nanowires grown directly on graphene. The insets show a higher magnification SEM view of the array and a STEM image of a single, axially heterostructured InGaAs/InAs nanowire

"Over the past two decades, research in the field of semiconductor nanowires has helped to reshape our understanding of atomic-scale crystal assembly and uncover novel physical phenomena at the nanometre scale," explains Xiuling Li, a professor of electrical and computer engineering at Illinois.

In the March 20th issue of *Advanced Materials*, the researchers present the first report of a novel solar cell architecture based on dense arrays of coaxial *p-n* junction InGaAs nanowires on InAs stems grown directly on graphene without any metal catalysts or lithographic patterning.

"In this work, we have overcome the surprising structure (phase segregation) and successfully grown single phase InGaAs and demonstrated very promising solar cell performance," explains postdoctoral researcher Parsian Mohseni, first author of the study.



The InGaAs/InAs nanowire array can be lifted from its graphene base and transferred to alternative platforms for bendable device applications (Credit : Parsian Mohseni)

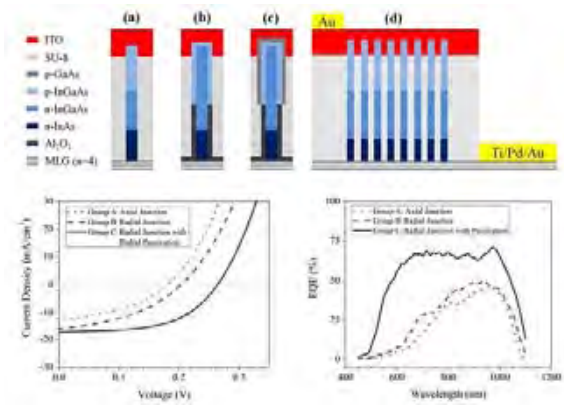
"Depending on the materials, nanowires can be used for functional electronics and optoelectronics applications," Mohseni adds. "The main benefits of this III-V photovoltaic solar cell design are that it is fairly low-cost, substrate-free, and has a built-in back side contact, while being conducive to integration within other flexible device platforms."

Li's research group uses a method called van der Waals epitaxy to grow nanowires from the bottom up on a two-dimensional sheet, in this case, graphene. Gases containing gallium, indium, and arsenic are pumped into a chamber where the graphene sheet sits, prompting the nanowires self-assemble, growing by themselves into a dense carpet of vertical wires across the graphene's surface.

In their earlier work in *Nano Letters 2013* using a graphene sheet, the researchers discovered that InGaAs wires grown on graphene spontaneously segregate into an InAs core with an InGaAs shell around the outside of the wire.

To improve the materials' efficiencies for solar power conversion, the researchers bypassed the unique Van der Waals epitaxy induced spontaneous phase segregation by inserting InAs segments in between.

The resulted ternary InGaAs NW arrays are vertical, non-tapered, controllable in size, height, and doping, and broadly tunable in composition thus energy for monolithic heterogeneous integration with 2D Van der Waals sheets including graphene.



Schematic representations of the three different nanowire geometries investigated (a-c) and a diagram of a nanowire array-on-graphene prototype solar cell device structure (d). The characteristic illuminated current density-voltage (J-V) curves and external quantum efficiency (EQE) spectra obtained from the three distinct device structures are shown in the bottom left and bottom right, respectively (Credit : Parsian Mohseni)

Under air mass 1.5 global solar illumination, the core-shell In0.25Ga0.75As (Eg ~ 1.1 eV) nanowire arrays on graphene demonstrate a conversion efficiency of 2.51 percent, representing a new record for substrate-free, III-V NW-based solar cells.

"Although InGaAs is far from being the optimum bandgap materials for high efficiency solar cells, the direct epitaxy on graphene platform established here has significant implications for a wide variety of III-V compound semiconductor NW based solar cells on graphene, as well as light emitters and multi-junction tandem solar cells, all of which can be released for flexible applications," Li says.

This article has been adapted from one by Rick Kubetz, Engineering Communications Office, University of Illinois at Urbana-Champaign.

Compound Semiconductor conference hits a new high

35 presentations equipped delegates with a comprehensive overview of the compound semiconductor industry

Around 300 delegates and over 30 sponsors descended on Frankfurt for the fourth CS International Conference, which was held at the Sheraton Airport Hotel this week.

This must-attend event for the leaders of the compound semiconductor industry set a new standard for its number of presentations.

The conference covered all aspects of the industry, with presentations grouped into six key themes:

Power Electronics
LEDs
Integration of CMOS and III-Vs
Wide Bandgap RF Devices
Front-ends for Mobile Devices
Lasers, PICs & PV

Presentations on these topics highlighted the growing penetration of compound semiconductors into the silicon

industry, and the use of silicon in the making of III-V chips. Leading developers of next-generation CMOS, such as IBM and Imec, are pioneering approaches to integrate high-mobility materials, for example InGaAs, into the channels of transistors in microprocessors, while silicon substrates are viewed as a low-cost platform for making LEDs, as well also power and RF electronics based on GaN.

Meanwhile, power amplifiers that are based on silicon are starting to go head-to-head with those made from GaAs for deployment in the latest smartphones. It appears that devices based on CMOS will gain market share, but GaAs will dominate the market for many years to come.

A more detailed report of the presentations at CS International Conference will appear in the April /May edition of *Compound Semiconductor* magazine. This issue will also contain details of the winners of the coveted CS Industry Awards.

For more information about CS International Conference, and opportunities available for the 2015 event, contact Stephen Whitehurst: stephen.whitehurst@angelbc.com Tel 0044 (0)2476 718 970. www.cs-international.net

Shedding new light on quantum physics for LEDs

Superconductivity and LED technology could provide a new approach to quantum devices

A team of University of Toronto physicists led by Alex Hayat has proposed a novel and efficient way to leverage the quantum physics phenomenon known as entanglement.

The approach would involve combining LEDs with a superconductor to generate entangled photons and could open up a rich spectrum of new physics as well as devices for quantum technologies. These could include quantum computers and quantum communication.

Entanglement occurs when particles become correlated in pairs to predictably interact with each other regardless of how far apart they are. Measure the properties of one member of the entangled pair and you instantly know the properties of the other. It is one of the most perplexing aspects of quantum mechanics, leading Einstein to call it “spooky action at a distance.”

Working with LEDs and superconductors to generate entangled photons (photo courtesy NSERC)

“A usual light source such as an LED emits photons randomly without any correlations,” explains Hayat, who is also a Global Scholar at the Canadian Institute for Advanced Research. “We’ve proved that generating entanglement between photons emitted from an LED can be achieved by adding another peculiar physical effect of superconductivity - a resistance-free electrical current in certain materials at low temperatures.”

This effect occurs when electrons are entangled in Cooper pairs-a phenomenon in which when one electron spins one way, the other will spin in the opposite direction.

When a layer of such superconducting material is placed in close contact with a semiconductor LED structure, Cooper pairs are injected into the LED, so that pairs of entangled electrons create entangled pairs of photons. The effect, however, turns out to work only in LEDs which use nanometre-thick active regions-quantum wells.

“Typically quantum properties show up on very small scales-an electron or an atom. Superconductivity allows quantum effects to show up on large scales-an electrical component or a whole circuit. This quantum behaviour can significantly enhance light emission in general, and entangled photon emission in particular,” Hayat says.
The research was published in *Physical Review B* on March 10th.

http://journals.aps.org/prb/pdf/10.1103/PhysRevB.89.094508

Silicon carbide goes quantum

Carbon anti-site vacancy pairs in SiC are sufficiently bright to allow detection at the single-photon level enabling the generation of single photons at a high repetition rate, This makes them potentially useful qubits for quantum information processing and applications in photonics

Silicon carbide is a semiconductor that is now widely used in a variety of micro-electromechanical systems (MEMS), LEDs and high-power electronics.

Its technological appeal stems from the fact that it is amenable to mature, robust nanofabrication methodologies and possesses both a high Young’s modulus and excellent thermal conductivity.

To many, silicon carbide (SiC) is a material that offers few surprises. Nevertheless, the increasing need for novel materials for implementing quantum technologies and nanophotonic integrated circuits is forcing scientists to revisit several traditional materials - SiC is one of them.

The crucial step in manipulating a material in the quantum regime is the ability to modify and probe individual quantum states, which can be employed as qubits.

Until recently, only diamond has offered a solid-state platform

for optically stable, room-temperature single quantum emitters.

The game has changed now, say scientists Stefania Castelletto and Hannes Kraus and their colleagues. who have isolated single emitters and identified microwave spin qubits in SiC.

The results were reported in the journal *Nature Materials*. The researchers, including those at the University of Sydney, identified individual defects, known as carbon anti-site vacancy pairs, in SiC that are sufficiently bright to allow detection at the single-photon level.

These emitters can generate single photons at a high repetition rate, which makes them potentially useful qubits for quantum information processing and applications in photonics. The defects have the practical benefit that they are optically active at room temperature.

Another notable advantage is their natural abundance in the host matrix. Consequently, there is no need for external ion implantation, as in the case of diamond, or for the epitaxial growth typical of III-V semiconductors.

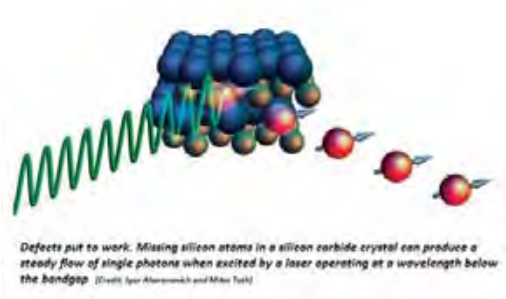
Electron irradiation and annealing provide the material restructuring needed to optically activate the defects. It is thought that the defects are clusters comprising carbon atoms that reside in silicon sites adjacent to carbon vacancies.

In a parallel report in *Nature Physics*, Kraus and his colleagues describe optically induced population inversion of the spin states of another type of single defect in SiC - a silicon vacancy. This result could pave the way to SiC solid-state masers and extremely sensitive travelling-microwave amplifiers.

What's more, by exploiting the double radio optical resonance technique, the team proved that the silicon vacancy has a spin-3/2 ground state - a topic that has been under debate for many years. They are therefore able to detect an optical magnetic-resonance signature from a silicon-vacancy defect at room temperature.

The ability to focus exclusively on a known defect at room temperature in a forest of paramagnetic centres is crucial for practical and scalable engineering of sensors and solid-state devices for quantum information processing.

Missing silicon atoms in a SiC crystal can produce a steady flow of single photons when excited by a laser operating at a wavelength below the bandgap. This is shown in the figure below.



Defects put to work. Missing silicon atoms in a silicon carbide crystal can produce a steady flow of single photons when excited by a laser operating at a wavelength below the bandgap (Credit: Igor Aharonovich and Mike Toth)

So, despite many years of intense research on SiC and its spectroscopic characterisation, why have single-photon emission and unambiguous identification of paramagnetic defects not been previously observed?

The answer to this question is rather simple. In traditional semiconductor physics, most spectroscopy is performed using above-bandgap laser excitation that predominantly excites near-gap emissions.

However, this approach cannot address deep-level states. Instead, individual defect states that reside within the forbidden energy gap must be optically accessed using sub-bandgap excitation. This is a critical issue for wide-bandgap semiconductors.

Indeed, this is the case for the infamous negatively charged nitrogen-vacancy centre in diamond, which is visible on green excitation but inaccessible by ultraviolet excitation.

SiC, not surprisingly, shows similar behaviour. Red and infrared excitation, as was used by Castelletto, Kraus and their colleagues, is not sufficiently energetic to promote electrons into the conduction band, but provides an excellent way to identify new quantum systems at room temperature.

Both works highlight the urgent need to revisit other wide-bandgap materials, including zinc oxide and AlN. Hopefully, it will not be long before more robust room-temperature quantum systems are unveiled.

The pivotal observation of single-photon sources and stimulated microwave emission from SiC complements the recent discovery of novel fluorescent SiC nanostructures (tetrapods) and ushers in a new era for this technologically important material.

Integration of single defects into nanomechanical systems will hopefully pave the way to the burgeoning field of optomechanics and enable unprecedented applications in sensing, quantum information processing and magnetometry.

At last, we may have a convincing candidate for scalable quantum devices at our fingertips.

Molex zCD AOC Interface Scalable Up To 400 Gbps

CDFP module is the first 400 Gb/s form factor and will enable the highest port and bandwidth density of any pluggable form factor

The interface of the recently released Molex Incorporated zCD active optical cable (AOC) interconnect solution has been selected by the CDFP MSA as the interface for the consortium's 400 Gbps hot pluggable module.

"We are pleased to bring to market one of the highest density interconnect assemblies available today," states Scott Sommers, global group product manager, Molex. "The zCD AOC solution delivers a winning form factor that will serve to advance industry adoption of 400 Gbps data rate technology."

Scalable up to 400 Gbps, the zCD interconnect is suitable for high bandwidth telecommunications, networking and enterprise computing data signaling rates. Based on singlemode silicon photonics technology, the Molex zCD AOC assembly transmits 28 Gbps over 16 bi-directional channels with robust signal integrity, electromagnetic interference (EMI) protection and thermal cooling properties. The tight pitch of the zCD interconnect solution enables OEMs to design systems of up to 5 terabytes capacity on one line card.

The zCD AOC transmits up to 4km for a fraction of the cost and power of long-reach optical modules. At 6W of power dissipation, it promises one of industry's lowest power fiber optic solutions and longest AOC reaches. The zCD AOC assemblies are designed for Ethernet, InfiniBand and proprietary protocol applications.

The mating zCD connector is available in a short body version for passive or active copper cables and a long body version for AOCs and transceivers and features a straight, back-route footprint with a 0.75mm pitch. An elastomeric gasket or metal spring fingers provides EMI containment and suppression. Designed to accept a broad range of thermal modules and heat sinks, the press-fit connector design ensures a robust and simple board termination.

"The zCD interconnect solution offers a high level of integration, performance and long-term reliability for Molex customers requiring 400 Gbps with individual lane data rates up to 28 Gbps," adds Sommers.

More research endorses the benefits of WSe2 for LEDs

By making diodes using tungsten diselenide, researchers have shown it is possible to produce photodetectors, photovoltaic cells, and LEDs

A team of MIT researchers has used a novel material that's just a few atoms thick to create devices that can harness or emit light.

This could lead to ultrathin, lightweight, and flexible photovoltaic cells, LEDs and other optoelectronic devices, they say.

Their report is one of three papers by different groups describing similar results with this material, published in the March 9th issue of *Nature Nanotechnology*.

The MIT research was carried out by Pablo Jarillo-Herrero, the Mitsui Career Development Associate Professor of Physics, graduate students Britton Baugher and Yafang Yang, and postdoc Hugh Churchill.

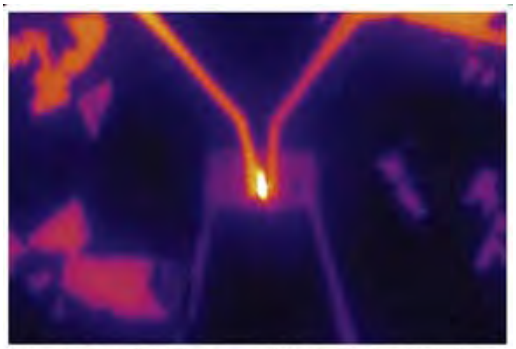
The material they used, tungsten diselenide (WSe2), is part of a class of single-molecule-thick materials under investigation for possible use in new optoelectronic devices - ones that can manipulate the interactions of light and electricity. In these experiments, the MIT researchers were able to use the material to produce diodes, the basic building block of modern electronics.

Typically, diodes (which allow electrons to flow in only one direction) are made by doping, a process of injecting other atoms into the crystal structure of a host material. By using different materials for this irreversible process, it is possible to make either of the two basic kinds of semiconducting materials, *p*-type or*n*-type.

But with the new material, either *p*-type or*n*-type functions can be obtained just by bringing the vanishingly thin film into very close proximity with an adjacent metal electrode, and tuning the voltage in this electrode from positive to negative. That means the material can easily and instantly be switched from one type to the other, which is rarely the case with conventional semiconductors.

In their experiments, the MIT team produced a device with a sheet of WSe2 material that was electrically doped half *n*-type and half *p*-type, creating a working diode that has properties "very close to the ideal," Jarillo-Herrero says.

By making diodes, it is possible to produce all three basic optoelectronic devices - photodetectors, photovoltaic cells, and LEDs; the MIT team has demonstrated all three, Jarillo-Herrero says. While these are proof-of-concept devices, and not designed for scaling up, the successful demonstration could point the way toward a wide range of potential uses, he says.



In the team's experimental setup, electricity was supplied to a tiny piece of tungsten selenide (small rectangle at center) through two gold wires (from top left and right), causing it to emit light (bright area at center), demonstrating its potential as an LED material.

IMAGE COURTESY OF BRITT BAUGHER AND HUGH CHURCHILL

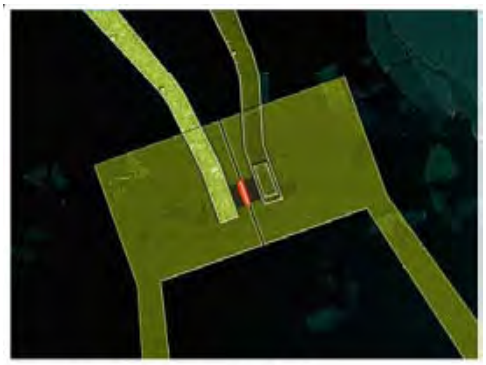
"It's known how to make very large-area materials" of this type, Churchill says. While further work will be required, he says, "there's no reason you wouldn't be able to do it on an industrial scale."

In principle, Jarillo-Herrero says, because this material can be engineered to produce different values of a key property called bandgap, it should be possible to make LEDs that produce any colour - something that is difficult to do with conventional materials. And because the material is so thin, transparent, and lightweight, devices such as solar cells or displays could potentially be built into building or vehicle windows, or even incorporated into clothing, he says.

While selenium is not as abundant as silicon or other promising materials for electronics, the thinness of these sheets is a big advantage, Churchill points out, "It's thousands or tens of thousands of times thinner" than conventional diode materials, "so you'd use thousands of times less material" to make devices of a given size.

In addition to the diodes the team has produced, the team has also used the same methods to make p-type and n-type

transistors and other electronic components, Jarillo-Herrero says. Such transistors could have a significant advantage in speed and power consumption because they are so thin, he says.



Microscope image shows the teams experimental setup.

Kirill Bolotin, an assistant professor of physics and electrical engineering at Vanderbilt University, says, “The field of two-dimensional materials is still at its infancy, and because of this, any potential devices with well-defined applications are highly desired. Perhaps the most surprising aspect of this study is that all of these devices are efficient. ... It is possible that devices of this kind can transform the way we think about applications where small optoelectronic elements are needed.”

The research was supported by the U.S. Office of Naval Research, by a Packard fellowship, and by a Pappalardo fellowship, and made use of National Science Foundation-supported facilities.

IQE`s III-V MBE technology to advance silicon photonics

Along with UCSB, IQE has grown 1.3μm InAs quantum dot lasers on silicon

IQE has announced that its epitaxial wafer technology has been used to help develop next generation quantum dot lasers on silicon substrates.

This is aimed at enabling the integration of photonics devices with silicon technology for low cost, high volume data communication applications.

The results of work by IQE in conjunction with the University of California Santa Barbara (UCSB) will be presented at the Optical Fibre Communications Conference (OFC) which is taking place this week in San Francisco.

Silicon photonics, which combines compound semiconductor devices with low cost silicon substrates, offers the potential to integrate highly sophisticated laser devices with more traditional low cost CMOS driver and waveguide technology.

The researchers believe this work represents an important step towards large-scale photonic integration in an ultra low-cost platform for high volume consumer applications which will lead to the mass adoption of silicon photonics.

A key feature in enabling the cost effective integration of photonic devices with silicon technology is the ability to grow compound semiconductor quantum dots onto silicon substrates using MBE growth technology that has a proven track record for high volume manufacturing of wireless products.

Researchers at UCSB demonstrated a novel quantum dot laser design that not only is grown on silicon but that performs as well as similar lasers grown on their native substrates.

IQE provided both the engineered germanium/silicon substrates and the III-V MBE template growth. The growth of the quantum dot laser structure and fabrication of the laser components were performed at UCSB.

Promising news for solar fuels

A hybrid formed from interfacing GaP with a cobaloxime catalyst could enable renewable solar fuels

Interfacing gallium phosphide (GaP) with a cobaloxime catalyst provides an inexpensive photocathode for bionic leaves that produce energy-dense fuels from nothing more than sunlight, water and carbon dioxide.

Interfacing the semiconductor GaP with a cobaloxime catalyst provides an inexpensive photocathode for bionic leaves that produce energy-dense fuels from nothing more than sunlight, water and carbon dioxide

There’s promising news from the front on efforts to produce fuels through artificial photosynthesis. A new study by Berkeley Lab researchers at the Joint Centre for Artificial Photosynthesis (JCAP) shows that nearly 90 percent of the electrons generated by a hybrid material designed to store solar energy in hydrogen are being stored in the target hydrogen molecules.

Gary Moore, a chemist and principal investigator with Berkeley Lab’s Physical Biosciences Division, led an efficiency analysis study of a unique photocathode material he and his research group have developed for catalysing the production of hydrogen fuel from sunlight.

This material, a hybrid formed from interfacing the GaP with a molecular hydrogen-producing cobaloxime catalyst, has the potential to address one of the major challenges in the use of artificial photosynthesis to make renewable solar fuels.

“Ultimately the renewable energy problem is really a storage

problem," Moore says. "Given the intermittent availability of sunlight, we need a way of using the sun all night long. Storing solar energy in the chemical bonds of a fuel also provides the large power densities that are essential to modern transport systems. We've shown that our approach of coupling the absorption of visible light with the production of hydrogen in a single material puts photoexcited electrons where we need them to be, stored in chemical bonds."

Bionic leaves that produce energy-dense fuels from nothing more than sunlight, water and atmosphere-warming carbon dioxide, with no by-products other than oxygen, represent an ideal sustainable energy alternative to fossil fuels. However, realising this artificial photosynthesis ideal will require a number of technological breakthroughs including high performance photocathodes that can catalyse fuel production from sunlight alone.

Last year, Moore and his research group at JCAP took an important step towards the photocathode goal with their GaP/cobaloxime hybrid.

Gallium phosphide is an absorber of visible light, which enables it to produce significantly higher photocurrents than semiconductors that only absorb ultraviolet light. The cobaloxime catalyst is also Earth-abundant, meaning it is a relatively inexpensive replacement for the highly expensive precious metal catalysts, such as platinum, currently used in many solar-fuel generator prototypes.

From left, Diana Cedeno, Gary Moore and Alexandra Krawicz of the Joint Centre for Artificial Photosynthesis conducted an efficiency analysis study of a unique photocathode material designed to store solar energy in hydrogen molecules. (Photo by Roy Kaltschmidt)

"The novelty of our approach is the use of molecular catalytic components interfaced with visible-light absorbing semiconductors," Moore says. "This creates opportunities to use discrete three-dimensional environments for directly photoactivating the multi-electron and multi-proton chemistry associated with the production of hydrogen and other fuels."

The efficiency analysis performed by Moore and his colleagues also confirmed that the light-absorber component of their photocathode is a major bottleneck to obtaining higher current densities. Their results showed that of the total number of solar photons striking the hybrid-semiconductor surface, measured over the entire wavelength range of the solar spectrum (from 200 to 4,000 nm) only 1.5 percent gave rise to a photocurrent.

"This tells us that the use of light absorbers with improved spectral coverage of the sun is a good start to achieving further performance gains, but it is likely we will also have to develop faster and more efficient catalysts as well as new attachment chemistries. Our modular assembly method provides a viable strategy to testing promising combinations of new materials," Moore says.

"Efficiency is not the only consideration that should go into evaluating materials for applications in solar-fuel generator technologies. Along with the durability and feasible scalability of components, the selectivity of photoactivating a targeted reaction is also critical. This is where molecular approaches offer significant opportunities, especially in catalysing complex chemical transformations such as the reduction of carbon dioxide."

This work is described in the paper, "Energetics and efficiency analysis of a cobaloxime-modified semiconductor under simulated air mass 1.5 illumination." by Alexandra Krawicz *et al* in *Phys. Chem. Chem. Phys*., 2014.

DOI: 10.1039/C4CP00495G

QD Vision develops 'first' 30 nm FWHM quantum dots

The firm's CdSe-CdS emitters are suited to applications such as electronic displays and solid-state lighting

QD Vision has announced the commercial availability of what it says is the industry's first green quantum dots (QD) at 30 nm Full-Width Half-Maximum (FWHM).

QD Vision claims its new 30 nm green QDs and enable display manufacturers to benefit from increased performance when developing high-brightness, full-gamut colour displays.

The firm's LCD products, where blue LED's are used together with red and green QDs emit spectrally narrow red, green and blue colours to obtain full-gamut colour at a good efficiency.

By controlling the FWHM of the QD emission through manufacturing processes, QD Vision says its green and red QDs deliver the necessary colour saturation to achieve 100 percent overlap of any major colour gamut standard. These new 30 nm FWHM 'Color IQ' optics will further improve the colour performance in LCD applications, such as TVs, monitors and all-in-one computers.

"QD Vision continues to keep quantum dots on the leading edge of display technology," says John Ritter, Executive Vice President of Product Development, QD Vision. "Our solutions offer the best down-conversion material on the market today, and we continue to develop even narrower FWHM products to produce the most saturated colours at the highest efficiencies for our customers, both now and in the future."

QDs are semiconductor nanocrystals that possess unique light emitting optical properties. The emission wavelength spectrum of QD light can be tuned to create almost any colour of the visible spectrum as defined by the CIE 1931 colour space.

FWHM, is a simple and well-defined specification used to

measure the narrowness (spectral purity) of the emission from light emitting materials, such as QDs. In short, a narrower QD emission produces a wider colour gamut, resulting in higher colour fidelity and improved backlight performance.

When used in an LCD product, the backlight emission passes through a colour filter. Some colour filters allow light leakage from one colour channel to another, resulting in de-saturated colours.

Unlike conventional phosphors with much broader light emission (e.g. FWHM ~ 60-100 nm), QDs have a narrower emission spectra, which helps to reduce the crosstalk between the colour channels and improve system efficiency. Also unlike phosphors, the individual emission spectrum of QDs can be fine-tuned to match the peak wavelength of a given colour filter to achieve the maximum gamut possible.

Vishay releases AlGaAs and silicon IR emitters/ photodiodes

The high-speed devices are designed for use in IR touch panels and come in 3 mm by 2 mm side-view SMD packages

Vishay Intertechnology has launched two new matched pairs of AEC-Q101-qualified, high-speed 940 nm infrared (IR) emitters and silicon PIN photodiodes in 3 mm by 2 mm side-view surface-mount packages.

For automotive and consumer IR touch panels, the VSMB10940X01/VEMD10940FX01 have a profile of 1 mm while the VSMB11940X01/VEMD11940FX01 offer a profile of 0.6 mm, which Vishay claims is the industry's lowest for side-looking, AEC-Q101-qualified components. These devices offer a 75 degree angle of half-intensity.

The VSMB10940X01/VEMD10940FX01 and VSMB11940X01/ VEMD1194FX01 are designed for use in IR touch panels for devices such as printer displays, eBook readers, smartphones, tablets, and ultrabooks, as well as automotive interior touch displays for multimedia and navigation.

The VSMB11940X01/VEMD11940FX01 allow for slimmer designs in these products while the larger photosensitive area of the VSMB10940X01/VEMD10940FX01 enables higher signal output.

Offered in clear, untinted plastic packages, the VSMB10940X01 and VSMB11940X01 IR emitters feature AlGaAs multi quantum well (MQW) technology. The devices provide high radiant intensity of 1 mW/sr typical at 20 mA, low forward voltage of 1.3 at 20 mA, and fast switching times of 15 ns.

The VEMD10940FX01 and VEMD11940FX01 photodiodes feature a daylight blocking filter matched with 830 nm to 950 nm IR emitters, and they offer reverse light current of 1.1 and 3 microamps, respectively. Both devices provide high radiant sensitivity from 780 to 1050 nm, low dark current of 1 nA, and 950 nm wavelength of peak sensitivity.

The VSMB10940X01/VEMD10940FX01 and VSMB11940X01/ VEMD1194FX01 provide a floor life of 168 hours and moisture sensitivity level (MSL) of 3 in accordance with J-STD-020. RoHS-compliant, halogen-free, and Vishay Green, the emitters and photodiodes support lead-free reflow soldering.

Samples and production quantities of the new IR emitter/ photodiode pairs are available now, with lead times of eight to ten weeks.

O-D GaAs based QDs compete with 3-D

Zero-dimensional gallium arsenide based quantum dots may someday have a big effect on solar energy and lasers

In physics, there's small, and then there's nullity classed as zero-dimensional.

University of Cincinnati researchers have reached this threshold with a special structure that may one day lead to better ways of harnessing solar energy, stronger lasers or more sensitive medical diagnostic devices.

UC student Teng Shi will present her semiconductor nanowire research at the American Physical Society meeting

These structures are GaAs/AlGaAs semiconductor nanowires.

UC doctoral student Teng Shi says she and a team of researchers have observed unique optical signatures indicating that electronic excitations within these nanowires can be confined to a zero-dimensional state called a 'quantum dot'.

This latest discovery is all about going small, but its significance is anything but. The research team's ability to control the confinement energy by varying the size of the quantum dot opens up a world of possibilities.

"Exploring the basic physics of semiconductor nanowires enables one to envision applications or to design structures for applications," says Shi of UC's Department of Physics. "These structures are potential candidates for a variety of applications including photovoltaics, lasers and ultra-sensitive nanosensors"

nanosensors."

Nearly 10,000 professionals, scholars and students will attend the APS meeting to discuss new research from industry, universities and laboratories from around the world.

This research advances work previously done on semiconductor nanowires at UC. By using a thin shell called a quantum well tube and growing it - to about 4 nanometres thick - around the nanowire core, researchers found electrons within the nanowire were distributed in an unusual way in relation to the facets of the hexagonal tube. The result is a quantum wire, like a long string many times thinner than a human hair.

Now they've taken things further, going from one-dimensional wires to zero-dimensional quantum dots. These little structures made using GaAs based materials could have a big effect on a variety of technologies.