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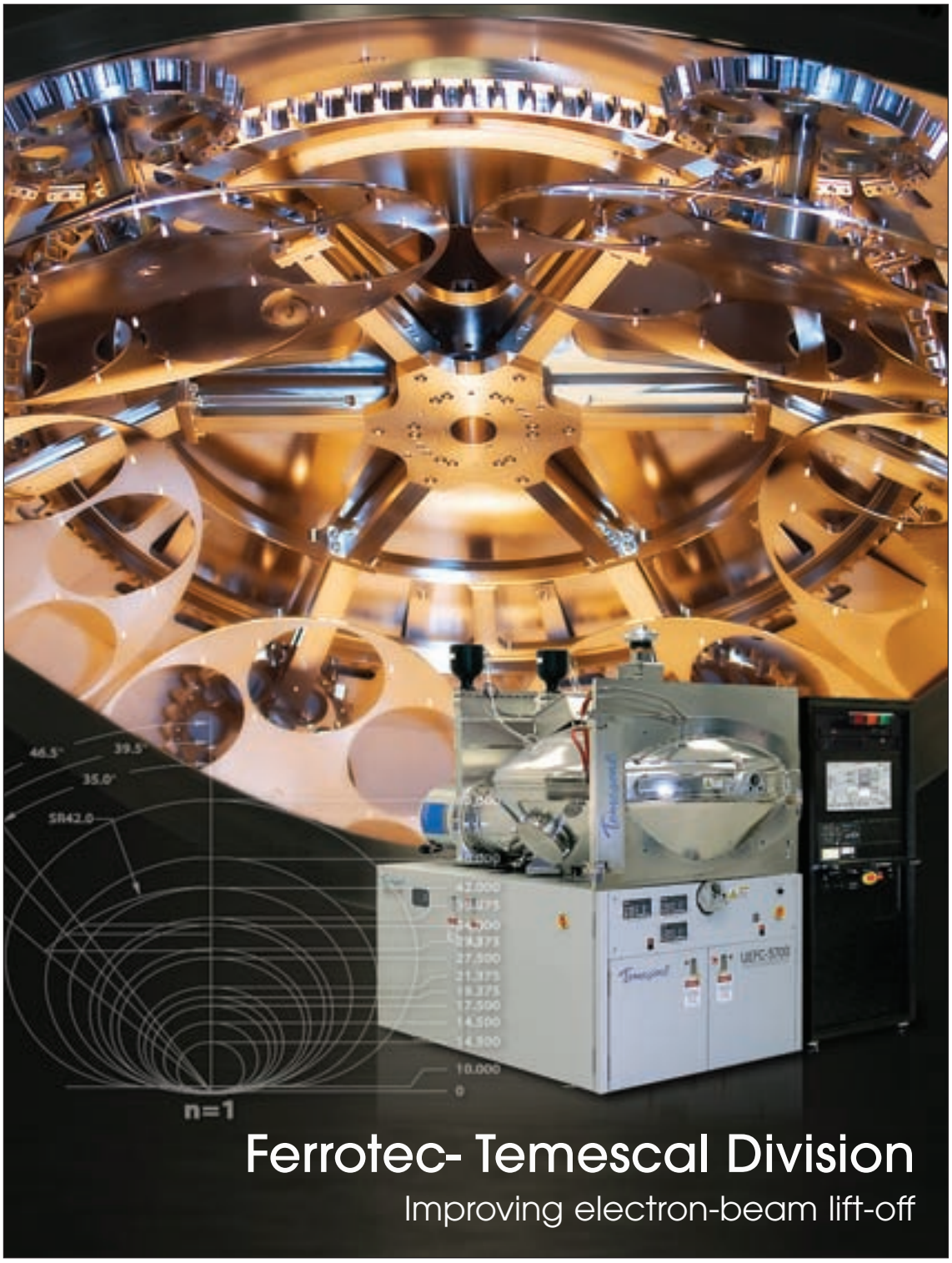


Ferrotec- Temescal Division

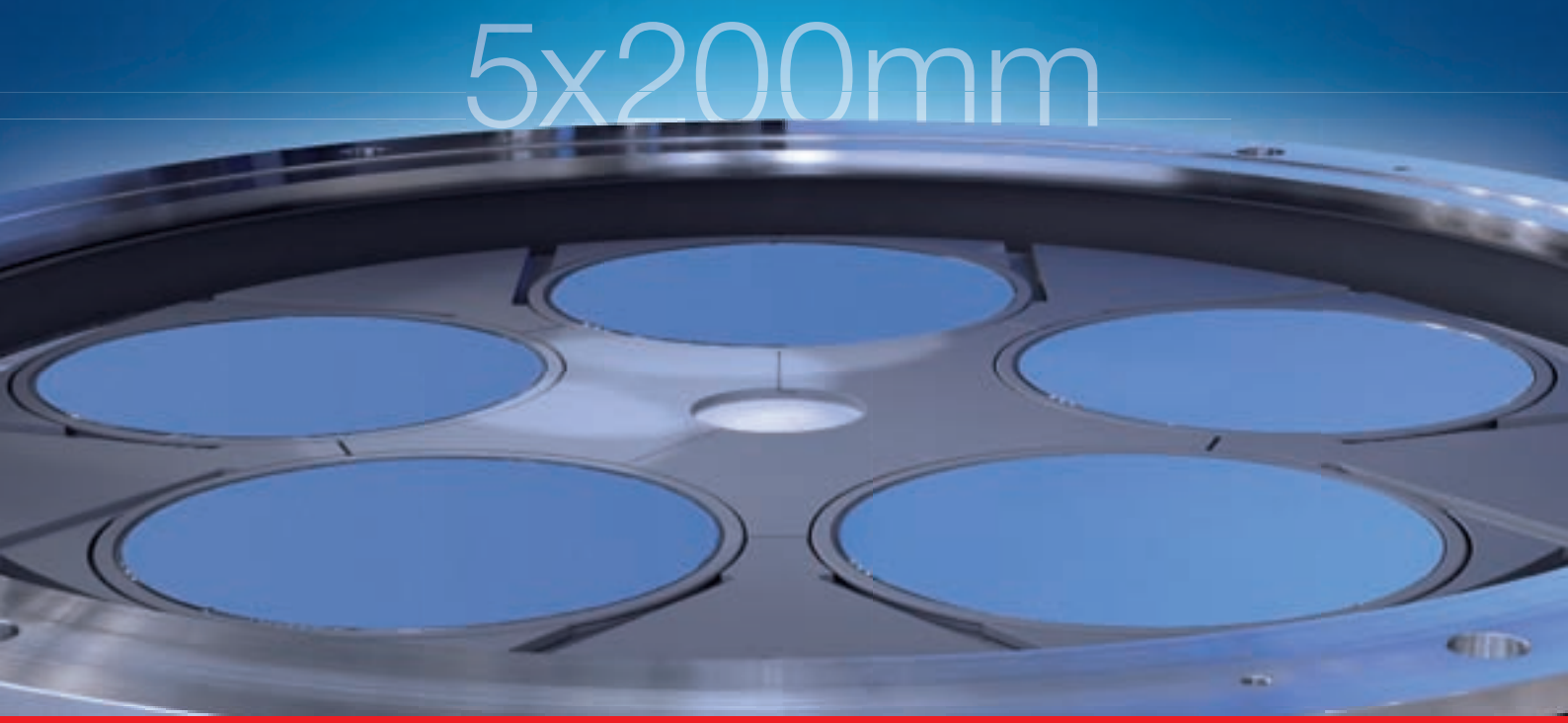
Improving electron-beam lift-off

AN ANGEL BUSINESS COMMUNICATIONS PUBLICATION

March 2013 Volume 19 Number 2

AIXTRON

200mm GaN-on-Si Batch Reactor



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  Excellent and symmetric uniformities,
  controlled bow behavior,
  using standard Si substrates.

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March 2013
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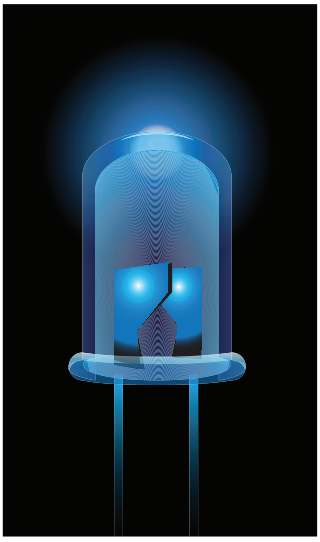
Droop courts controversy again



Some puzzles seem simple, but the deeper you delve into them, the further you are from a solution. That's the case with a selection of endgame positions in chess, various moral dilemmas, and uncovering an explanation for why an LED diminishes in efficiency as the current passed through it is cranked up.

The latter problem, which goes by the name of droop, looks at first sight as though it could be solved by a postgraduate student in a few months. But far, far more hours than that have been devoted to trying to get to the bottom of this mysterious malady, and as of yet, there is no consensus of opinion over its origin.

Until recently, it seemed that theorists were starting to narrow down some of the potential causes of droop. A few years back, some were arguing that it could be caused by Auger recombination, while others had ruled it out, and only more recently has it seemed that if an Auger-related processes is to blame, it must involve phonons and alloy disorder.

Now, however, the simplest form of Auger recombination is firmly back on the agenda, getting the blame for droop once again. This time it is a partnership between researchers at Technion-Israel Institute of Technology and the US Naval Research Laboratory that is making this claim. They argue that they have arrived at a different conclusion from their peers by calculating Auger rates in realistic active regions: Their model includes quantum wells, while those of others are based on bulk material (see page 65 for details).

If they are right, then one way to reduce droop in the wells is to make them thicker, because this reduces the carrier density. However, thicker wells have a major downside in conventional LEDs, because they lead to a separation of electrons and holes, due to the strong internal electric fields in these devices.

An alternative option put forward by the US-Israeli team is to introduce grading into the well. Calculations suggest that this can lead to a three-fold reduction in Auger recombination rates, and boost LED output by a fifth.

It will be interesting to see how the nitride community views this latest contribution to the debate on droop. As it drags on, it seems to me that many researchers are becoming increasingly entrenched in their own views, so I don't think that claims for Auger recombination as the cause of droop will be universally popular. But I expect that they will be welcomed by some.

Dr Richard Stevenson
Editor

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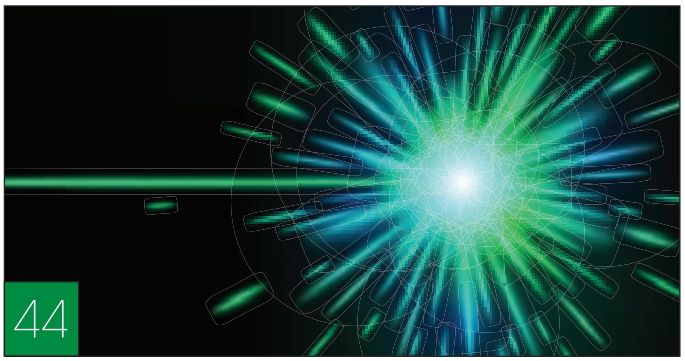

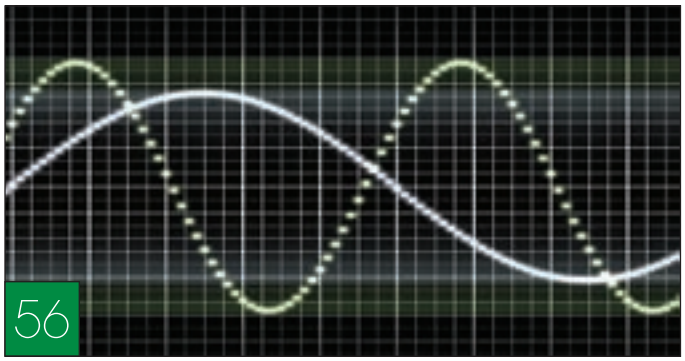

news analysis

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Soraa GaN-on-GaN LEDs break barriers

SORAA has announced the next generation of its high external quantum efficiency GaN-on-GaN LEDs.

The firm says its new LED outperforms the best-documented LED laboratory result by Nichia Chemical Co. at current densities of 100 A/cm^2 and beyond as described in the paper, "White light emitting diodes with super-high luminous efficacy," J. Phys. D: Appl. Phys. 43, 354002).

Soraa has published a paper on its ground breaking LEDs, entitled, "Bulk GaN based violet light-emitting diodes with high efficiency at very high current density" in Applied Physics Letters, 101, 223509. In it, Soraa reports an external quantum efficiency of 68 percent at 180 A cm^{-2}.

"The record breaking performance from our next generation of GaN-on-GaN LEDs is a credit to the extremely talented research and development team at Soraa, and a testament to the vision of our founder and GaN-on-GaN pioneer, Dr. Shuji Nakamura," says Mike Krames, CTO of Soraa. "But what's amazing is that we have just scratched the surface in terms of performance gains from our GaN-on-GaN LED technology."

Soraa says its GaN-on-GaN LEDs handle significantly more current and emit ten times more light per unit area of LED wafer material than LEDs created by depositing GaN layers on cheaper foreign substrates like sapphire, SiC or silicon.

However, the cost of GaN substrates is huge compared to its couterparts. For example, according to Lux Research, bulk GaN currently costs about $1,900 or more for a 2" substrate, compared with $25 to $50 for a far larger 6" silicon substrate. Lux predicts that HVPE (the cheaper alternative to MOCVD) 2" GaN substrate costs will fall by more than 60 percent to $730 per substrate in 2020, while 4" HVPE substrate costs will fall by 40 percent to $1,340 per substrate.

Soraa's GaN-on-GaN technology leverages the advantages of the native substrate, including over a thousand times lower crystal defect densities that allow reliable operation at very high current densities (the same principle that enabled Blu-ray laser diodes).

In addition to superior crystal quality, the native substrate's optical transparency and high electrical and thermal conductivity enable a very robust, simple LED design that delivers maximum performance. Another advantage of the GaN-on-GaN approach is that it enables considerable flexibility in the choice of crystal growth plane.

Solar Junction and Amonix unite to cut CPV costs

SILICON VALLEY-BASED solar energy company Solar Junction, has signed a co-development agreement with Amonix, a designer and manufacturer of utility-scale CPV solar power systems.

"This agreement solidifies a new partnership between two advanced technology leaders in CPV," says Pat McCullough, Chief Executive Officer at Amonix. "It's our goal, by combining our world record module technology with Solar Junction's world record solar cell, that we can increase efficiencies while driving CPV costs down. The results of this collaboration, and its lower levelised cost of electricity (LCOE), will be revealed soon."

In October 2012, Solar Junction surpassed its own world record, achieving 44 percent efficiency at a concentration of 942 suns. Amonix secured the world record for a CPV module in May of 2012, by converting over one-third (33.5 percent) of the energy of direct sunlight into electricity. This record is internationally recognised as the gold standard for solar power efficiency. Together, these benchmarks for high

concentration photovoltaics confirm these companies have a roadmap to reach the forecasted 30 percent cost reduction compared to photovoltaic technologies. The National Renewable Energy Laboratory (NREL) verified both records.

Solar Junction's new record continues to demonstrate the value of its A-SLAM materials, which uniquely provide CPV system manufacturers the foundation to deliver the most efficient conversion of solar to electrical energy. CPV panels work by concentrating sunlight onto small multi-junction cells, which Solar Junction manufactures at its North San Jose facility.

Emcore wins $7.4 million contract from US Air Force

THE AIR FORCE division of the US Department of Defence has awarded Emcore a $7,364,902 cost-plus-fixed-fee contract for the "Advanced Multi-Junction Space Cell Producibility Programme".

The aim of the project is to improve the manufacturing processing capabilities and qualify state of the art solar cells to at least 33 percent efficiency. In a production environment, the program is looking to qualify high efficiency, flexible or rigid, multi-junction space solar cells.

The programme is focussing on a number of critical requirements which are needed in warfight-specific satellites.

These include high performance, lightness, compactness and low cost. The cash will be used to develop Emcore's III-V multi-junction solar cells. The basic structure of the firm's highest efficiency solar cell (currently quoted as a minimum of 29.5%) is shown below.

The project is expected to be completed by April 13th, 2018

Sumitomo to use Soitec technology on GaN substrates

SOITEC and Sumitomo Electric Industries have signed a licensing and technology-transfer agreement. Sumitomo Electric will use Soitec's proprietary Smart Cut technology to manufacture engineered GaN substrates.

This announcement is a key step in the on going strategic alliance, launched in December 2010 to leverage Sumitomo Electric's expertise in materials technology and Soitec's unique Smart Cut layer-transfer technology to develop the global market for GaN substrates used in high-performance LED lighting applications.

The joint development program between Soitec and Sumitomo Electric has already successfully demonstrated the capability to produce four- and six-inch engineered GaN substrates in a pilot production environment. High-quality, ultra-thin layers of GaN have been repeatedly transferred from a single source wafer onto multiple substrates developed by Sumitomo Electric. The engineered wafers have exhibited high functionality at a low production cost.Having proven the effectiveness of the technology- transfer process, Sumitomo Electric will now industrialise the product and invest in Smart Cut technology.
Soitec's Smart Cut technology has been developed in collaboration with the CEA-Leti of France, one of the world's premier microelectronics research laboratories.

It uses both implantation of light ions and wafer bonding to respectively define and transfer ultra-thin, single-crystal layers from one substrate to another. It works like an atomic scalpel, allowing active layers to be managed independently from the supporting mechanical substrate. The technology enables the development of new families of standard and custom engineered wafers. It was made viable for high-volume commercial production by Soitec, and is now protected by more than 3,000 Soitec-owned or controlled patents worldwide.

Soitec leverages the Smart Cut technology to manufacture engineered wafers for the world's leading chipmakers, and holds exclusive rights to use and license this technology to third-party materials and process suppliers.

Nichia powers Excelitas UV LED lighting modules

EXCELITAS TECHNOLOGIES has launched CurX, the firm's first UV LED solution for the printing and curing industry. CurX is suited for demanding applications such as digital ink printing, screen printing, flexo printing, offset printing, and the curing of coatings, adhesives, glues and varnishes.
The CurX UV-LED module is a linear, scalable, high-end UV LED curing "flood" module available in 365 nm, 385 nm and 395 nm ranges of UV output. The device, which incorporates LED technology from Nichia, delivers up to 50 percent higher irradiance than other products on the market, and features an ultra compact design for easy integration.
It also features a sophisticated water cooling system that provides a consistent operating temperature for maximum performance. CurX is comprised of a ceramic substrate with multiple UV LED dies, a driver, and controller for fast switching and easy dimming.

The CurX UV-LED module is fully customisable to meet specific needs of customers and requires no mechanical switches.

"In keeping with our commitment to continuously innovate, I am delighted that the CurX UV-LED module now provides the printing and curing industry with a high-performance, energy-efficient, longer life solution," says Joel Falcone, senior vice president and general manager, Excelitas Technologies.

Mobiles: Qualcomm's CMOS could kick IQE'S GaAs

QUALCOMM TECHNOLOGIES, INC. has introduced the Qualcomm silicon CMOS nbased RF360 Front End Solution.

This is a system-level solution that addresses cellular radio frequency band fragmentation and enables for the first time a single, global 4G LTE design for mobile devices.

Band fragmentation is the biggest obstacle to designing global LTE devices, with 40 cellular radio bands worldwide.

The Qualcomm RF front end solution comprises a family of chips designed to mitigate this problem while improving RF performance and helping OEMs more easily develop multiband, multimode mobile devices supporting all seven cellular modes, including LTE-FDD, LTE-TDD, WCDMA, EV-DO, CDMA 1x, TD-SCDMA and GSM/EDGE.

Qualcomm says its RF front end solution includes the industry's first envelope power tracker for 3G/4G LTE mobile devices, a dynamic antenna matching tuner, an integrated power amplifier-antenna switch, and an innovative 3D-RF packaging solution incorporating key front end components.

Earlier this year, UK based firm Nujira announced its development of silicon based CMOS power amplifiers which also use envelope tracking (see page 10 for details). The firm says these devices boost the linearity, efficiency and output power for CMOS PAs beyond the performance of gallium arsenide power amplifiers (PAs).

The announcement from Qualcomm may well have impacted the share price of compound semiconductor wafer manufacturer IQE. It fell over 13 percent in a day. IQE manufactures gallium arsenide wafers used to make chips in next generation mobiles.

The Qualcomm RF360 solution is designed to work seamlessly, reduce power consumption and improve radio performance while reducing the RF front end footprint inside of a smartphone by up to 50 percent compared to the current generation of devices.

The solution reduces design complexity and development costs, allowing OEM customers to develop new multiband, multimode LTE products faster and more efficiently.

OPEL financing in motion

Concentrating PV developer OPEL Technologies has successfully completed a $7.2 million private placement which was oversubscribed from the previously announced $5.5 million. The financing consisted of 14,400,000 Units at a price of C$0.50 per unit.

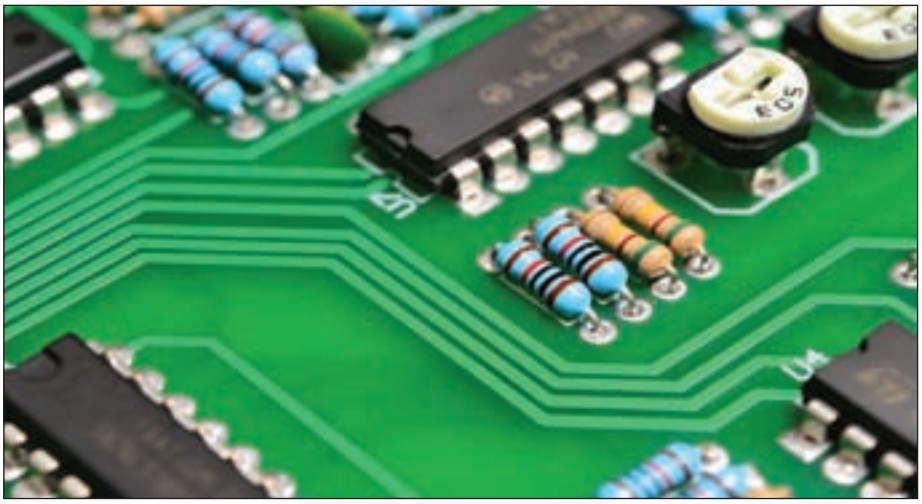
Each unit comprises one common share and one common share purchase warrant. One full warrant allows the holder to acquire one common share of OPEL at an exercise price of C$0.75 per share until February 14th, 2015.

The private placement was conditionally accepted by the TSX Venture Exchange. The securities issued pursuant to the private placement will be subject to a hold period which expires on June 15th, 2013.

The company paid cash commissions of 7 percent of the funds raised and issued a number of broker warrants equal to 10 percent of the units raised. Each broker warrant allows the holder to acquire one common share of OPEL at a price of C$0.50 until February 14th, 2016. The financing was provided by IBK Capital. IBK has a long-standing history of supporting OPEL and its business. This funding will provide the firm with the capital required to complete a $1.3 million equipment acquisition, fund ODIS's internal and third party development efforts, general administrative expenses and working capital.

With the capital in place, OPEL is in a position to aggressively continue development work towards its previously announced milestones and its strategy of the monetisation of the POET Technology.

Power Amplifiers: Nujira CMOS could spell the end for GaAs



UK BASED FIRM Nujira has released the details of significant test results that demonstrate how ET technology unlocks the potential of RF CMOS PAs for high end 3G and 4G smartphone applications.

The firm is a specialist in Envelope Tracking (ET) technology. Envelope tracking is an approach to RF amplifier design in which the power supply voltage applied to the power amplifier is constantly adjusted to ensure that the amplifier is operating at peak efficiency for the given instantaneous output power requirements. Traditional CMOS PAs suffer from low inherent linearity, limiting their application to low cost 2G and 3G devices. ET removes this limitation and boosts the linearity, efficiency and output power for CMOS PAs beyond the performance of today's GaAs PAs, even for high linearity LTE signals.

Extensive lab testing by Nujira has shown that the combination of the firm's ET power modulators and a prototype CMOS PA device achieves the performance required for 4G. The key metrics achieved were 57 percent efficiency, 28dBm average output power, and -38dB ACLR, with a high peak-to-average power ratio LTE signal.
These high end performance results have been made possible by Nujira's patented ISOGAIN Linearisation. ISOGAIN removes the need for Digital Pre Distortion in CMOS PAs and linearises the PA at no extra cost, power or complexity, while keeping the device in a highly efficient compressed state across a wide power control range. By demonstrating the potential for high end applications of CMOS PAs, Nujira has opened the door for what is set to be a hugely disruptive technology shift in the RF market.

Tim Haynes, CEO of Nujira comments, "The exploding complexity of the RF front-end in today's smartphones is driving unprecedented rates of change in the component industry. Our test results are a significant breakthrough, demonstrating that CMOS PAs can also be used in high-end 3G/4G smartphone applications. The combination of CMOS PAs with Nujira's patented ET architectures could ultimately signal the death of the GaAs industry for handset applications. In the longer term, these results open the door for further CMOS integration, enabling a highly integrated RF front-end architecture for complex multi-mode, multi-band handsets."

Nujira's mission is to dramatically improve the energy efficiency of transmitters for 3G and 4G handsets, base stations and TV broadcast applications by reducing the amount of waste energy dissipated as heat in the RF Power Amplifier circuit. Nujira's patented Coolteq Modulator technology dynamically controls the power supply to the circuit in line with the amplitude of the signal, enabling the creation of highly efficient RF Power Amplifiers.

RFMD welcomes envelope tracking

RF MICRO DEVICE'S ET-based solutions leverage the company's leadership in RF power management and cellular power amplifiers (PAs) to improve system-level efficiency in high-data rate applications.

The new RF solutions - the RF7389, RF7390, RF7459, RF8081, and RF8085 - comprise ET PMICs, ET multimode multi-band (MMMB) PAs, and ET ultra-high efficiency PAs.

According to RFMD, the PA products are predominantly gallium arsenide (GaAs based), while the PMIC products are based on silicon.

RFMD's expanding ET product portfolio is compatible with the leading LTE chipsets and provides full ET compatible coverage of all FD-LTE and TD-LTE bands (1-14, 17-21, 25-28, 38, 40, 41, and 44). RFMD anticipates the combination of ET technology and RFMD's advancements in RF power management will be a disruptive combination that raises the bar significantly in RF performance.

In February, Nujira and Qualcomm announced that they were players in the envelope tracking market using silicon CMOS solutions which could displace GaAs based solutions. Eric Creviston, president of RFMD's Cellular Products Group, says, "RFMD is at the forefront of technology development in RF power management, and we are enthusiastic about the deployment of ET-based solutions.

We believe the importance of power management technologies such as average power tracking (APT) and envelope tracking will continue to expand in smartphones, enabling RFMD to leverage our combined leadership in power amplifiers and RF power management and increase our RF content opportunity."

Lumileds emitters offer best beam candle power?

PHILIPS LUMILEDS has introduced LUXEON S, its second generation illumination-grade multichip emitters. The company says they offer twice the lumen density of existing solutions - an R9 value that exceeds 80 and has 50 percent better Colour over Angle variation over existing solutions.

Designed for retail, architectural and entertainment applications, LUXEON S emitters deliver up to 50 lumens per square millimetre and a high light output of up to 8000 lumens in narrow beams with sharp shadows. The LUXEON S1000, S2000, S3000 and S5000 emitters simplify the design of compact spotlights and downlights for architectural, retail and entertainment lighting solutions.

Because of the challenges in creating a small footprint with tight beam angles and high lumen density, luminaire designers have had to deal with large optics and limited lumen levels.

With LUXEON S, luminaire designers have more flexibility and can achieve beam angles in the 8 degree range in a compact design, with light levels that rival traditional CDM light sources.

The firm claims this flexibility enables never-before-possible Centre Beam

Candle Power of over 50,000 candela, compared to other LEDs, like Chip on Board solutions, with a larger Light-Emitting Surface that achieve less than 20,000-25,000 candela.

The new emitters feature correlated colour temperatures of 2700K and 3000K with a CRI of 80 or 90, as well as CCTs of 3500K, 4000K and 5000K at CRI of 80. In the 90 CRI products, R9 value exceeds 80, making them ideal for applications requiring exceptional colour renderings such as in premium retail and museum applications.

Cree smashes R&D record with 276 lumen-per-watt LED

CREE claims it has hit another industry first with a barrier-breaking 276 lumen-per-watt white R&D power LED.

This significant milestone exceeds Cree's previous R&D industry record of 254 lumens per watt and demonstrates Cree's continued commitment to innovate and accelerate the adoption of LED lighting.

Cree's innovative SC^3 Technology Platform, available today in Cree XLamp LEDs, enables this record-breaking R&D result. The SC^3 Technology Platform features advancements in LED chip architecture and phosphor and boasts a new package design to deliver the most advanced LED components in the industry. Cree reports that the LED efficacy was measured at 276 lumens per watt, at a correlated colour temperature of 4401 K and 350 mA.

"The core of the Cree R&D culture is a relentless focus on innovation that ultimately drives LED adoption," says John Edmond, Cree co-founder and director of advanced optoelectronics. "The innovation from our labs is the foundation for our lighting-class XLamp LEDs. Higher performance LEDs can enable new and better LED-based applications and drive down the solution cost of LED designs."

BACC & Bridgelux advance LED street lighting

THE BAY AREA CLIMATE COLLABORATIVE (BACC) and Bridgelux are collaborating to accelerate the market for advanced street lighting technologies through the Bay Area Next Generation Streetlight Initiative.

The initiative is a region-wide project to upgrade over 200,000 municipal streetlights to the next generation of LED technology.

In partnership with the nationally-recognised UC Davis California Lighting Technology Centre (CLTC), the BACC is delivering leading-edge education, tools and guidance through the Bay Area Next Generation Streetlight Initiative, to accelerate the move to next generation streetlighting.

Bridgelux's sponsorship of the Initiative will support outreach to Bay Area municipalities on the LED lighting opportunity, as well as the development of key resources. These include the recently published guide "Next Generation Streetlights: LED Technology and Strategies for Action," which delivers education and specific steps for streetlight conversions.

With the ultimate goal of pooling regional interest in LED streetlight conversions to secure improved purchase and financing terms, the initiative will serve as a business model that local governments can replicate to upgrade streetlights at lower costs, relieving municipal budgets while bolstering the region's economy.

Over five years, regional upgrades could deliver up to $50 million in reduced costs for local governments, over 100,000 metrics tons of CO2 avoidance, and many jobs. The BACC is a public-private partnership initiative of the Silicon Valley Leadership Group, launched by regional civic and business leaders in 2009 to accelerate the Bay Area clean energy economy through high-impact, market-oriented projects that can be replicated and scaled.

Transphorm changes the face of power conversion with GaN

AT THE 2013 ARPA-E Energy Innovation Summit, Transphorm announced that its novel 600V GaN module has enabled the world's first GaN-based high power converter.

Transphorm will demonstrate the High Electron Mobility Transistor (HEMT) products, built with its customer-partner Yaskawa Electric, Japan at the APEC 2013 industry conference. The announcement underscores the significant technical and commercial progress that Transphorm has made since being awarded ARPA-E funding in 2011 to reduce the vast amount of electric power waste globally.

Yaskawa's product, a 4.5kW PV power conditioner, is powered by Transphorm's 600V GaN half-bridge modules, which have enabled it to achieve several industry firsts. It is claimed to be the first high power converter product in the world utilising GaN technology and also the first efficient PV power conditioner to operate at 50KHz.

Simultaneous achievement of a 40 percent reduction in inverter size and 98 percent efficiency operation is enabled by Transphorm's EZ-GaN module technology.

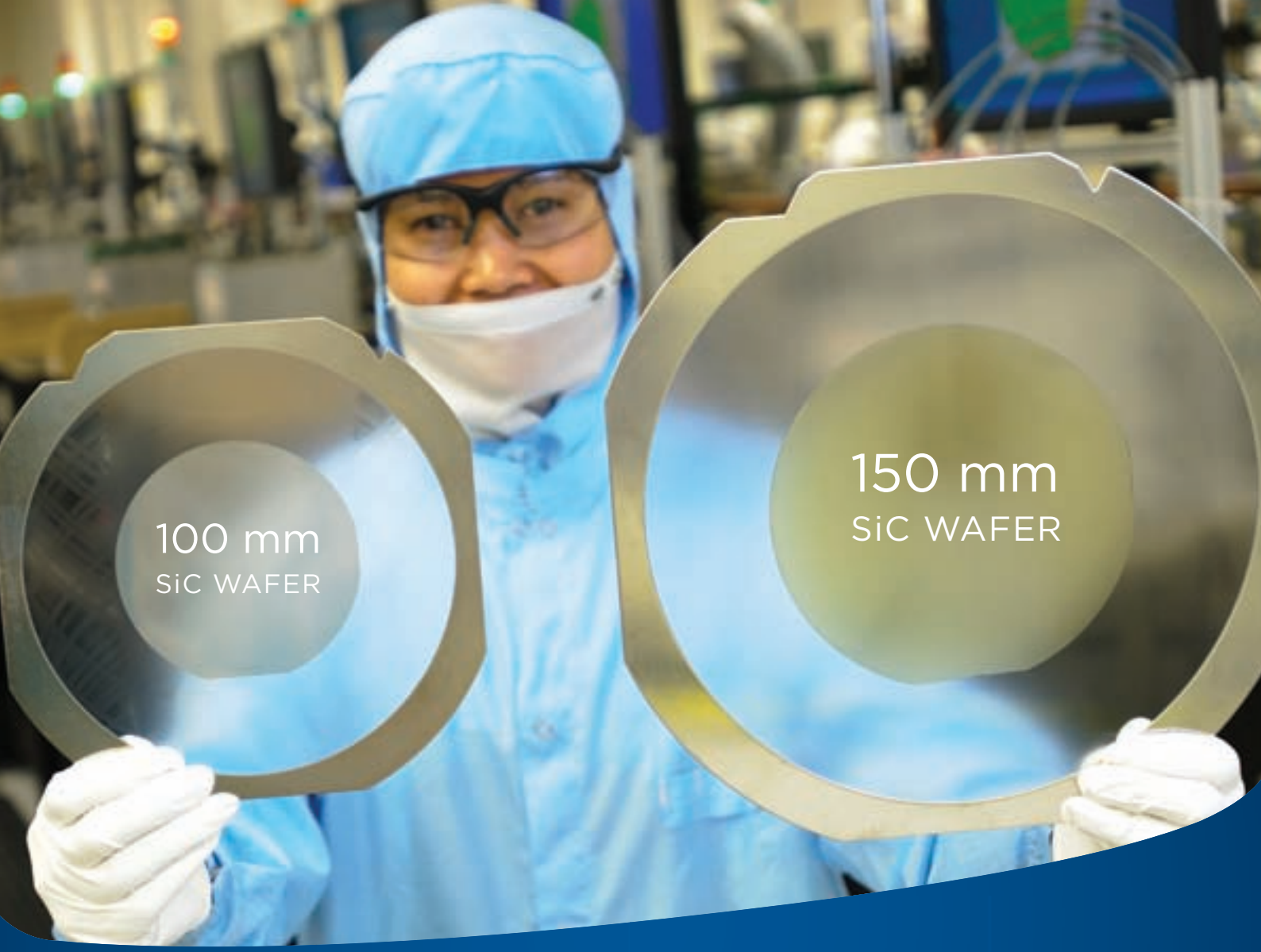
Transphorm's patented, high-performance EZ-GaN module technology, combines low switching and conduction losses offering reduced energy loss of over 50 percent compared to conventional silicon based power conversion designs while simultaneously operating at higher frequency.

"The partnership between Yaskawa, the world leader in inverter solutions, and Transphorm, the world leader in GaN-based power conversion, has produced the world's first high power GaN power converter," says Umesh Mishra, CEO of Transphorm. "This is a disruptive first step which signals the broad adoption of GaN-based power conversion solutions."

"By teaming with Transphorm, Yaskawa is again the technology leader in introducing new technologies into the market place with tremendous benefits to customers and society" adds Tatsuya Yamada, General Manager Environment & Energy Business Div. Drives Division of Yaskawa Electric.

Transphorm's efficient, compact, and easy-to-embed solutions simplify the design and manufacturing of a wide variety of electrical systems and devices, including power supplies and adapters, PV Inverters for solar panels, motor drives and power conversion for electric vehicles.

The firm's EZ- GaN platform can reduce power system size, increase energy density and deliver high efficiencies across the grid. For customers looking for a low-risk roadmap to the next generation of power conversion technology, EZ-GaN provides a cost-effective and easy-to-use solution ready for commercial scale.



CREE SiC AND GaN MATERIALS

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With more than 25 years of development and manufacturing experience, Cree is driving innovation with the industry's broadest range of SiC and GaN materials. Delivering substrate and epitaxy options in up to 150 mm diameters, Cree provides a vertically integrated materials product offering combining industry-leading volume, scale, quality and vast intellectual property portfolio.

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- 150.0 mm

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- p-type
- High Purity SI

SiC epitaxy:
- n-type
- p-type
- thick epitaxy

GaN epitaxy:
- GaN, AlN, AlGaN, InGaN, SiN layers
- HEMT structures

Cree materials are ISO/TS 16949 certified.

CREE®

LumaSense tool could reduce wastage

LumaSense Technologies has released the UV 400 and UVR 400 pyrometers.
These are the newest generation of non-contact temperature measurement instrumentation for MOCVD processes in the LED industry. The company believes the UV 400 and UVR 400 are in a unique position to help manufacturers using MOCVD improve efficiency and reduce waste in their LED manufacturing process. Using a centre wavelength in the UV spectrum (400nm) these pyrometers make it possible to measure real wafer surface temperature, while traditional pyrometers are only able to measure the susceptor/pocket temperature under the wafer. This allows the most accurate and repeatable control of the wafer temperature which in LED production is critical to the final product wavelength and manufacturing yields. The wide temperature range of 650 to 1300°C allows for measurement of various applications such as GaN buffer layer growth or multiple quantum well growth.
The fast response time of up to 8ms allows the measurement of fast processes.

True photon-counting instrumentation guarantees the best achievable signal to noise ratio and stability. In addition to the UV 400 pyrometer, the UVR 400 features a 635nm laser reflectometer, which enables the real-time measurement of the thickness and growth rate of the GaN layer during epitaxy growth.

GT & Soitec to collaborate

GT ADVANCED TECHNOLOGIES (GT) and Soitec have signed a development and licensing agreement allowing GT to develop, manufacture and commercialise a high-volume, multi-wafer HVPE system.

The tool will be used to produce high-quality GaN epi layers on substrates used in the LED and other growth industries such as power electronics. The higher growth rates and improved material properties made possible by the HVPE system are expected to significantly reduce process costs while boosting device performance compared with the traditional MOCVD process.

Initial pre-payment of the licensing fees as outlined in the agreement is already underway, but further specific terms were not disclosed.GT will develop, manufacture and commercialise the HVPE system incorporating Soitec Phoenix Labs' (a subsidiary of Soitec) unique and proprietary HVPE technology.This will include a novel and advanced source delivery system that is expected to lower the costs of precursors delivered to the HVPE reactor. The HVPE system will enable the production of GaN template sapphire substrates on a large scale.

Forepi orders multiple Aixtron CRIUS II-L reactors

In the third quarter of 2012, long-term customer Formosa Epitaxy Inc. (Forepi), Taiwan, placed a new order for multiple CRIUS II-L MOCVD production systems in a 69 x 2-inch configuration. All systems will be used for the manufacturing of ultra-high brightness (UHB) GaN-based blue and white LEDs. Aixtron's local service team started installing and commissioning the new systems in the fourth quarter of 2012 at Forepi's new factory in the Pin-Jen industrial zone, Taiwan. Delivery will be completed in the second quarter of 2013.

In May 2012, Forepi had already purchased several CRIUS II-XL and AIX G5 HT reactors.

"This new order reflects our on-going satisfaction with Aixtron's products," comments Forepi's chairman Frank Chien. "Aixtron has proven itself as an excellent partner, providing superior customer care by responding to our requests and delivering the needed solutions. With short time-to-production, and highest performance and throughput, Aixtron's latest MOCVD generations meet the specific challenges of larger wafers and maximum chip yields."

All CRIUS II-L systems will be delivered with Aixtron's new ARGUS Topside Temperature Control (TTC) system. The new method eliminates temperature variation within each run and run-to-run, enabling unmatched production yields. "This latest multiple tool order reflects Forepi's growth as a top-tier LED chip manufacturer. We are pleased to support this prized customer with our latest technology. Besides reactor size and design, we believe that successful in-situ measurement and control offer the greatest optimisation potential because they provide a direct impact on yields," comments Christian Geng, General Manager Aixtron Taiwan.

Opel Technologies alters stock option

OPEL TECHNOLOGIES INC Board of Directors has amended the company's stock option plan to increase the number of shares reserved for issuance under the Plan from 18,472,000 to 26,475,000. The reserved number of 26,475,000 represents 20 percent of the issued and outstanding common shares of the company. The current plan was approved by shareholder on June 21st, 2011. This amendment to the plan is subject to the approval of the TSX Venture Exchange and will be submitted for shareholders approval at the upcoming AGM in June.

There are currently 17,399,000 options outstanding under the plan and 461,000 options available for future grants. With the increase in the reserved number, the company will have 8,003,000 available options for future grants under the amended plan.

As Cree's lighting sales rise, its LED lights shine bright on Central Park, US. (Cree)

LED market teeters on recovery

Do Cree's rising sales finally signal sustained growth for the LED industry? asks Compound Semiconductor.

Following pleasing earnings, Cree's Chuck Swoboda has high hopes for future growth in LED industry.

AMID SLOW MARKET TRENDS, US-based LED developer, Cree, recently posted refreshing earnings. Year-on year, revenues rose 14 percent to a record $346 million, while net income increased 69 percent to $20.4 million

The company's strong start to fiscal year 2013 comes at a time when industry's equipment manufacturers, substrate, components and product developers alike, have been anxiously waiting for a massive LED surplus to clear. Put at 45 percent in 2011, and led by oversupply from Chinese manufacturers, growth in demand has been slow. At the same time, saturated demand from the backlight market and a sluggish general LED lighting market, have only added to pressure on average LED selling prices. Do Cree's positive results signal the beginning of the end of these trying times?

Cree's chief executive and president, Charles Swoboda, thinks so. Witnessing rising orders across all his business's segments, LED components, LED lighting, and power and RF products, he says: "We still continue to deal with excess capacity in the LED market, but growth in lighting has started to improve the supply and demand dynamic."

Jonathan Dorsheimer, managing director of Lighting and Solar Equity Research at Canaccord Genuity believes the company has also benefited from timely product introductions to the Chinese

market, including its recent GaN-on-SiC LEDs. "This SC3 product family is cost effective and competitive," he says. "Its simpler design allows for a lower cost structure so Cree has been seeing a lot of margin expansion as a result of traction in the China, and wider Asia Pacific market, with this product."

Indeed, following eight quarters of consecutive declines in gross margin, the end of 2012 offered respite to Cree's margins, which then bounced back to 37.5 percent in the last quarter, and rose again to 39.2 percent, in the latest quarter.

And as Dorsheimer highlights, the company has also taken advantage of recent rapid growth in the solid state lighting market. Its lighting product line grew 14 percent sequentially in this quarter. "The company is known for its 'TrueWhite' technology which gives them an advantage," he adds.

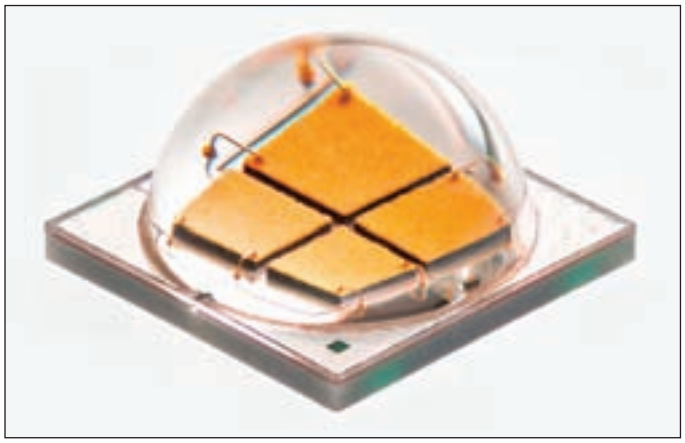
But Cree's technology wins aside, Dorsheimer reckons the LED industry is actually picking up, saying: "[We're at] the cusp of beginning a multi-year bullish secular growth scenario."

As government policies eradicate incandescent and halogen bulbs, and demand for LED alternatives rises, the gap between conventional and LED lighting prices will close. Indeed, Dorsheimer anticipates a price competitive product by 2014. "This is only natural," he adds. "The price gap will close and an inflection [in LED lighting uptake] will take place at this time."

But as the market matures, longer term challenges will also surface. While Cree is a clear leader alongside other LED manufacturers, including Osram, Nichia, LumiLEDs and Epistar, competition will also come from entrenched fixture companies.

"Incumbent lighting companies such as Acuity and Cooper, have distribution [channels] and brand awareness from a traditional lighting perspective," points out Dorsheimer. "Now they are developing [LED] technology and pulling it in."

Clearly the competition in the LED market will remain intense for some time yet, but Swoboda reckons Cree will hold its own. As he puts it: "We're going to keep pushing, and I think there's lots of technology to be developed... We want to make sure we position Cree as one of the [companies] out there that people should be thinking about first."



Cree's Xlamp MK-R LEDs, based on SC3 technology, boast a luminous efficacy of up to 200 lm/W (at 1W , 25°C) (Cree)

But while Cree drives new products and innovations into the LED lighting and components markets, what about its RF and power electronics business segment? Late last year, the business unveiled the industry's all-SiC high-frequency power module. And now sales across this business segment are reported to have increased more than $2 million from the first quarter with revenues coming in at $22.6 million. The future looks bright and as Swoboda says, Cree will now expand its SiC power module family in the coming year. But while he expects sales to continue to rise, without a doubt, the LED market is where the action will be.

"In the LED industry we are going from basically 0 percent penetration to [as much as] 80 percent penetration over the next ten years, a multi-billion dollar industry is being created," says Dorsheimer. "In contrast, the power and RF market is very fragmented with chips going into, say, electric cars and solar inverters. A company such as Cree might get a pop at one of these markets, but the long-term sustainable growth isn't there yet."

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Emcore retreats to the skies

Business is buoyant for exotic solar cells in space, but back on Earth the industry limps on. *Compound Semiconductor* talks to Emcore to find out more.

IN LATE JANUARY, this year, US-based Emcore, delivered its one millionth multi-junction solar cell to US satellite maker, SSL, previously known as Space Systems/Loral, representing more than a megawatt of power delivered into space.

This landmark figure followed its summer 2012 milestone, which saw the 100th spacecraft powered by its solar equipment launched.

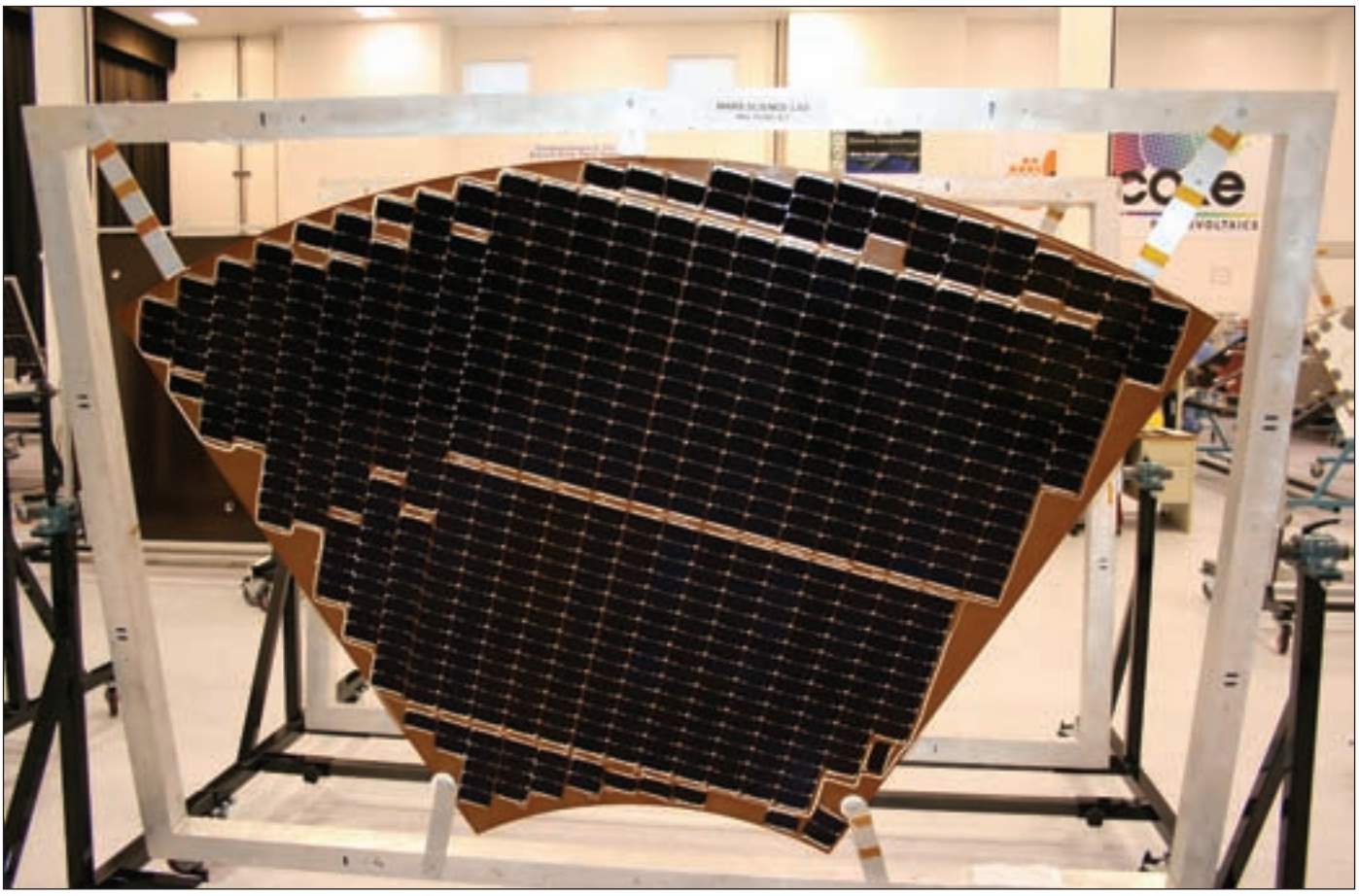
As chief operating officer, Christopher Larocca, said at the time: "We have a total of 120 more satellites under contract to be launched and powered by our solar equipment over the next several years."

But while the solar power and fibre-optics manufacturer's III-V systems continue to find favour in space, the story at ground level is quite different.

In August 2010, Emcore joined forces with San'an Optoelectronics, China, to launch the joint venture Suncore Photovoltaics. Together the businesses were to develop and manufacture CPV modules and systems, for terrestrial applications, that would produce electricity by focusing sunlight onto Emcore's multi-junction solar cell.

In March 2012, manufacture at Suncore's 200 MW Huainan facility started, including the supply of 50 MW to a utility-scale CPV farm in Golmud, one of the sunniest locations in China. And then six months later, Emcore divested its share of Suncore to a US Suncore subsidiary. This time, Larocca said: "This will allow us to focus efforts on our core competency of multi-junction solar cell technology for both space and terrestrial power applications."

But without a doubt, the lion's share of Emcore's solar business lies in space. As vice president of business development, Navid Fatemi, puts it: "The [terrestrial CPV] market has been either flat or declining since 2008, and Emcore was in the systems business all this time. There is 15 MW [of capacity] installed at the Golmud power plant, but we haven't seen much growth anywhere else other than China... so we divested the CPV systems business with Suncore."



An array of Emcore's solar cells for providing power in space

According to Fatemi, the company is still supplying its terrestrial cells to a few domestic customers – "in small quantities relatively speaking" – and sending the bulk of this business to China. But as he highlights, space is where the big wins are for Emcore, now the company has stepped back from the uncertainties of the CPV solar industry.

"Space is the completely dominant market for us," he says. "We have more than 50 percent of the US space market and around 40 percent of the global market, so our outlook [especially] in the States, depends on the satellite industry."

And the company's latest financial results reflect this move. Revenue for the photovoltaics business was up 13 percent to $19.6 million, from the last quarter, which chief executive Hong Hou, attributed to strong demand in space programs. Meanwhile, margins leapt 8 percent to 30.5 percent, following the sale of the lower-margin terrestrial systems lines.

Thanks to a steady stream of satellite-related projects, Hou and colleagues now expect the solar business to generate a "nice" operating profit, with revenues remaining flat, but at the current high level. So what of the future? Fatemi will not be drawn on details, saying: "We expect slight growth for the next year. I've been in this business for many years and every time experts predict a downturn or up-tick, it hasn't, in my view, been very accurate."

Flexibility and high efficiency are two of the major benefits of switching from a conventional cell design to an inverted metamorphic structure

Still, with the company's third generation, triple junction, 29.5 percent efficient solar cell well established - the company recently announced a $5 million contract with ATK to power the AMOS-6 telecoms satellite - attention surely turns to the much-awaited inverted metamorphic (IMM) solar cell. As early as 2007, *Compound Semiconductor* reported company executives flaunting the new architecture, promising at least 33 percent efficiency and delivery by 2010. Today, Emcore predicts the cell will ship come 2016.

"We hold the world record for space solar cell efficiency with this cell and are still very much focused on this architecture," says Fatemi. "We believe we are ahead of world competition with development of the IMM cell, and our belief is we should have qualified products by 2015, and with today's plan, these will be in production by 2016."

Zephyr Photonics eyes high-tech markets

Optoelectronics developer, Zephyr Photonics, has set its sights on datacoms and high performance computing markets as it launches a fab and foundry business, reports *Compound Semiconductor*.

EARLY THIS YEAR, Zephyr Photonics launched a semiconductor fab and foundry unit. At a time when mainstream epiwafer makers are stream-lining assets and the industry consolidates, why would an organisation that has historically developed military-specification components make the bold move of launching this new business?

The Nevada-based optoelectronics developer will not exactly be turning around wafers in the thousands, like epiwafer powerhouse IQE. However, the company will exploit its ITAR-compliant, ISO:9001:2008 certified manufacturing facility to deliver high performance devices to a range of – hopefully – up and coming markets.

Boasting a 'growing staff of PhDs', chief executive Tom Steding says: "Our semiconductor fabrication and foundry services business includes a 10,000 square foot cleanroom, and [will] match the growing demands of fabless semiconductor companies." So what next?

Defence focus

For more than 25 years, Zephyr Photonics - previously called OptiComp - had fabricated InP and GaAs-based photonics devices for the US government. During this time the company developed a vertically-integrated manufacturing facility, honing its III-V MBE growth processes as well as fabricating and assembling harsh environment optoelectronic modules based on proprietary wide-temperature VCSELs.

"We might have used our electron beam lithography to [structure] photonic crystals or lay down a short run of integrated circuit traces onto a structure to create a 3D stack," says Zac Clark, director of Fab Services. "So we have this long history of processing independently from the rest of a manufacturing line... to create any kind of device."

Come 2011, the business had been acquired by Torch Hill Investment Partners, a Washington DC private equity firm that wanted to deliver the company's products to the wider market-place. Steding, ex-chief executive of software security business, Red Condor, was brought in to head up Zephyr, and now he believes the time has come to ramp up activity on all fronts.

As he highlights, the company has two key streams of revenue, for which its foundry services are crucial. First, its components business includes wide temperature VCSELs, detectors and optical benches, designed for harsh environments. For example, the company claims its VCSELs can operate at 5 Git/s at 150 °C or higher, enabling optical interconnects in applications beyond today's commercial 850 nm VCSELs. And then the company also uses these components to manufacture sub-system components and modules including active optical cables and transceivers.

"Our foundry services is the factory for the components business," says Steding. "It keeps us at the leading edge of these technologies, but also supplies these critical components to our module business."

But where are the growing markets? Looking beyond defence applications, the chief executive believes the high-performance computing industry will primarily fuel demand for its business. As well as focusing on reducing cost per Gbit/s, this sector

Chief executive, Tom Steding, believes high performance computing will be a key market for his company.

Zephyr's facility is home to III-V MBE growth, e-beam lithography, automated wafer probing, wafer lapping, die attach and more

demands components that can tolerate high temperatures and process high 10 Gbit/s per channel data rates. Steding is certain Zephyr's products will fit the bill. For example, its VCSELs feature strained InGaAs quantum well active regions for improved gain, while proprietary distributed Bragg reflector designs promise the necessary performance in harsh conditions.

"On board optical interconnects are going to be vital to high performance computing. Our high-temperature components can handle the energy densities and high temperatures of these systems," he adds.

And as Steding's colleague, Tim McAllister, vice president of business development highlights: "The whole silicon photonics market place is opening up. We are looking at partnerships with customers that are seeing an increasing demand for the high density [integration of] VCSELs to support these chips."

But it's not just high performance computing and data communications; the oil and gas, and mining industries are additional target markets. According to Steding, the company's VCSEL designs enable interconnects that operate to 155 °C.

"This resilience to temperature and vibration... [means they are] suited to extreme heat conditions in down hole oil drilling applications," he says.

And the company claims to be already seeing results. "Since we made this announcement, we've had calls from small companies that have been working at a university level but now need more fabrications," claims McAllister. "There is quite a gap between the wafer processing capabilities a university provides and the services and equipment we have been able to put together following years of advanced photonics research."

So 2013 looks like an interesting year for the Zephyr team. Steding asserts the foundry has a lot of spare capacity and its business is ready to ramp up activities to meet new demand.

Meanwhile McAllister has an eye on what he describes as numerous start-ups and other businesses working in high speed data applications, high-performance computing as well infrared applications for consumer electronics. "After years of development, we have a number of patents and more on the way that will help these companies cut their time to market."

Wireless contestants diversify and win

As the RF components market remains robust, RF Micro Devices, Skyworks, and TriQuint are vying for market share. *Compound Semiconductor* talks to Dale Pfau from global finance firm, Cantor Fitzgerald, about the winners and the losers.

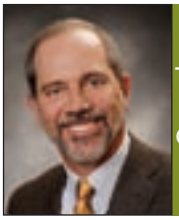
THE RACE IS ON to win market share in the ever-so steady RF components space. As volume growth rates remain robust at around 15 percent a year, Skyworks and RFMD recently reported strong quarterly earnings, and have forecast a healthy guidance for the March quarter.

Likewise, TriQuint has unveiled solid earnings exceeding analyst estimates, but following a disappointing forecast for the next quarter, shares have stumbled several percentage points.

"It is extremely obvious that RFMD and Skyworks are taking market share," asserts Dale Pfau, analyst from US-based Cantor Fitzgerald. "In my opinion, TriQuint isn't even participating in major conversations with handset OEMs... and is dangerously close to becoming a marginal player in advanced mobile devices." (TriQuint refutes this claim. Its view is given in the box "TriQuint's take on the smartphone business")

Pfau believes both Skyworks and RFMD have been able to

As Apple reports an 18 percent increase in its sales - the slowest rise since 2009 - customer diversification proves crucial for RF components makers (Credit: Apple)



TriQuint's chief executive, Ralph Quinsey, believes increasing LTE adoption will drive high performance RF filter sales

"TriQuint has the largest exposure to Apple... but Samsung isn't even a 10% customer for the company," highlights Pfau. "Apple had a strong fourth quarter, but first quarter shipments of iPhones are lower. Anyone with exposure to Apple has had to significantly cut production forecasts for the March quarter

predict a relatively strong March guidance because each also has a relatively broad customer base.

TriQuint doesn't. And what's more its largest customer – Foxconn, Taiwan-based contract manufacturer for Apple – is suffering from a near-term slowdown at the US consumer electronics multinational. In the last fiscal year, more than 30 percent of TriQuint's revenues came from Foxconn, while some 25 percent of SkyWorks' revenues, and 10 percent of RFMD's revenues, could be attributed to Apple. Crucially, Skyworks and RFMD also win between 20 percent and 30 percent of revenue from Samsung, and are ramping up supply to Nokia and Research in Motion.

"TriQuint has the largest exposure to Apple... but Samsung isn't even a 10 percent customer for the company," highlights Pfau. "Apple had a strong fourth quarter, but first quarter shipments of iPhones are lower. Anyone with exposure to Apple has had to significantly cut production forecasts for the March quarter."

So where next for TriQuint? Pfau expects the III-V content in mobile phones to continue to rise, but adds: "It's going up but not as fast as the total RF content. You are seeing additional content, such as antenna matching structures and filters, rising, and these are not going to be manufactured with, say, GaAs."

Indeed, TriQuint now appears to be turning its attention to the filter market. As chief executive Ralph Quinsey recently stated: "We are expanding capacity for high-performance filters in anticipation of strong demand in the second half of 2013 and beyond. These are terrific markets with demand being driven by LTE... and only one other player can provide a full suite of advanced filters."

Meanwhile the overall RF components market is expected to not only grow in size, but also complexity. "We have things like envelope tracking and carrier aggregation coming, and this demands complete systems solutions and close integration with baseband suppliers," says Pfau.

"But companies such as Skyworks and RFMD can architect the entire front end for you. This expertise is winning."

TriQuint's take on the smartphone business

TRIQUINT'S expectations for its future in the GaAs power amplifier business differ a great deal from those of analyst Dale Pfau from Cantor Fitzgerald. While Pfau claims that the company is dangerously close to becoming a marginal player in the smartphone business, TriQuint believes that it will continue to play a significant role in this sector.

"We are on the table with the OEMs," asserts Shane Smith, TriQuint's Vice President of Global Marketing for Mobile Devices. "There is not a customer that we don't have any conversations, or presence, or examples of design wins with."

However, he acknowledges that TriQuint's share of GaAs power amplifier market has dipped recently. According to him, this is partly due to a relatively small proportion of TriQuint's products being shipped to the more successful mobile phone manufacturers of late, while those handset manufacturers that rely more heavily on the company for components have struggled in recent times.

For example, TriQuint is the leading GaAs-based, front-end supplier to Research in Motion. This firm manufactures Blackberry smartphones, which were not particularly popular last year, but may revive following the launch of the Blackberry 10.

Capacity limitations have also been behind TriQuint's loss of market share in the GaAs-based power amplifiers sector. According to Smith, this has recently been addressed with a $200 million investment in capital equipment, followed by investment in qualifying products and developing them throughout last year.

"In 2013, we have qualified lines ready to support the volume with a competitive product portfolio that is winning design wins." This includes the Samsung Galaxy S4 that is slated for release on 14 March. "We have a significant number of design wins in those models," says Smith. "It's more than one component."

TriQuint's sales will also be bolstered by increased diversification. "We are growing not only in III-V technology. We are growing in silicon technology that doesn't use our fabs but is vital in our modules," says Smith, who adds: "And we are not only growing in cellular, with its advanced LTE requirements in filters and PAs. We are also growing in wireless LAN."

Seren prepares to launch novel LEDs

Can a UK start-up unlock the potential of nitride LEDs?

Bagging a hefty £1.8m in equity and an extra £230,000 from the UK-based Technology Strategy Board last year, the future looks promising for Seren Photonics. Launched as a University of Sheffield start-up in 2010, equity researchers have tipped the high brightness LED developer for exit come 2015. And with the company now busy forging manufacturing partnerships with chip makers around the world, the analysts' predictions look set to come true. So where next?

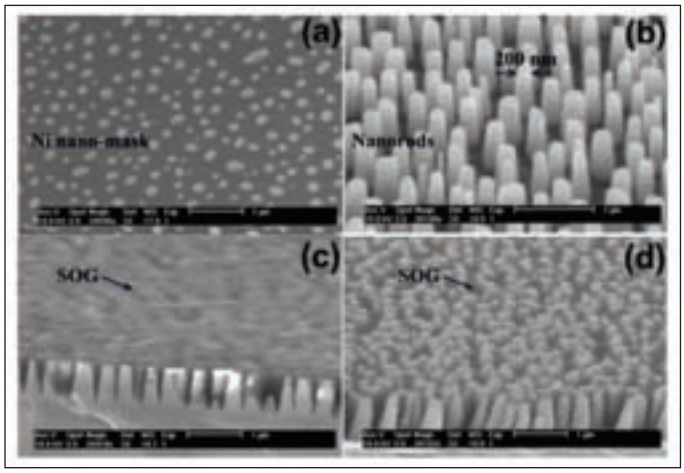
Since its inception, Seren Photonics has promised to deliver ultra-high efficiency LEDs to the lighting industry by applying novel post-processing techniques to bare chips. Technology pioneer and company chief technology officer Professor Tao Wang has always kept quiet about how his methods work, and while still fairly tight-lipped due to pending patents, details are emerging. In a bid to boost brightness, Seren has focused on developing InGaN/GaN nano-rod light emitting diodes. Nanorod LEDs are not a new concept – myriad researchers have already used lithography and dry-etching techniques to fabricate these devices – but Wang claims his LEDs perform better, saying: "Our studies indicate these InGaN-based nanorod LEDs can now be truly employed for practical applications for the first time."

Wang's process starts with depositing a 200 nm SiO_2 film onto any standard III-nitride epiwafer, with a 10 nm nickel layer then deposited onto this. The epiwafer is annealed and the nickel layer self-organises into nano-scale islands used to form silicon oxide nanorod arrays via standard reactive ion etching.

This silicon dioxide nanorod mask is then used to plasma etch an LED epiwafer down to its n-type layer, but this dry-etching process inevitably damages the epiwafer. However, Wang's patent-pending process "heals" etching-induced damaged prior to final device fabrication, giving InGaN-based nanorod LEDs with an upright sidewall. His team uses surface plasmon coupling to enhance the quantum efficiencies of the InGaN/GaN quantum wells. Thanks to the nano-rod architecture, a film of silver or gold nano-particles can be deposited around the nano-rod quantum well structures, optimising the surface plasmon coupling effect, known to boost light emission.

"Normally you [deposit] nano-particles of silver or gold close to the InGaN quantum wells... But in a standard epi-wafer you deposit silver particles on top of the *p*-layer, and they are at least 200 nm from the quantum wells, so the surface plasmon coupling effect is almost zero," explains Wang. "If you use a nano-structure you can put the silver particles around [this], so the distance between the quantum well and silver approaches zero, massively improving the surface plasmon coupling effect."

Having successfully fabricated devices – with internal quantum efficiency increased by a factor of 8 in green nano-rods – Wang says Seren is ramping up efforts to grow structures on sapphire



Scanning electron microscopy image of a) nickel masks b)GaN nanorods c)GaN nanorods after Wang's patent-pending healing process, and spin-coated ready for LED fabrication d) The nanorods after back-etching to expose the top p-type layer

substrates. "Most [devices] are grown on gallium nitride but the price of free-standing GaN is extremely high, so it is impossible to use this as a substrate for green LEDs," he says. But as Wang highlights, his post-processing method can also be applied to epitaxy growth "We can improve the quality of the GaN on sapphire with our technology," he says. "We put nanostructures into the intermediate layers, which is cost-effective and we also get a high recombination efficiency."

But despite success, Seren's LEDs are not widely available yet. As Wang says, the company has produced LEDs, but we will have to wait two to three years to see them on the market. In the meantime Seren is busy forming joint ventures with other companies to develop its technology. The company has confirmed a manufacturing agreement with an "Indian manufacturer" while according to Wang, talks are also underway with other companies in Germany, China, Taiwan and Korea. Indeed, other media reports suggest China- and Taiwan-based LED chip manufacturers are testing Seren's LEDs with pilot production line samples showing improved brightness.

And as the company edges closer to commercialisation, Wang is pushing forward with his research. His group has recently fabricated InGaN/GaN green multi-quantum well structures based on nano-disks, rather than nanorods, that are said to boost internal quantum efficiency by a factor of up to 88. Wang is excited.

"We've just got the data and the increase in IQE is incredible," he says. "We now plan to submit our results to a high profile journal, *Science* or *Nature*."

Electron-beam liftoff:

Collection efficiency & paths to improvement

Liftoff metallization has been classically accomplished in the compound semiconductor industry with masks to achieve a uniform batch process. New process methodologies promise to significantly reduce those mask losses and offer significant improvements in both uniformity and collection efficiency in the future. By Gregg Wallace, Ferrotec USA Corporation, Temescal Division.

Liftoff carriers orient wafers to maintain the perpendicularity rule from a virtual point source near the electron beam impact point to a point on the center of each wafer in a carrier. Considering perfect 90° incidence to an essentially "flat wafer center" it is then obvious that incidence from the same point source at the e-gun to the outer edge of the wafer causes an imperfection to perfect normal incidence. The lack of perpendicularity at the wafer edge represents a process limit for "ideal liftoff conditions".

These constraints lead to larger diameter wafers requiring greater distance between the E-beam source and the wafers surface to maintain near normal incidence at the wafers edge. In general, +/- 5° from 90° incidence is an accepted rule for good liftoff processing geometry.

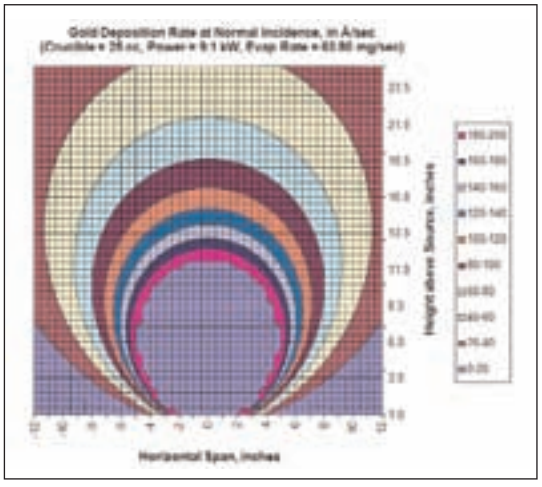


Figure 1

Figure 1 maps the radiating zones of gold vapor flux by effective deposition rate at locations above an E-gun. Most simply, this is the flux topography above an E-gun. It is important to note, the map is for a specific set of evaporation conditions as described at the top of the chart.

The flux lines would be different if a material other than gold were evaporated even under the exact same E-Gun conditions.

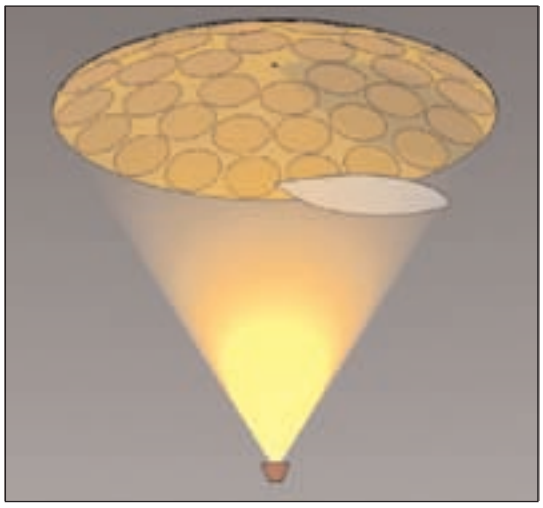
This image can be mathematically described as cosine radiation from a point source. The product of the equation will be deposition rate which is highest close and directly above the source.

This material flux, under similar conditions, is highly reproducible and this is what offers engineers the benefit of predictable production. However the flux pattern's shape is ruled by cosine curve mathematics and is highly dependent on control of the conditions listed below:

- Bulk Characteristics of the material being evaporated: density, melting point, thermal coefficients of expansion & conductivity, etc
- Maximum power capacity of the material being evaporated
- Size of crucible used (thermal mass)
- Deposition Power
- Beam Shape
- Use of sweep

Cosine curves are expressed in exponential form as cosine to the "n" power of an angle theta describing a position above the (point) source. As the exponent "n" changes (becoming >1) the cosine

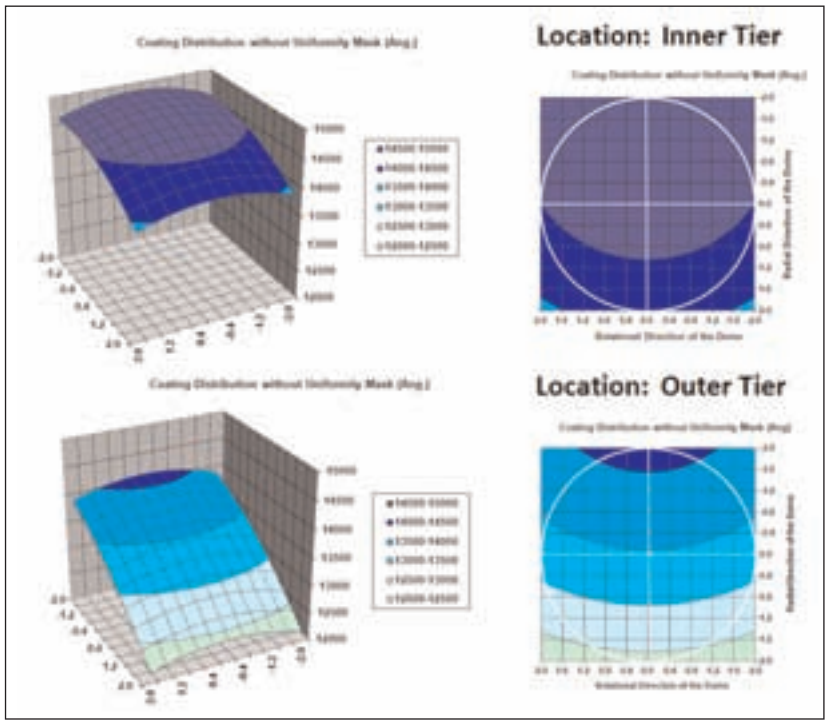
Figure 2



curve exhibits a characteristic elongation changing its shape from a unit circle (n=1) to what may be better described as an inverted teardrop as n exceeds a value of ~3. Temescal has collected hundreds of vapor flux maps from E-Gun deposition tests. As a result, we have developed software which both predicts coating performance from E-Guns and automatically generates uniformity masks used to create batch coatings of uniform thickness. Figure 2 shows how a mask functions in an e-gun system. Figure 3 shows such a prediction for an unmasked film deposited from an e-gun onto a small liftoff carrier with two tiers of wafers.

Across a single-axis-of-rotation carrier, the thickness distribution of an unmasked liftoff film reflects the form of radiation from a point source. That is, a rich inner flux zone deposits thicker films on wafers carried in the inner-tier positions, while a weaker outer flux zone deposits thinner films onto wafers carried in outer-tier positions.

Figure 3



In order for a mask to improve uniformity in this environment, it must selectively block material moving to the substrate. This allows a mask to deliver a uniform thickness film to all the wafers on a rotating carrier. System providers regularly re-design equipment, often to accommodate larger wafers by increasing source-to-substrate distance or to provide larger batch sizes. However as the next figure demonstrates, mask designs for liftoff must also change with any change occurring to the wafer carrier. When a carrier's size is increased (to hold larger, or more wafers) its' uniformity mask must also grow to balance its' ability to block the rich inner flux zone to a now larger yet weaker outer flux region of the carrier.

Figure 4 illustrates how the declining trend in the outer tier flux rate would continue as a carrier is enlarged (a continuation of the violet dotted line). This obligates the mask also be enlarged to increase material capture from the central zone to balance the entire batch coating to a common thickness.

In Figure 5, a carrier's spherical dome radius (the source-to substrate distance) has been superimposed onto the flux map. This indicates the surface where wafers would be carried to make liftoff films. Note the span between different flux or deposition rate zones and their decline as the diameter of a carrier is increased. A reference mask position is also shown indicating the horizontal plane where a mask would be located. The mask's projected shadow onto the carrier (and wafers) would then trim flux to achieve good uniformity over a specific carrier/wafer batch.

Figure 5 shows flux, the wafer carrier and mask position as viewed through a chamber door looking horizontally into the system. To clearly show mask shape and its shadow effect onto the dome and wafers better, it is more appropriate to change the view to one looking down from the chamber's top, straight through the wafer and mask onto the centrally mounted E-Gun source.

Figure 6 uses such a top-down projection showing a sequence of growing carrier diameters and their correspondingly growing masks for this specific gold deposition. The carrier is represented by a gray circle in the diagram. The mask starts as a gray outline leaf shape in 6-i) and grows in shape and size as the carrier's diameter increases.

Numbers displayed on a helical arc radiating from the center offer the deposition rate, in Å/s, that would result at the outer edge of the carrier as its' diameter increases. Note: The process evaporation power is held constant in the model, only the carrier and mask change.

Figure 6-i through 6-iv illustrate the impact of increasing a carrier's surface area. Carrier size growth is expressed in terms of the half-angle created by the carrier's outer edge and a vertical center-line dropped directly to the E-Gun source. The first diagram shows a dome with a 25° half angle, and in the succeeding diagrams the half angle increases in increments of 10°.

Figure 7 presents three graphs of modeling data in more detail for a substrate carrier as it grows from 0° half-angle to a 60° half-angle size, they chart:
i) dome surface area
ii) the declining rate of deposition at the outer edge of the carrier with each step of growth
iii) a calculation of the ideal collection of material beneath the growing dome surface, normalized for liftoff incidence and the use of a mask to make the batch a uniform material thickness. Again, this is for ideal cosine gold deposition from a flux cloud of cosine shape n = 3.3. This represents a typical production deposition condition in a fab.

The graphs in Figure 7 show that a single-axis-of-rotation substrate carrier with a half-angle of approximately 40° yields the best possible collection efficiency. Dome growth beyond ~40° results in more material being lost to the mask than gained on the carrier or wafers. Beyond that point, material collection on the dome declines as a percentage of total material evaporated. The decline is due to the increasing need for uniformity mask growth to compensate for the low deposition rate at a carriers' outer edge. Ideal* collection is never realized as a small percentage of evaporated materials are

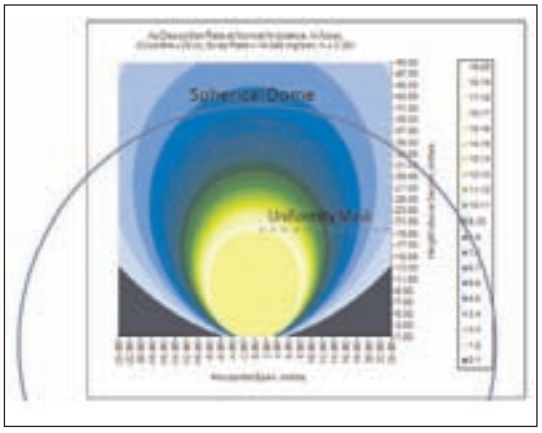


Figure 5

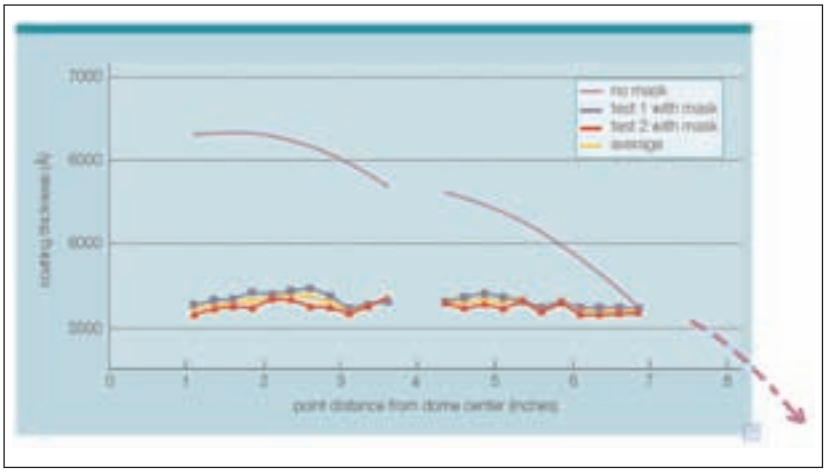


Figure 4. Masked vs. Unmasked Deposition

inevitably lost in conditioning and other stages of actual production runs. However, generalized evaporation losses, from an ideal*, are experienced by equally by all sources regardless of system geometry or application. Therefore they can be considered to represent a normalized loss coefficient across all processes being modeled for comparative efficiency purposes. Continued modeling now reveals that maximum collection efficiency in a masked, single axis rotation liftoff process is available from a system with a half-angle of ~40°. "Conceptual construction" of such a tool indicates it would carry 60 wafers in a 53 inch wide carrier, as shown in Figure 8.

While large, it's conceivable a segmented carrier could be made for loading as in other production tools. "Conceptual modeling" indicates this batch would collect Au material in identical flux conditions at an effective 2.1 Angstrom/second rate (due to larger radius of outer wafer tier).

An ideal* cosine model of the cloud indicates 26.7% of the gold evaporated will be collected on the 60 wafers. To offer a comparison this figure would represent 38% Au collection improvement over Temescal's FC-4400's collection efficiency which carries 30 wafers/batch operating under the same flux conditions. Modeling the "ideal geometry" gives rise to another question which is, 'Is there any way for liftoff coating collection to be improved beyond this?'

In 2002, Temescal's work in flux mapping software compelled a focus on mask related losses. Experiments were made attempting to reduce the need for uniformity masks in systems. An alternative concept for liftoff wafer motion was developed called HULA an acronym for High Uniformity Liftoff Assembly. The system maintains the wafer's orthogonal relationship needed for liftoff while also providing planetary motion which moves the wafer

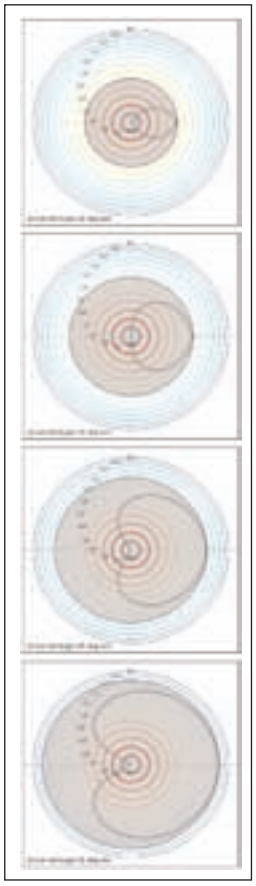
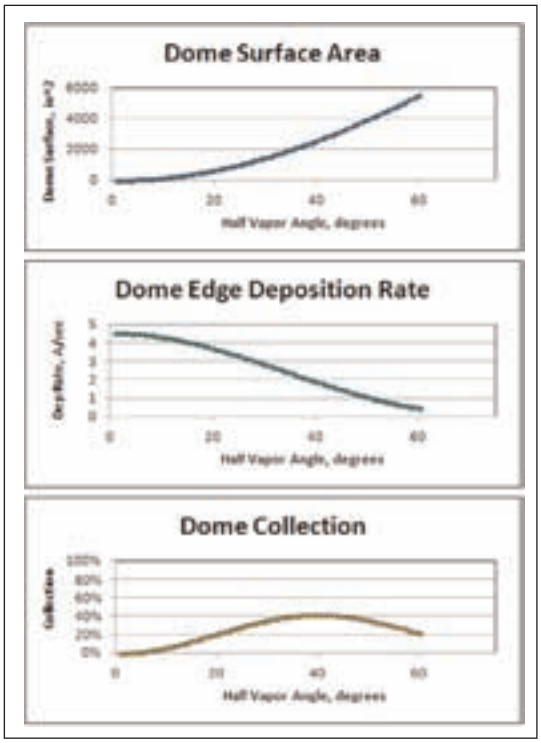


Figure 6

Figure 7



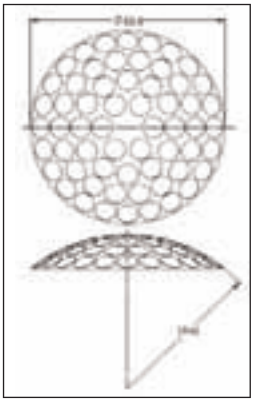


Figure 8

between high and low (inner and outer radius) flux zones during deposition. Time averaging wafer residence between the zones offers uniform films without the need for masks. HULA fixtures demonstrated that wafers can be coated with high uniformity at effectively increased deposition rates without the need for masks. Figure 9 shows such a HULA fixture.

Conventional single-axis-of-rotation carriers fix wafers in inner and outer tier positions. Outer radius wafers get low deposition rates by virtue of location and single-axis-rotation. Inner radius wafers get rich flux and are coated faster. They therefore require selective masking reducing collection to match that of the outer tier wafer. In Figure 10, a mask is represented by the green triangle. Once installed, masks allow all wafers to be coated at the same

Figure 9. HULA Substrate Carrier

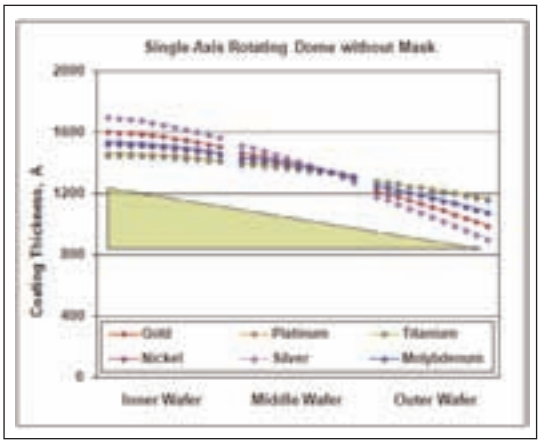


Figure 10

rate over a fixed number of carrier revolutions. Variations in different material/turret-pocket flux may be addressed by rate changes or through supplemental masks used to trim a select material/turret-pocket. Regardless of the mask employed, the maximum deposition rate in these systems is established by the deposition rates at the outer-tier position of the carrier for each material. The yellow arrow In Figure 11 indicates that this mask, optimized for gold uniformity resulted in a nominal 1000 Angstrom films.

By contrast, a HULA averages a wafer's time spent in a range of flux zones by rotation and eliminates the need for the mask. This provides a normalized and effectively higher average deposition rate to all wafers on the carrier. It improves collection efficiency and uniformities of all different materials in a turret gun. Unmasked batch uniformities of <+/-3% for all turret-pockets from a source are regularly realized using the HULA. As Figure 12 shows, higher effective deposition rates (indicated by the yellow arrow) allow thickness set-points to be reached in shorter time. In many fabs, such an

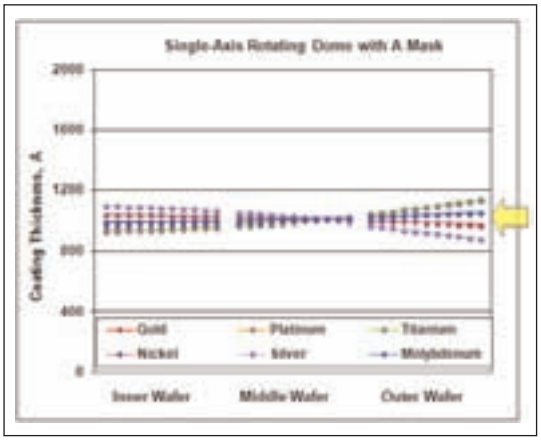


Figure 11

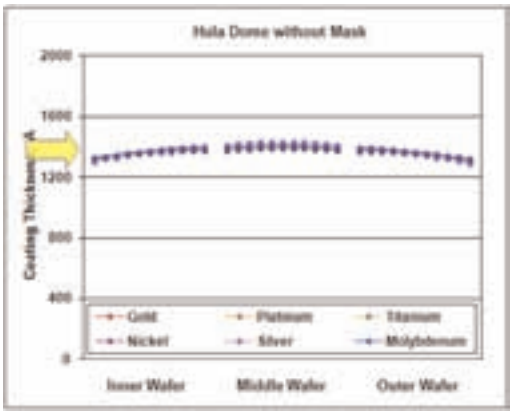


Figure 12

	Production FC-4400 Current Standard	Idealized System Highest Efficiency	UF-5700 w/3 Arms 2-Axis HULA Motion	Units
Substrate Carrier	1	1	3	#
Carrier Diameter	42.2	53	27.2	in
Spherical Radius	42	42	43	in
Total Carrier Surface	1500	2485	1789	in^2
6" Wafer Area (-edge)	25.95	25.95	25.95	in^2
Batch Wafer Count	30	60	42	#
Total Wafer Area	778.5	1557.0	1089.9	in^2
Remaining Carrier Area	721.7	927.7	699.3	in^2
Carrier 1/2 Angle	30.2	39.1	40.0	deg.
% Total Flux on Carrier	37.3%	42.6%	45.4%	%
% Total Flux on Wafers	19.3%	26.7%	27.7%	%
Effective Deposition Rate	2.9	2.0	3.0	Ang/sec

Evaporant: Au
Evap. Rate: 0.014543 g/sec
1st Evap. Time: 1327 seconds
n: 3.3

Table 1

improvement in deposition rate has yielded an extra run/shift.

Modeling a HULA carrier as a comparison exercise was the next logical step to understand if a HULA fixture could improve on collection efficiency of the "ideal 60 wafer system" conceptualized earlier. Modeling a HULA system with 3 domes of 14 wafers/each allowed it to fit in an identical n = 3.3 vapor flux conditions used before. The HULA batch of 42 x 150mm wafers fits in easy-exchange small domes in the same 40° half-angle modeled earlier. An ideal cosine flux for this HULA shows 27.7% of the gold evaporated will be collected on the 42 wafers. This represents a 43% collection efficiency improvement over Temescal's existing FC-4400 with 30 wafers and a 5% improvement of the "ideal 60 wafer" modeled results.

This completes comparison of ideal* modeled deposition across all three systems. Clearly the smaller batch HULA with easy-exchange carriers and a slightly higher collection efficiency offers a compelling design for consideration. These three cases are illustrated in Figure 13. Table 1 presents the following data with respect to the three carriers compared in Figure 13: dimensional assumptions constraints (e.g., wafer-edge exclusion) ideal* collection results. The same vapor cloud and material evaporation power was used in the modeling of each scenario.

Table 2 presents measured results from two production tools in Temescal laboratories. These were made in 2012 during customer acceptance tests. It is important to note that ideal* modeled collections do not have any correction for typical losses, such as; spitting, process variables associated with beam sweep, or for the conditioning processes common in pre-deposition. Process comparisons outlined here introduce part of the fundamental advantages of the Auratus Process which has now been in production for three years across two continents. Please contact Temescal for more information and access to sample trials.

The author would like to thank Ping Chang – Senior Staff Scientist, Dr. Phillip Greene – Staff Scientist, Cris Kroneberger – Engineering Manager and Pheng Sin – Staff Designer for their help in the development of this article.

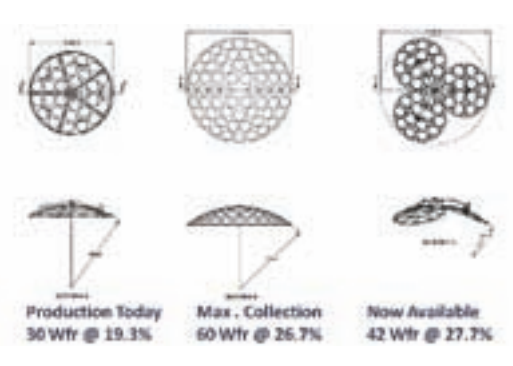


Figure 13

Production Tests - Gold Collection Step	UF57104	FC44113	Ratio
The amount collected by wafers according to cosine distribution, %	27.80%	19.46%	1.43
Total evaporation, grams & cc	43.74g 2.27cc	46.00g 2.39cc	
Total coating thickness, Angstroms	6488	6312	
Batch size, # of wafers	42	30	
Total ramp and soak time, seconds	480	480	
Deposition time, seconds	2008	2005	
Total wafer surface, cm^2	7031.40	5022.46	
Collection of Au during deposition, cc	0.48	0.33	
Collection of Au during deposition, grams	8.60	6.12	
Collection of Au during deposition, %	20.10%	13.61%	1.41
Equivalent deposition time during ramp & soak time, seconds	270	270	
Undeposited Au consumption during ramp & soak, grams	1.18	0.82	
Undeposited Au consumption during ramp & soak, %	2.71%	1.83%	
Au collected on wafers had ramp/soak been deposition time, grams	9.99	6.94	
Au collected on wafers had ramp/soak been deposition, %	22.83%	15.43%	1.58

Table 2

CSindustry awards2013

and the winners are...

Substrates & Materials Award

CREE

For:
150-mm 4HN Silicon Carbide Epitaxial Wafer

Device Design and Packaging Award

SETI

For:
III-Nitride Varactors with
Capacitively-Coupled Contacts

Compound Semiconductor Manufacturing Award

AIXTRON

For:
G5+ : 5 x 200mm GaN-on-Si MOCVD Reactor

Innovation Award

Ferrotec - Temescal Division

For:
Auratus Deposition
Enhancement Methodology

Metrology, Test and Measurement Award

Jordan Valley
Semiconductors

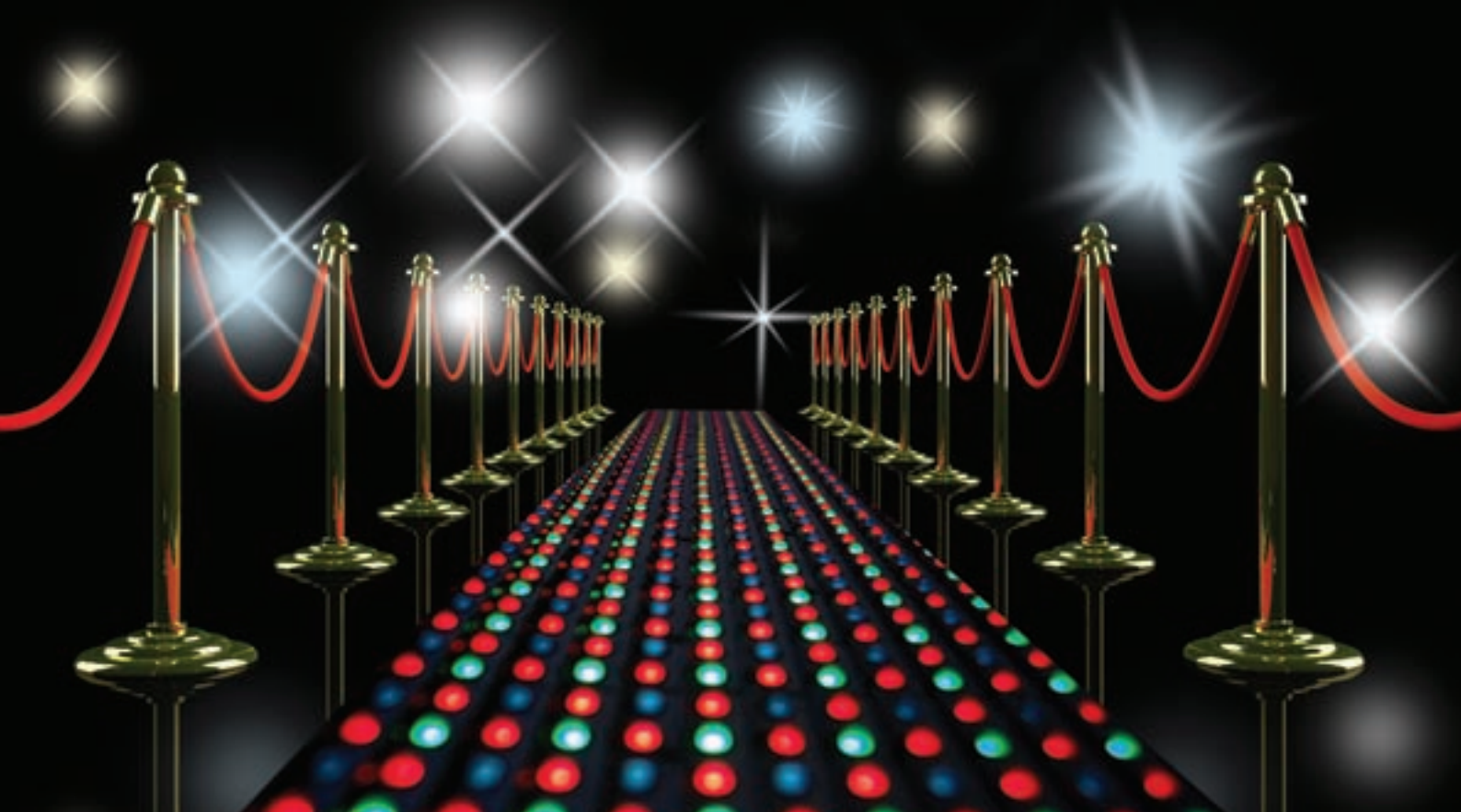
For:
QC3 Fast HRXRD Metrology Tool

R & D Award

TriQuint
Reach Further • Reach Faster™

For:
Near Junction Thermal Transport Program

Please look out for the next issue of Compound Semiconductor and see the winning entries in full



Commercial status of the GaN-on-silicon power industry

Firms developing and producing GaN-on-silicon devices for the power electronics industry come in many different flavours. Some sell on the open market; some just ship to a chosen few; others offer foundry services; and there are also those that form partnerships. Zel Diel from Venture-Q LLC considers these various approaches and their implications, before looking at how far companies have progressed towards commercialization of their technology.

The developers and producers of GaN-on-silicon power electronics are pursuing various strategies. Some are looking to sell their devices on the open market; others are targeting the closed merchant market; and there are also those that are offering foundry services, or licensing their technology (see Figure 1 for a pictorial representation of these different approaches).

Launching products on the open merchant market is a well-known business strategy that is common for mature technologies. The manufacturer tries to win sales directly or through a distributor. US firm Efficient Power Conversion (EPC) operates in this manner, with its distributor, Digi-Key, selling the eGaN transistors that it introduced in 2010.

An alternative approach is to offer a product in the closed merchant market. This strategy, which is common with a new technology, is often employed within the scope of a partner business engagement. The primary virtue of this approach is that it limits access to a vendor's know-how and its intellectual property (IP). Companies pursuing this strategy include the US firms International Rectifier (IRF) and Transphorm. One feature of this form of commercialization is that the vendor-partner relationship is often conducted within the scope of a non-disclosure agreement.

Within the compound semiconductor industry, there are also manufacturing foundry services providing access to GaN-on-silicon technology. Companies offering this include RF Micro Devices, which has an rGaN-HV technology that is available to its merchant customers and business partners. A noteworthy feature of this commercialization is the vendor-customer or partner relationship that enables access to the vendor's technology and manufacturing.

Markets for GaN-on-silicon products include inverters for wind turbines and solar farms. This class of electronics is more efficient than the incumbent silicon technology at converting the output from these renewable sources into a form that can be fed into the grid

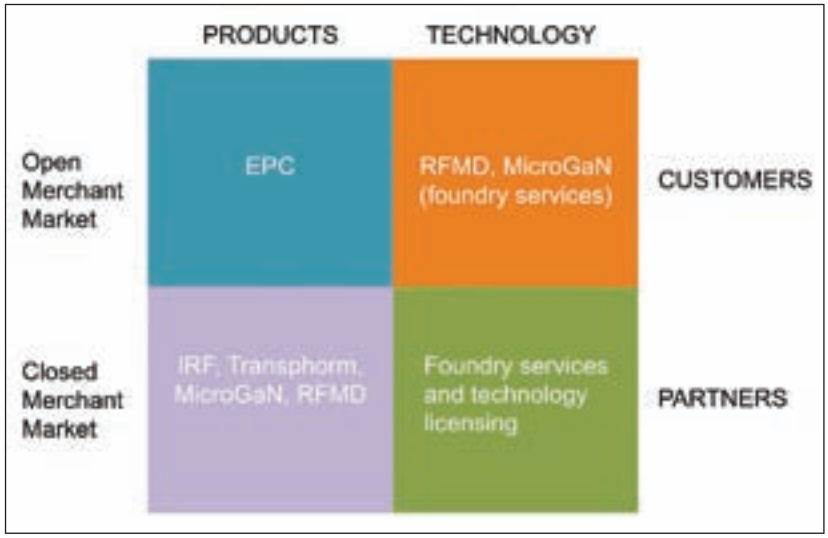


Figure 1. Analyst Venture-Q categorises the developers of GaN-on-silicon technology into those operating in either open or closed markets; and those that develop products, or develop technologies

In many established and evolving industries some companies offer a license to access new or mature technologies. Although this may not be that prevalent in the III-V industry to date, it is a feature of the silicon industry – for example, IBM Microelectronics licensed its SiGe technology in the late 1990s.

In addition to these different types of models for commercialization, firms are differentiating themselves by either pursuing their goals single-handedly, or teaming up with others through business partnerships and joint ventures. The later option is commonly found in new technologies, with partnerships bringing together complementary resources and capabilities of two or more vendors. Two examples of this are: the Fuji-Furukawa partnership, formed for the commercialization of GaN MOSFET technology; and the joint venture between Fujitsu and Sumitomo's Eudyna (now Sumitomo Electric Device Innovations, SEDI), which

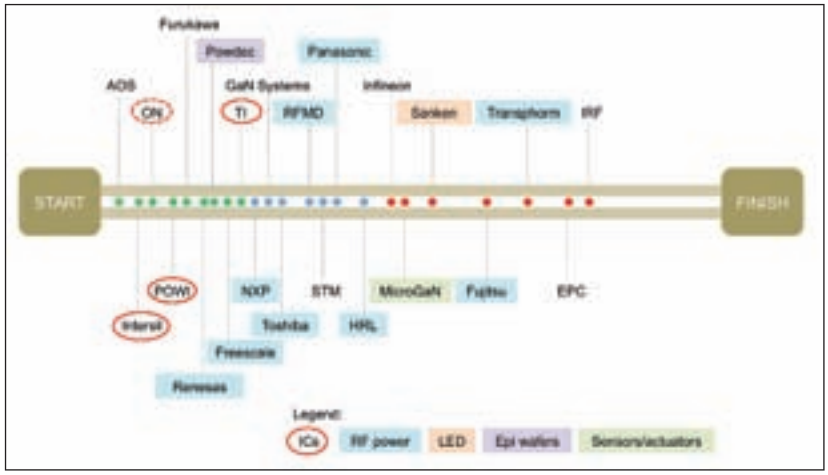


Figure 2. Venture-Q has grouped 23 firms involved in GaN-on-silicon technology into a leading group of seven (red circles), a subsequent group of 8 (blue circles), and a trailing group of 8 (green circles)

was established in 2004 to commercialize RF power GaN technology.

The variations outlined so far reveal that there is much to consider in order to objectively assess the status of commercialization of GaN-on-silicon technology. At Venture-Q LLC, a provider of market reports, we have made such an assessment in a rigorous manner, and in the remainder of this article we will provide a high-level view of the commercial status of the GaN-on-silicon power industry. For all of the leading firms, we detail how close they are to commercializing their technology, and where they rank in relation to each other. Our findings represent the status of the market as of December 2012.

At that point in time we believe that 23 vendors were engaged in the commercialization of high voltage GaN-on-silicon HEMTs, ICs, and modules for power conversion applications. Their activities range from patent filing activity to device design, fabrication, and packaging. Only those with development efforts directed towards technology commercialization are included in our vendor list, which implies that those pursuing exploratory research activities are omitted from our study. Additional exclusions include pure-play vendors of RF power GaN HEMTs. However, we do consider vendors that are now producing high-voltage GaN HEMTs on SiC and plan to make the transition to a silicon platform.

The types of GaN-on-silicon power devices that we consider include HEMTs, MOSFETs, and hybrid HEMT-MOSFET devices, while ICs include integration of GaN-only devices and both GaN and silicon devices. The makers of modules that we account for include those producing system-in-package and sub-system level modules, such as motor drives and power supplies.

Some of the features worth noting in Table 1 are: Efficient Power Conversion is the only vendor offering products in the open merchant market; there are only three vendors offering product in the closed merchant market – Transphorm, MicroGaN and RFMD; only two firms are providing foundry services (MicroGaN and RFMD); and only NXP and ON Semiconductor are engaged in collaborative developments with major R&D institutions. Another way of looking at this data is that, in 2012, only five vendors offered products and/or foundry services in the merchant market, with the remaining 18 vendors engaged in technology development – either in collaboration with R&D institutions, or within their internal R&D organizations.

Pecking order

We have placed all 23 companies on a commercialization timeline (see Figure 2). Positions are determined by a number of technology and business related factors, which vary widely among vendors. The 23 firms can be divided into three groups: a leading group of seven vendors, which

predominantly focus on discrete power devices and modules (these firms are shown by red circles); a subsequent group of eight vendors, mostly offering RF power GaN devices (blue circles are used to define this group); and a group of eight vendors, most of which are silicon IC vendors (identified by green circles).

Most of the vendors in our list of developers and producers of GaN-on-silicon devices are addressing emerging high-voltage, power-conversion applications by leveraging their existing expertise and capabilities in GaN-based technologies (see over for specific details of all 23 firms). Nine vendors, including Transphorm, Fujitsu, HRL, Panasonic, RFMD, Toshiba, NXP, Freescale and Renesas, have a background in RF power GaN technology. Another, Sanken, can leverage its expertise in LED manufacturing, while MicroGaN and Powdec can build on their strengths in sensor/actuator technology and epiwafer manufacturing, respectively.

One other common background for our 23 companies is that of silicon MOSFET vendors. IRF, Infineon, STM, TI, ON Semiconductor and Alpha & Omega all fall into this category. They have approaches to GaN technology development that include internal R&D, acquisitions, and partnerships. Meanwhile, start-ups EPC and GaN Systems, plus Furukawa (R&D), are focusing exclusively on GaN-on-silicon power technology, and two vendors - Power Integrations and Intersil – are concentrating on ICs.

It's interesting to note that there is only one company in our list of 23, Sanken, that is looking to leverage its LED manufacturing technology. Its efforts are limited to manufacturing equipment, rather than know-how, and its development of GaN-on-silicon HEMT technology for power conversion spans more than a decade. The plans and progress of Sanken reveal that the publicized near-term threat of LED vendors entering the power electronics market is both unrealistic and unfounded. Why? Because LED manufacturing has minimal correlation with the technological know-how required to manufacture high-voltage, GaN-on-silicon power HEMTs. Gaining that expertise requires a decade of R&D effort. It is possible, however, that LED vendors could gain access to such expertise via either acquisitions, partnerships or joint ventures.

The companies that are developing GaN-on-silicon technology have three big challenges ahead of them: containing the current collapse phenomenon; developing the technologies for manufacturing E-mode HEMTs; and validating device reliability. On top of this, GaN HEMT production costs must fall to drive deeper penetration into the power electronic market, a step that will require manufacture on 200 mm silicon. In our view, to address these issues while reducing the time it takes to generate revenue and profits, vendors will start to partner with each other more strongly than before, while some firms will be acquired by others.

Any questions relating to this article can be directed to the author: ZelDiel@venture-Q.com

Vendor	Products		Technology	Development		Product Types		
	Open market	Closed market	Foundry services	Collaborative	In-house	Discrete	IC	Module
IRF		●				●		●
EPC	●					●		
Transphorm		●						●
Fujitsu					●			
Sanken					●	●	●	
MicroGaN		●	●			●		
Infineon					●	●		
HRL					●	●		
Panasonic					●	●	●	
STM					●	●	○	
RFMD		●	●			●		
Toshiba					●	●		
GaN Systems					●	●		
NXP				●		●		
TI					●	○	●	
Freescale					●	●	○	
Powdec					●	●		
Renesas					●	●		
Furukawa					●	●		
POWI					●		●	
ON Semi				●		●	○	
Intersil				●			●	
Alpha & Omega					●	●		

Table 1. Vendor commercialisation status for GaN-on-silicon HEMT technology, as of December 2012

Key features of the GaN-on-silic

The leading group of seven vendors (identified in red circles in figure 2) currently focuses on discrete power devices and modules for power conversion applications.

- **International Rectifier (IRF),** which leads the time-to-commercialization race, is driven by a strong motive — re-entry into the high-voltage power arena. The company is reinforcing its lead with a comprehensive portfolio of patents and patent applications.
- **Efficient Power Conversion (EPC)** remains the only vendor offering commercial-grade, E-mode GaN-on-silicon HEMTs for power conversion applications in the open merchant market.
- **Transphorm** focuses on application-specific modules. It leverages RF power GaN-on-SiC device technology developed at the University of California, Santa Barbara, and Cree, which has assigned its high-voltage GaN power device patents and patent applications to Transphorm.
- **Fujitsu Semiconductor** announced its commercialization effort in November 2012. The company leverages its legacy leadership in RF power GaN technology for power conversion applications. It invented the HEMT and led commercialization of RF power GaN technology by forming Eudyna in 2004.
- **Sanken Electric** focuses on high voltage GaN-on-silicon power HEMTs for use in power conversion applications, such as power supplies, at both the component and system level. It leverages LED manufacturing expertise and more than a decade of R&D efforts in GaN HEMT technology.
- **MicroGaN** is building on its legacy, GaN-based sensor and actuator technology. It is a member of the German NeuLand programme and it is in a close relationship with Infineon.
- **Infineon** is leading two major German programmes related to GaN technology—NeuLand and HiPo. Through this it has established a 150 mm GaN-on-silicon processing pilot line in Villach, Austria. Infineon and STMicroelectronics essentially share a market duopoly in super-junction MOSFETs. Therefore, Infineon's commercialization motive and strategy tends to be, in contrast to IRF, of a defensive nature. As a result, Infineon's position on the commercialization timeline lags the leading vendors featuring offensive strategies.

The second group consists of eigh circles in figure 2), most of which a GaN devices.

- **HRL Laboratories** leverages its automotive power conversion ap chargers for electric vehicles. Ge
- **Panasonic** is looking to build or power conversion applications, i and uninterruptible power suppli demonstrated the first monolithic inverter circuit.
- **STMicroelectronics (STM)** ente technology arena by licensing V manufacturing technology. Howe on SiC devices.
- **RF Micro Devices'** efforts to co power conversion applications r legacy RF power business.
- **Toshiba** leverages its RF power GaN-on-silicon technology deve its central corporate research ce
- **GaN Systems** is a start-up estab government to develop GaN-on- conversion applications.
- **NXP Semiconductors** leverages co-developing high-voltage, GaN 200 mm wafers with A*STAR Re

con developers and producers

nt vendors (identified in blue are currently vendors of RF power

RF power GaN technology in
pplications, such as battery
eneral Motors is a HRL owner.
n its RF power GaN technology in
ncluding inverters for industrial use
ies. In late 2009, Panasonic
c integration of a six-HEMT

ered into the GaN-on-silicon
elox's GaN-on-silicon diode
ever, the current business focus is

mmercialize GaN technology in
epresent an expansion of its

GaN technology, while its
lopment efforts are confined to
ntre.
blished by the Canadian
silicon products for power

s its RF power GaN technology by
N-on-silicon power devices using
search Institution in Singapore.

The third group consists of eight firms (identified by green circles in figure 2) that are mainly silicon IC vendors. These vendors explore and/or develop monolithically integrated GaN HEMTs with silicon devices for power conversion applications.

- **Texas Instruments (TI)** is developing a high-voltage, GaN-on-silicon technology for power conversion applications. The company focuses on monolithic integration of GaN HEMTs and silicon devices. Discrete GaN power devices would play the role of its low-voltage NexFET power MOSFETs in high-voltage applications. TI is not in the discrete power devices business, but rather develops such products to complete its system-level solutions.
- **Freescale Semiconductor** leverages its new RF power GaN technology for power conversion in electric and hybrid electric vehicles.
- **Powdec** leverages its epiwafer technology in power conversion applications in close relationships with Furukawa (a minority investor) and Sheffield University, UK.
- **Renesas Electronics** gained access to RF power GaN technology via the NEC Electronics acquisition in 2010. Renesas recently engaged in the commercialization of GaN-on-silicon technology for use in industrial power conversion applications.
- **Furukawa Electric** formed an R&D partnership with Fuji Electric to develop GaN MOSFETs for power conversion applications. Prior to partnering, Furukawa's focused on the development of GaN HEMTs in its Yokohama R&D Laboratories.
- **Power Integrations' (POWI)** business focus is on monolithic integration (ICs). It acquired Velox (a vendor of GaN-on-silicon based diodes and HEMTs) in addition to licensing SiC technology for power ICs from SemiSouth (now defunct).
- **ON Semiconductor** collaborates with imec to develop GaN-on-silicon power devices in its facility in Oudenaarde, Belgium.
- **Intersil** explores the use of GaN-on-silicon technology for monolithic integrations (ICs). It collaborates with GeorgiaTech University on the development of this technology and has filed relevant US patent applications.
- **Alpha & Omega Semiconductor (AOS)** collaborates with GeorgiaTech on the development of GaN-on-silicon power devices. The current focus is on Schottky diodes.

Slashing the cost of solid-state lighting

How can LED epiwafer costs fall to a level that can spur mass adoption of solid-state lighting? By turning to growth on 200 mm silicon substrates, loaded into a multi-wafer MOCVD reactor featuring advanced thermal management and optimised wafer recesses, argues Aixtron's Boerge Wessling.

The GaN-on-silicon LED is having a resurgence. It was a hot topic several years' ago, and it is well and truly back in the limelight, with LED chipmakers now developing manufacturing processes for producing devices on this platform. If they succeed, they will slash the cost of this solid-state emitter. According to market analysts, switching from LED production on 100 mm sapphire, a common platform today, to 150 mm or 200 mm silicon should lead to substantial savings in the high double-digit level.

Slashing the cost of the LED promises to drive a hike in the sales of bulbs based on this technology. This is only possible, however, if a stable, reproducible epitaxy technology is available that enables LEDs grown on silicon to deliver similar levels of performance to those on the market today.

Recent announcements indicate that there are no longer major concerns regarding the brightness and efficacy of LEDs grown on

silicon. Now the biggest barrier to high-volume, profitable production of this class of device is a sufficiently high yield. At Aixtron of Aachen, Germany, we are addressing this issue with the launch of our AIX G5+, an MOCVD system dedicated to the growth of LEDs on 200 mm silicon substrates (see Figure 1).

Requirements for high-yield epitaxy on large area substrates of silicon, or sapphire for that matter, include optimisation of the reactor temperature profile and precursor delivery. The AIX G5+ delivers on both fronts, thanks to an optimized RF heating coil and a novel gas inlet, which provides excellent gas flow stability and uniformity on the full batch area of 5 x 200 mm wafers.

The challenge of delivering high yield LED manufacturing is far tougher on silicon substrates than it is on those made from sapphire: In addition to uniform gas flow distribution and optimised temperature management, it requires minimisation and management of silicon wafer bow. If the wafer deforms, this leads to undesirable non-uniformities in emission wavelength. To combat this, MOCVD processes must be developed that produce satisfactory chip yields. In addition to wavelength uniformity, the wafer must be flat when cooled to room temperature, to enable high-yield in various processing steps, such as lithography.

Origins of bow

Wafers start to bow when they are heated up to typical MOCVD process temperatures. This heating comes from the reactor's wafer carrier, which heats the bottom of the substrate. In comparison, the wafer's top surface is exposed to the process chamber, so it is at a lower temperature. The vertical thermal gradient that results across the wafer causes its expansion to be greater at its top than at its bottom. This leads to a spherical bow, which is more pronounced for thinner, larger wafers. Consequently, deposition on 200 mm substrates is particularly challenging.

The only way to address this heating-related bow is to control the temperature of the reactor wall facing the top surface of the wafer. This feature is present on the AIX G5+, which accommodates a warm reactor ceiling that lowers the bow of a standard thickness 200 mm silicon wafer by up to about 30 percent compared to other reactors.

Bowing issues are exacerbated by differences in the thermal expansion coefficients of silicon and the nitride layers. During epilayer deposition, wafer bow evolves according to the strain characteristics and the thickness of the layers that are deposited. If the strain is not managed properly, the resulting bow leads to non-uniform wavelength characteristics, layer cracking, and even wafer breakage.

To prevent this from happening, strain management techniques are applied, such as the introduction of interlayers that have a strain that counterbalances that associated with the nitride layers. These strain reduction techniques can minimise bow during different growth steps, in order to prevent layer cracking, and ultimately they can lead to the formation of a flat wafer after growth and cool-down.

If these techniques are applied successfully, wafer bow is minimal. For example, it is possible to produce a 200 mm LED epiwafer on silicon with a bow of less than 10 μm (see Figure 2). The wafers, which have been grown in a reactor featuring *in-situ* curvature measurement tools to monitor any deformations, are crack-free.

Although it is possible to minimise wafer bow with the techniques outlined above, it is impossible to eliminate it during the deposition process. This means that for the growth of the multi-quantum well structure, the key region within the device, it is critical to provide a uniform wafer temperature at a given wafer bow. It is possible to do this with the AIX G5+, because the wafer recesses can be customised to account for the thickness of the structure and the customer's proprietary strain management techniques.

The design of the reactor determines whether a wafer will bow with rotational symmetry (to the form of a bowl) or warp (resembling a potato chip). If the wafer bows to the form of a bowl, the distance between the wafer's edge and its carrier is the same along its entire circumference. This means that the temperature has a symmetrical profile and can be accounted for by recess designs. Adopting this approach is not possible if the wafer warps, because variations in temperature over its surface are much more complex.

It is only possible to realise rotational symmetry of the bow in either single wafer reactors, or in 'Planetary Reactors', such as the AIX G5+, where every wafer experiences an environment similar to that found in a single-wafer reactor. The benefits of symmetry extend beyond an increase in epitaxial binning yield, and include fewer handling issues and reduced yield loss in subsequent wafer processing steps. An indication of the yields produced by five different wafer recess designs in an Aixtron AIX G5+ is presented in Figure 3. Variations in design lead to variations in wavelength distributions, and for the structure formed in this particular run, the best matched design delivers a yield of 95 percent in a 5 nm bin (no edge exclusion). Extend the bin to 10 nm, and yield rockets to 99.97 percent.

Substrate thickness

Curvature of the wafer depends on several factors. It is proportional to thickness of the film and its stress, and it is inversely proportional to the square of wafer thickness (Stoney's equation). So, in addition to using strain management layers and an optimised reactor to minimise bow, engineers can try to combine thin epilayers with a thick substrate. Thin layers are advantageous for other reasons – they shorten growth times and the cost of the ingredients that are required to make the epiwafers. However, it is very tricky to trim the thickest part of any

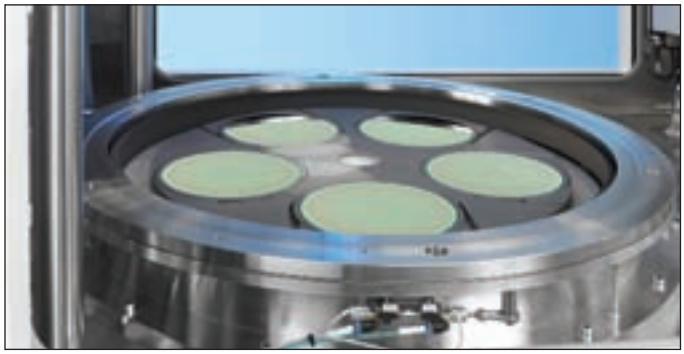


Figure 1. An Aixtron AIX G5+ Planetary reactor, designed for the growth of five 200 mm GaN-on-silicon epiwafers

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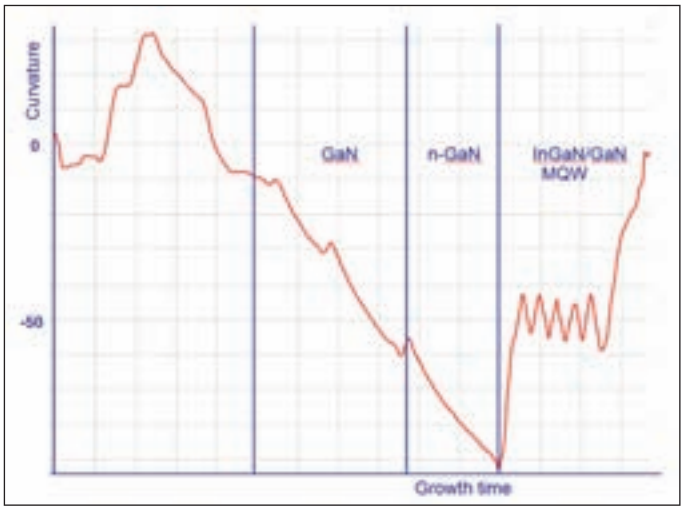


Figure 2. In-situ curvature measurement of a 200 mm GaN-on-silicon wafer. The nitride stack of films is 6 µm-thick, and features a multi-quantum well structure, a buffer and n-doped GaN. The wafer is crack-free, with remaining bow less than 10 µm

LED, the GaN buffer. Lattice mismatch between GaN and silicon is 17 percent, which is more than that between GaN and sapphire, and, in general, a thick buffer is needed to minimise epitaxial defects.

Process engineers select the thickness of the substrate based on the design of the deposited structure, its thickness, and their capability to manage wafer bow. Today, growth of LEDs on silicon is still in its infancy, and silicon substrates with a thickness of up to 1.5 mm are often used to develop this technology. This path is the simplest one to making GaN-on-silicon LEDs, but engineers will want to migrate to thinner wafers to enjoy cost benefits – a 1.5 mm-thick, 200 mm wafer is significantly more expensive than a 725 µm standard wafer. What's more, the retrofit cost for existing 200 mm silicon processing lines can be minimized with thinner wafers.

Avoiding meltback

Silicon substrates have another downside for LED growth – undesirable chemical reactions. Gallium can form an alloy with bare silicon, destroying its crystal structure at the substrate's surface. To prevent this from happening, the sensitivity of silicon towards gallium must not only be taken into account when choosing the correct initial growth conditions, which is the use of AlN as a seed layer. In addition, approaches that prevent this gallium-silicon reaction from ever taking place must be considered when designing a multi-wafer, high-throughput MOCVD reactor.

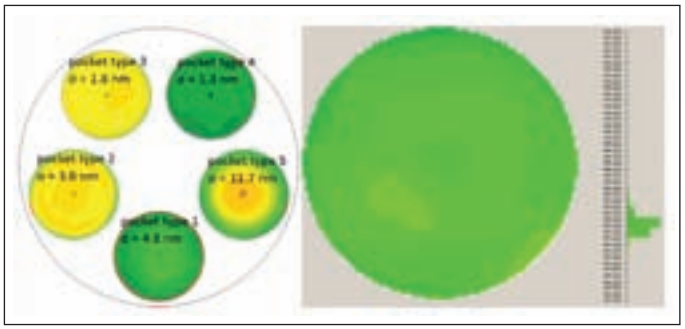


Figure 3. Uniformity optimization in an AIX G5+ reactor (5 x 200 mm) using different susceptor pocket types (left); plot of optimized uniformity (right). Standard deviation is 1.3 nm

Reactions that must be prevented include the interaction of residual gallium atoms in the reactor, which were left over from the previous run, re-evaporating during the heat-up phase of a subsequent growth run and causing 'meltback' etching on the wafer. When this happens, it diminishes the quality of growth and impacts device yield. To combat this, methods have to be devised to prevent gallium from reacting with the bare silicon substrate.

In the AIX G5 HT series, which includes the AIX G5+, interaction of residual gallium with the silicon substrate is prevented with an approach that 'resets' the chamber. This equips it with well-defined, reproducible and clean starting conditions, and gives the chamber the best starting point for repeatable, stable run-to-run performance.

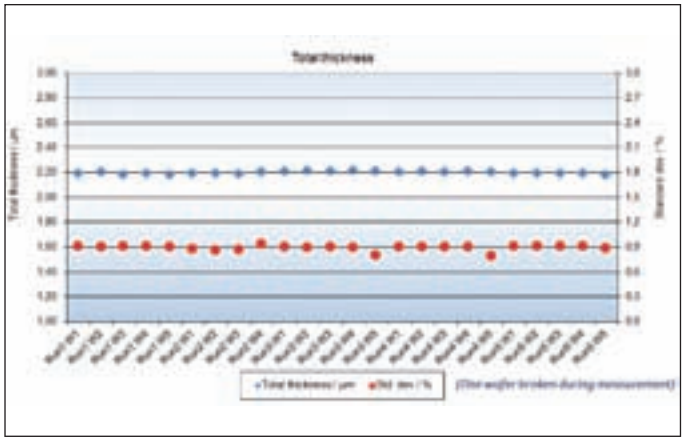


Figure 4. Thickness variation of four consecutive growth runs in an Aixtron AIX G5+

A series of five consecutive runs of GaN-on-silicon structures using the same epitaxy recipe and the 'reset' methodology produces epiwafers with thicknesses within +/- 1 percent (see Figure 4). All wafers have comparable on-wafer uniformities, with standard deviations less than 1 percent (all data without edge exclusion).

Using this 'reset' approach on the AIX G5+ enables the production of high-quality, 200 mm GaN-on-silicon LED epiwafers. This reactor, which has been purpose-built for that particular task, provides: the industry's largest throughput; a stable, repeatable epitaxy performance based on an automated chamber reset; and a unique kind of bow management, being able to deliver final bows of less than 10 µm for thick structures on 200 mm silicon. In short, it is the reactor for driving the lighting revolution.

German efforts advance semi-polar materials

Lasers and LEDs that are grown on semi-polar planes deliver very impressive performance at green wavelengths, but commercial success of these devices is hampered by a lack of affordable, high-quality substrates with appropriate orientations. To address this, a German team is developing various methods to make semi-polar material, and studying its properties in detail. Richard Stevenson reports.

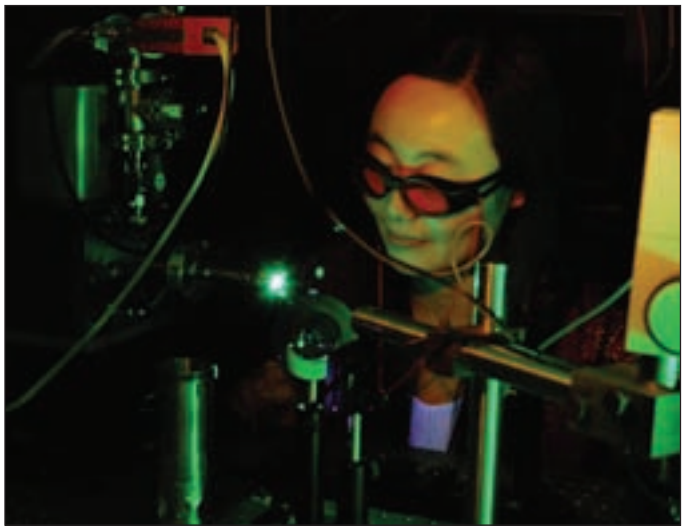
There is no question that GaN LEDs and lasers are a great success. They backlit billions of screens, they lie at the heart of countless Blu-ray players, and they are driving a revolution in energy-efficient lighting. However, that is not to say that these devices are without fault. In fact, they have several downsides, including internal electric fields that pull apart the electrons and holes in the quantum wells, hampering light emission (see Figure 1).

Separation of the carriers by internal fields, which is referred to as the quantum confined Stark effect, has impeded the development of conventional GaN-based green lasers that could be deployed in red-green-blue laser displays. Producing nitride devices that emit at this wavelength requires indium-rich InGaN quantum wells, but the greater the indium content, the stronger the internal electric fields that pull the carriers apart.

Internal fields are also bad news for LEDs. One of the weaknesses of this device is droop, a reduction in light-emitting efficiency at higher drive currents. The origin of this mysterious malady is hotly debated, but its two most popular explanations – Auger recombination and a spilling over of electrons from the quantum well – suggest that internal electric fields are detrimental. That's because these fields increase the likelihood that electrons will spill over into the hole-emitting region of an LED; and they also prevent efficient operation of devices with wide wells, which enable a reduction in carrier density and lower Auger recombination rates.

To overcome the problems associated with these electric fields, some researchers have switched from conventional substrates to those that are described as semi-polar or non-polar. Growing devices on alternative platforms either reduces substantially or eliminates the internal electric fields in the device (see Figure 2). Milestones in the advancement of such devices include: The first reports of non-polar lasers in 2007, independently developed by Rohm and the University of California, Santa Barbara; semi-polar green lasers fabricated by a partnership between Sony and Sumitomo Electric that emit a continuous output above 100 mW at wavelengths longer than 530 nm; and non-polar LEDs announced by Panasonic at the International Electron Devices Meeting that deliver a light output efficiency of almost 40 percent at a current density of 1 kA cm^{-2}.

These performances highlight the benefits that result from moving to growing devices on semi-polar and non-polar substrates. However, switching to these novel planes pays a heavy price: A hike in the cost of the substrate, which stems from the difficulties associated with making it. GaN substrates that provide a platform for the growth of *c*-plane devices, mainly lasers, have been available for several years, and prices are falling, with 2-inch material now costing around $1000. These substrates tend to be made by a HVPE process, leading to the deposition of a relatively thick layer of GaN on a foreign substrate, such as sapphire or GaAs. The wide bandgap crystal is subsequently removed and sliced into wafers. Cutting perpendicular to the growth direction yields *c*-plane substrates, while slicing in other directions produces semi-polar or non-polar material.



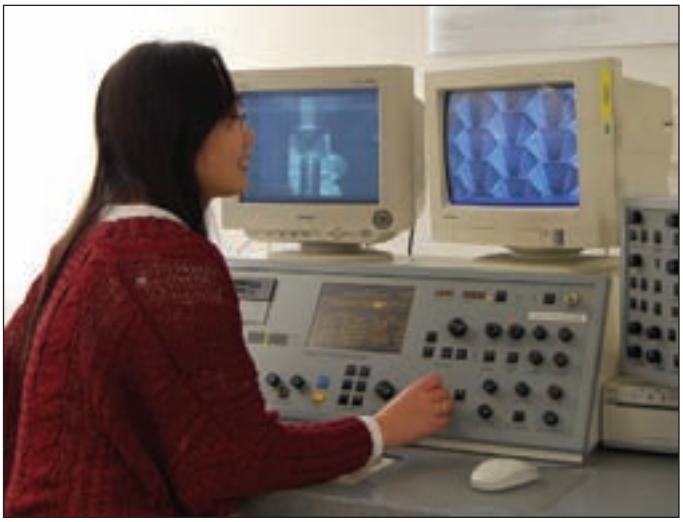
Semi-polar planes are promising orientations for making green-emitting structures

The downside of this approach is that because it is not easy to grow a very thick GaN crystal, the sizes of the semi-polar and non-polar substrates that are sliced from it are limited. They are typically just 10 mm by 20 mm in size, and sometimes just 10 mm by 10 mm, and they retail for around $1000. In addition to the high cost of the real estate on these planes of GaN, their small sizes are incompatible with wafer processing lines. Together, this pair of weaknesses forms a major barrier to the commercial progress of non-polar and semi-polar lasers and LEDs.

Slashing prices

Since 2006, a group of German Universities have been collaborating to try and develop low-cost foundations for the growth of semi-polar and non-polar optoelectronic devices. Their programme, which is named PolarCoN and is co-ordinated by Ferdinand Scholz from Ulm University, won funding from the German Research Foundation in 2008. Now in its second phase, this €4.5 million project involves, in addition to the University of Ulm, seven other universities: Stuttgart University, Otto-von-Guericke University Magdeburg, TU Braunschweig, TU Berlin, Regensburg University, Freiburg University and Kassel University.

"Originally, our main target was the green laser," admits Scholz, who explains that researchers outside of the project, such as those at Sumitomo, have now succeeded in that endeavour. "We



Scanning electron microscopy reveals the surface of the wafer containing inverse GaN pyramids with semi-polar facets

would still like to get such a device – a green laser is always a good demonstrator that you are successful – but we now focus on more basic relations of non-polar and semi-polar material." Efforts have been directed at producing high-quality material – principally on semi-polar planes, but also on non-polar planes – and understanding the bandstructure of this material and how its influences electrical transport.

During the project the team has looked at the growth of bulk GaN and developed techniques to form semi-polar GaN films and novel lasers on sapphire substrates. In addition, the group has provided new insights into growth conditions on different planes and explanations for the differences in photoluminescence of quantum wells grown on different types of substrate.

The most attractive approach to forming semi-polar GaN is to deposit this on *r*-plane sapphire. "[This] is more expensive than *c*-plane, but it is still in the range of $70 for 2-inch," explains Scholz. Producing high-quality GaN on this plane of sapphire is very tricky, however, because GaN tends to be plagued with stacking faults that propagate throughout the material.

These stacking faults occur due to local differences in crystalline structure. GaN is a hexagonal material, and its atomic units follow the sequence *ABAB*… The other common crystalline structure for compound semiconductor materials is cubic: GaAs crystals are an example of this, and their units align in the order *ABCABC*. Stacking faults arise in GaN when the units have a sequence *ABC*, which involves a shift in the position of the planes.

"For *c*-plane devices, [stacking faults] don't matter so much," says Scholz. "You have a lot of stacking faults close to the foreign substrate, such as sapphire, but they run parallel to the interface and you don't find them later if the material grows nicely." In stark contrast, in non-polar material, the planes of stacking faults are aligned perpendicularly to the plane of the wafer, and they will always reach the surface. Similarly, in semi-polar material the planes of stacking faults are inclined at an angle to the substrate, so they also reach the surface. In both cases, no growth technology is currently capable of eliminating these faults.

Growth on triangular pyramids

Scholz and his co-workers at the University of Ulm have developed a technique that slashes the density of stacking faults through modifications to the substrate. Back in 2004, they were improving the quality of GaN with a well-known technique called epitaxial lateral overgrowth. This begins by taking a sapphire wafer and depositing onto it a GaN film and a SiO_2 mask. The wafer is then patterned, with SiO_2 selectively removed to create open stripes in the mask, before the structure is put back in the MOCVD chamber. Using optimized growth conditions, GaN stripes with triangular cross-section selectively grow out of these windows. Hence, Scholz's team have realized pyramid-shaped GaN, which has semi-polar facets but is formed by *c*-plane growth – so the problems of stacking faults are avoided.

This team has gone on to form a range of LEDs on these facets. Early results included 425 nm LEDs producing more than 3 mW when driven at 110 mA. "We later focused on a longer wavelength," says Scholz. "You get problems with indium

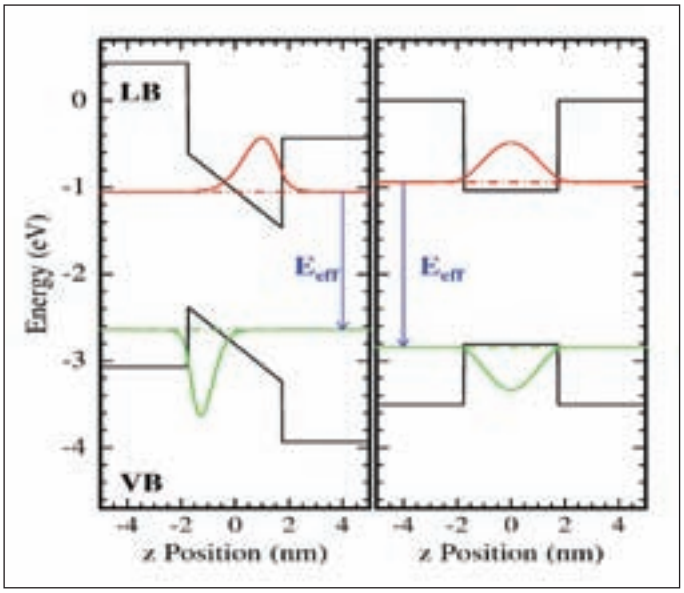


Figure 1. Conventional GaInN quantum wells are embedded in GaN barriers and grown in the c-direction (left). The GaInN quantum well gets compressively strained due to the different lattice constants of the two materials. This leads to an internal piezoelectric field and a tilting of the conduction (CB) and valence band (VB) edges. One consequence of this is a spatial separation of the electrons in the CB (which move to the right) and the holes in the VB (moving to the left). Moreover, the effective band gap is slightly reduced. This effect is called the quantum confined Stark effect. Removing the internal electric field allows the electron and hole wavefunctions to overlap perfectly, improving light emission from this structure (right)

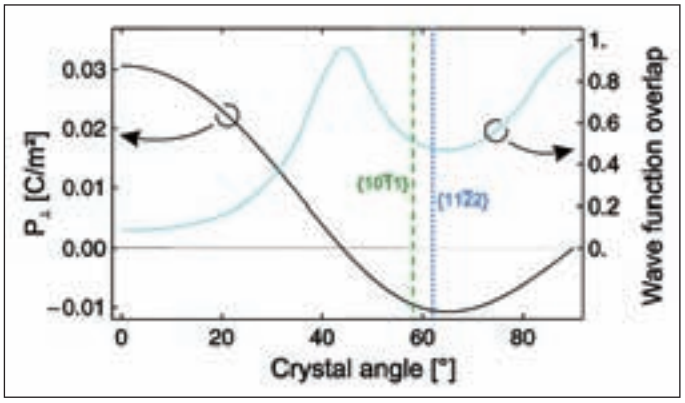


Figure 2. Polarization (left axis) and wave function overlap (right axis) for a GaInN quantum well between GaN barriers. 0° refers to c-plane quantum wells, 90° to non-polar planes. Two low-index, semi-polar planes are marked at about 60°

incorporation, and the power drops drastically. We are currently trying to improve it."

Another problem with this type of LED is that it is very difficult to optimise its *p*-type doping. "You can't easily measure the *p*-type doping in such structures, because SIMS (Secondary Ion Mass Spectroscopy) and Hall measurements do not work," explains Scholz. One technique that can be used to identify problems is transmission electron microscopy (TEM), but it can take two months to get results with this approach.

However, although TEM doesn't provide fast feedback, it has played a very important role in characterizing these semi-polar LEDs. It is able to determine the thickness of the quantum wells grown on the facets, and revealed that this is thicker near the apex of the stripe. Compositional fluctuations are also present in the InGaN quantum wells, according to locally resolved high-resolution X-ray measurements, which show increasing indium richness near the apex. Scholz and his co-workers have attributed these variations in the composition and thickness of the wells to

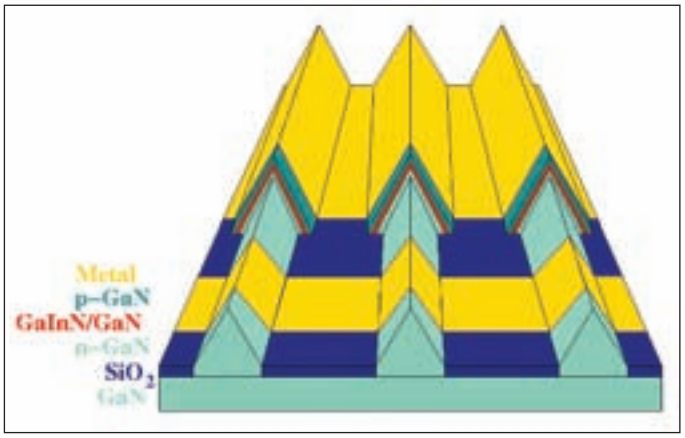


Figure 3. Masking and regrowth on the c-plane leads to the formation of triangular pyramids with semi-polar facets. Researchers at the University of Ulm are trying to develop lasers on these structures

gas diffusion effects. It is thought that as the precursor molecules diffuse down to the bottom of the stripes, the effective diffusion length of the indium molecules is shorter than that for the gallium-containing species, and this reduces the growth rate for the well and its indium content.

One upshot of these variations within the well is a broadening of the LED output. It's not clear if this is beneficial for commercial applications, and when Scholz has discussed this with colleagues working in industry, they have been concerned that differences in drive current lead to changes in the colour emitted by this device.

Novel lasers

What may raise a few eyebrows is that the team from Ulm are also trying to develop semi-polar lasers on these triangular pyramids (see Figure 3). "It seems to be very difficult to think about a laser," admits Scholz, "but it depends on which kind of laser you hope to realise, and how much stripe material you need. You can consider whether you can realise a laser that runs along the stripe."

To optimise the design, the dimensions of the stripe should be tailored for waveguiding, and the feature sizes should be reduced to minimize variations in the thickness and indium composition of the quantum well. Judicious selection of the spacing of the structures and their dimensions may also enable them to form gratings for distributed feedback lasers (see Figure 4).

The team from Ulm are working on that, and now grappling with the problem of forming good waveguides via high-quality overgrowth of AlGaN on the stripes. "Our goal is to get optically pumped lasers this year," says Scholz. "We have some optical gain measurements, but they are not that great yet."

In addition to forming triangular pyramids, Scholz and his co-workers have fabricated arrays of hexagonal pyramids by creating hexagonal apertures in the dielectric mask, and then growing the structures out of these holes. This work allowed the team to

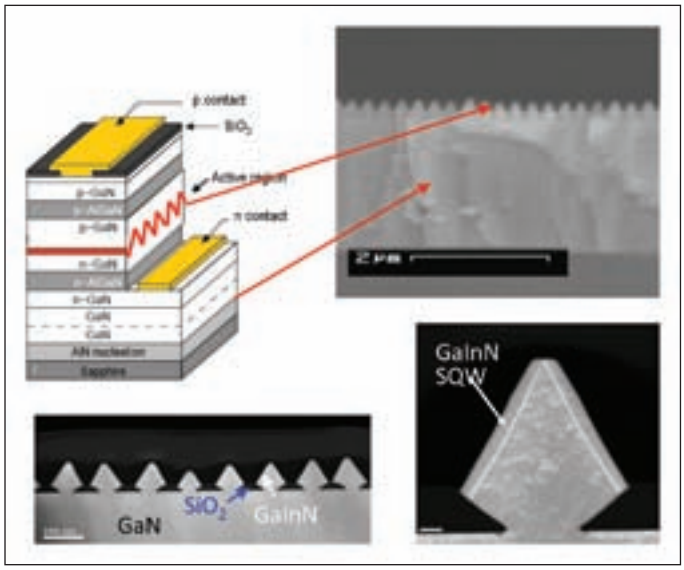


Figure 4. Lasers formed on semi-polar facets can have feature sizes that could enable distributed feedback

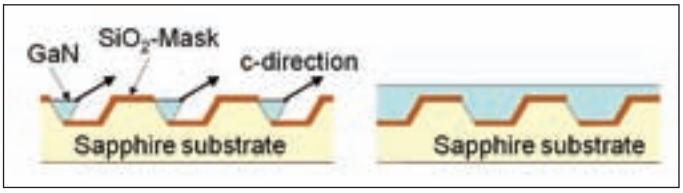


Figure 5. One way to form semi-polar GaN wafers is to initiate GaN growth on c-plane side-walls of trenches etched into sapphire wafers with specific non-c-plane orientations

investigate how the angle of the facet impacts variations in the thickness and composition of the wells. It also led to the fabrication of a more uniform surface of material, which had a greater area of semi-polar planes.

One application of such structures is luminescence conversion. A partner in that work is Osram Opto Semiconductors of Regensburg, Germany. "[Osram] are interested in getting green light by optically pumping such material with highly efficient blue LEDs. They are currently comparing their polar quantum well structures grown conventionally in *c*-direction with our semi-polar material," explains Scholz.

From hills to plains

From 2008 onwards, the researchers at Ulm have also been trying to form engineered substrates with a flat, semi-polar surface using *c*-plane growth. "Triangular shaped devices are not liked in industry, because you have to produce contacts on a very fancy surface," explains Scholz.

His team's efforts have followed in the footsteps of researchers in Japan: Nobuhiko Sawaki's group from Aichi Institute of Technology, Japan, which have developed flat {10$\bar{1}$1} GaN surfaces by etching trenches with {111} sidewalls in silicon; and more recently, Kazuyuki Tadatomo's team at Yamaguchi University, that produced pure {11$\bar{2}$2} GaN by patterning *r*-plane sapphire with 3 μm wide, 1 μm deep stripes running along the in-plane *m*-direction and separated by 3 μm-wide terraces.

If the growth on these structured substrates were perfect, material would just grow on one type of sidewall, known as the +*c*-wing (see Figure 5). In this case GaN would grow out of the trench, grow laterally over the ridges separating the trenches and eventually coalesce, creating a flat surface with a semi-polar nature. In practice, however, GaN also grows laterally in the opposite direction after having filled the trench in the wafer. This forms a -*c*-wing, which is riddled with defects (see Figures 6, 7 and 8). In comparison, the quality of material outside this area is far higher. According to Scholz, material produced by his team has: "on average, stacking faults below 10^4, per centimetre, and dislocation density below 10^9 cm^{-2}."

Comparisons with companies

In 2010, the progress of the German team would have been compared to that of two companies outside of Europe that announced tremendous progress towards the manufacture of semi-polar GaN substrates. In the summer of that year, Ostendo Technologies Inc. and Technologies and Devices International Inc. (at that time part of the Oxford Instruments Group, but now owned by Ostendo) announced their joint development of semi-polar (11$\bar{2}$2) GaN layers on sapphire substrates. And in November, Sumitomo Electric unveiled its large-scale production of the world's first 2-inch semi-polar/nonpolar GaN substrates for green lasers. This platform had a dislocation density of the order of just 10^5 cm^{-2}.

Impressive announcements from Sumitomo and TDI could have jeopardized further funding of PolarCoN, but they didn't. "In Germany, we are in this good situation where the funders do not kill a project after such a message," says Scholz, who believes that continued backing of the project was aided by its broad aims: Not to only make semi-polar GaN, but to also understand the nature of this material. According to him, there are still opportunities to improve the technologies for making semi-polar and non-polar GaN, and the findings that stem from PolarCoN could benefit companies from Germany or other parts of Europe that may make these materials in future. Although it is now more than two years since these announcements from both Sumitomo and the collaboration between TDI and Ostendo, little is known about the material produced by these companies.

"I would think that TDI is just growing on *r*-plane sapphire," says Scholz. "Maybe they have found a method to get just one phase of semi-polar material. But there is no scientific publication about that, so it's very hard to discuss this." Sumitomo is just as secretive. "From what I see, there is not even a publication from groups who may have used that substrate," claims Scholz.

He and his co-workers are continuing to develop their flat semi-polar substrates, and deposit heterostructures on them. They began with quantum wells, and the strong intensity of the photoluminescence emanating from them encouraged the development of LEDs on this semi-polar platform, which are compared to devices on sapphire. "The intensity of the electroluminescence [from these semi-polar devices] is less than that from *c*-plane counterparts, which is to some extent due to non-optimised *p*-doping," says Scholz, who plans to continue to develop these devices.

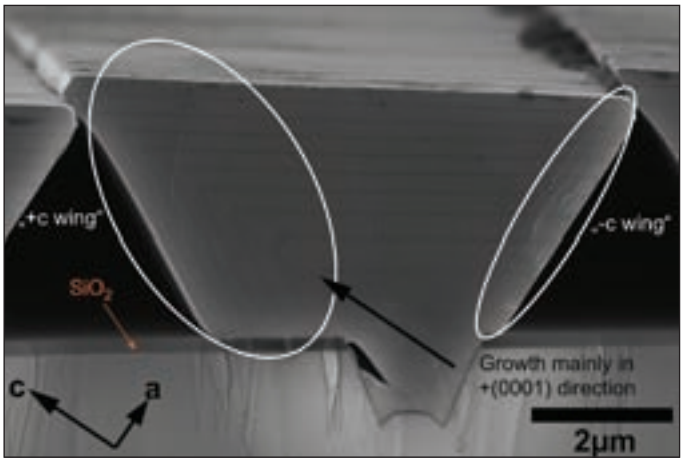


Figure 6. Transmission electron microscopy highlights the reduction in the crystal quality of GaN in the –c-wing

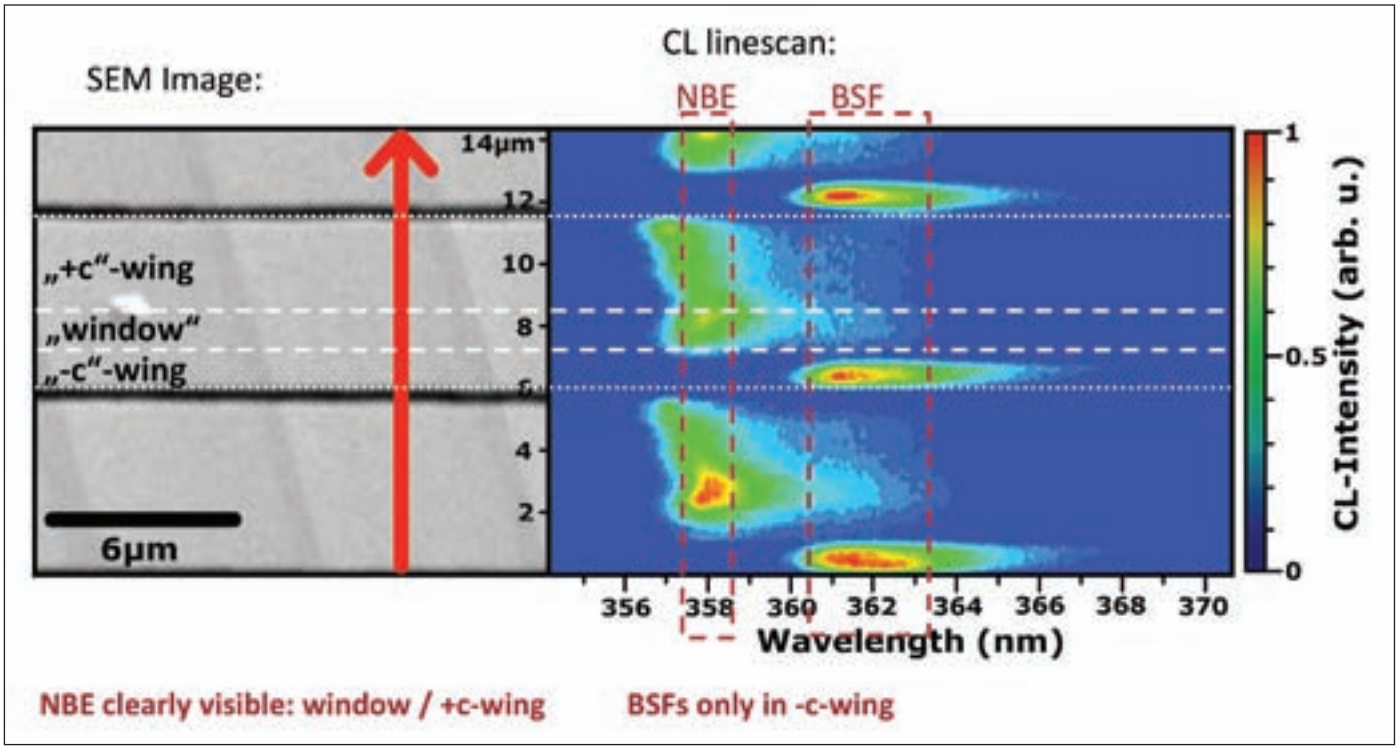


Figure 7. Cathodoluminescence measurements by a team at Otto-von-Guericke-University Magdeburg show that basal plane stacking faults (BSFs) are only present in the –c wing. Near band edge (NBE) emission is strong outside this region, due to far higher crystal quality

Growth mechanics

One of the biggest questions surrounding the growth of non-polar and semi-polar material is this: How do the deposition conditions compare to those for the growth of conventional GaN? Some groups claim that they are considerably different, but in general terms, Scholz believes that they are broadly similar.

"It was a very controversial discussion in our group, and to some extent the results were different in different groups," explains Scholz, who admits that the details of the growth conditions play a major role in drawing conclusions. He believes that the growth conditions for most facets are very similar, but studies conducted by TU Berlin have confirmed earlier studies done in Ulm that incorporation of indium is markedly enhanced on the {1011} plane, compared to other semi-polar orientations.

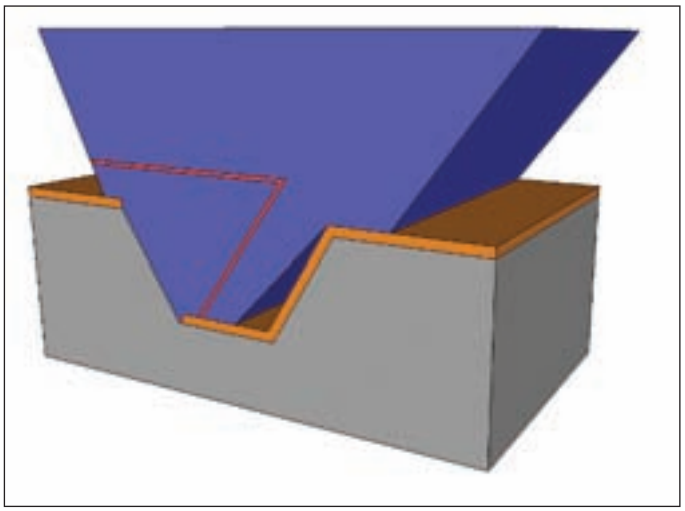


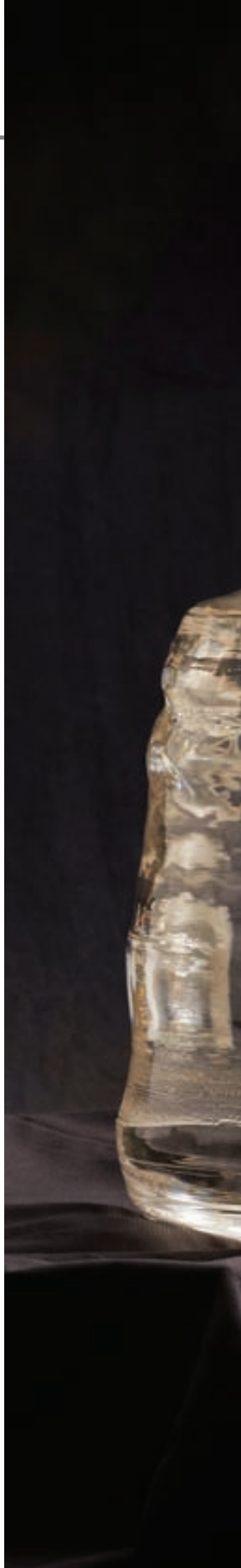
Figure 8. Inserting SiN interlayers improves the quality of GaN

Another important contribution from a PolarCoN team partner – TU Braunschweig – is an explanation for the substantially shorter emission wavelength for InGaN quantum wells grown on *m*-plane SiC, compared to *c*-plane sapphire and *c*-plane and *m*-plane SiC. X-ray diffraction measurements reveal very similar levels of indium incorporation for all the wells, and Scholz and his co-workers argue that the shift in emission wavelength stems from growth on SiC. This leads to high levels of stacking faults, which create quantum-wire-like structures. "That means you produce a local different bandgap," explains Scholz, with emission from this structure depending on the alignment of this bandgap to that of the host material. In this case, a type-II bandstructure results.

Funding for this study and other efforts within PolarCoN runs until 2015, which gives the team some more time optimise its substrates and devices. Scholz has set his team in Ulm two targets for the remainder of the programme: "One is to produce a DFB laser, making use of triangular stripes, operating at least by optical pumping, if not electrical pumping. And the other is to produce a nice wafer, which means optimising HVPE growth of semi-polar material." Success on both fronts would be a fitting way to end this six-year effort.

Vertical integration streamlines sapphire production

It's great for a business to adopt a holistic approach to sapphire manufacturing. When a firm begins with the processing of raw materials and ends with wafer polishing, it enables a trimming of manufacturing costs, the application of proprietary processes to many steps used in sapphire substrate production, and improvements to the reliability of product supply, argues Raja Parvez from Rubicon Technology.



Most companies rely on other firms to provide materials, components or process technologies. But there is another way – vertical integration. This delivers several benefits in competitive markets, including enhanced cost efficiencies, far greater control of the quality of crucial production inputs, and the ability to provide customers with assurance that their orders will be delivered on schedule.

It is not a new idea to adopt a vertically integrated approach to running a manufacturing business. Back in the 1800s, US Steel tycoon Andrew Carnegie introduced the concept by owning virtually every part of the steel-making value chain, from iron ore through steel mills to the building of railroads. By the 1920s, Ford Motor Company was also employing a vertically integrated approach – it decided to make the steel for its cars. And since then, vertical integration has been applied to almost every type of manufacturing around the globe – including sapphire.

At Rubicon of Bensenville, IL, that's what we do. We have created the most vertically integrated business model in the sapphire industry to reliably and cost-effectively provide ultra-pure, defect-free material with diameters of 6-inches or more.

Sapphire and solid-state lighting

Our biggest market is that of substrates for the production of LEDs. These solid-state sources are needed for the backlighting of displays and the new wave of energy efficient LED lighting. The backlighting market is much more established: According to Displaybank, in 2012 total LED penetration stood at 41 percent, and it is forecast to reach 95 percent in 2014.

In comparison, the LED lighting revolution is still in its infancy. Market research firm DisplaySearch calculates that the total average LED penetration in general illumination was 1.4 percent in 2010 and forecasts that it will reach 9.3 percent in 2014. Meanwhile, IMS Research estimates that the overall LED market reached nearly $10.9 billion in 2012 with $2.9 billion coming from lighting. By 2015, this analyst projects that the LED market will reach $13.9 billion, with the lighting market nearly doubling to $5.8 billion two years from now. This mass adoption of the LED will be accompanied by significant reduction in the price of solid-state lighting systems and components. This begins with the LED – including the sapphire wafer and chip.

One significant opportunity for LED chip manufacturers to trim their costs is to transition to

Through vertical integration, Rubicon Technology has been able to scale the growth of bulk sapphire crystal from 3.5 kg to 30 kg, 85 kg and then 200 kg without compromising high quality or high yield

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larger diameter substrates. According to analysis in 2012 by the US Department of Energy, 15 percent of the cost of the LED package is in the substrate, with the package accounting for a substantial fraction of the cost of the luminaire. If LED chipmakers migrate to larger diameter substrates, they will benefit from operational savings that more than offset the cost of the larger platforms. The lower-cost LEDs that result will then help to drive mass adoption of LED lighting for commercial and residential use.

Today, more than 90 percent of LEDs are built on sapphire, with the remainder on SiC, followed by other materials. To date, alternative substrates have failed to offer the performance and cost advantages of sapphire.

One platform that is attracting a lot of attention today is silicon. Proponents of this foundation are attracted to potential operational efficiencies that result from using 8-inch diameter wafers and the opportunity to use fully depreciated CMOS equipment. But these advantages must be weighed against the significant mismatches in the thermal expansion coefficients of silicon and GaN. Addressing this requires a costly, complex buffer layer to mitigate cracking and breakage. The manufacturing yields for GaN-on-silicon are reportedly still very low, while long-term reliability is unproven. So, until the technological hurdles are solved, silicon might be a niche solution, but is not expected to displace sapphire as the preferred substrate for LED production. Note that for cases where 8-inch diameters are important, we are capable of production volumes of 8-inch polished sapphire wafers.

Another frequently mentioned alternative to GaN-on-sapphire is GaN-on-GaN. However, 2-inch GaN substrates cost $1,000 or more, a hundred times the cost of sapphire. These high costs stem from a very complex fabrication process, and prevent a significant volume of this material from being available.

Given this backdrop, most LED chipmakers are looking to large diameter sapphire wafers to cut costs. Using this particular platform will enable more throughput in each run of the MOCVD reactor, making better use of the reactor 'real estate' and ultimately diminishing the cost per unit of area processed. In addition, large wafers reduce edge loss, and also provide post-MOCVD efficiencies.

Depending on the type of MOCVD reactor used, LED chip manufacturers using 6-inch wafer platforms can achieve up to 48 percent greater usable area, per reactor run, compared with 2-inch wafers. The overall surface area of a 6-inch wafer is nine times that of a 2-inch wafer, and its outer curvature is less, enabling greater use of the surface area, culminating in a reduction in edge loss (see Figure 1). What's more, when placed in an MOCVD reactor, there is greater coverage area in the reactor, resulting in further gains that are due to less waste of processing materials. Put all this together and all these efficiency gains associated with production on larger substrates become very compelling when LED chip production ramps up in large volumes to support a high growth market like general lighting.

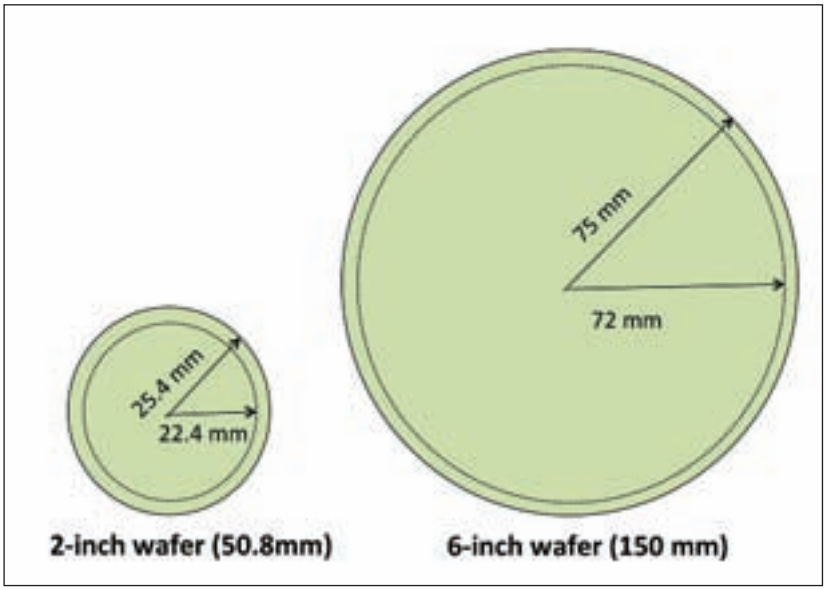
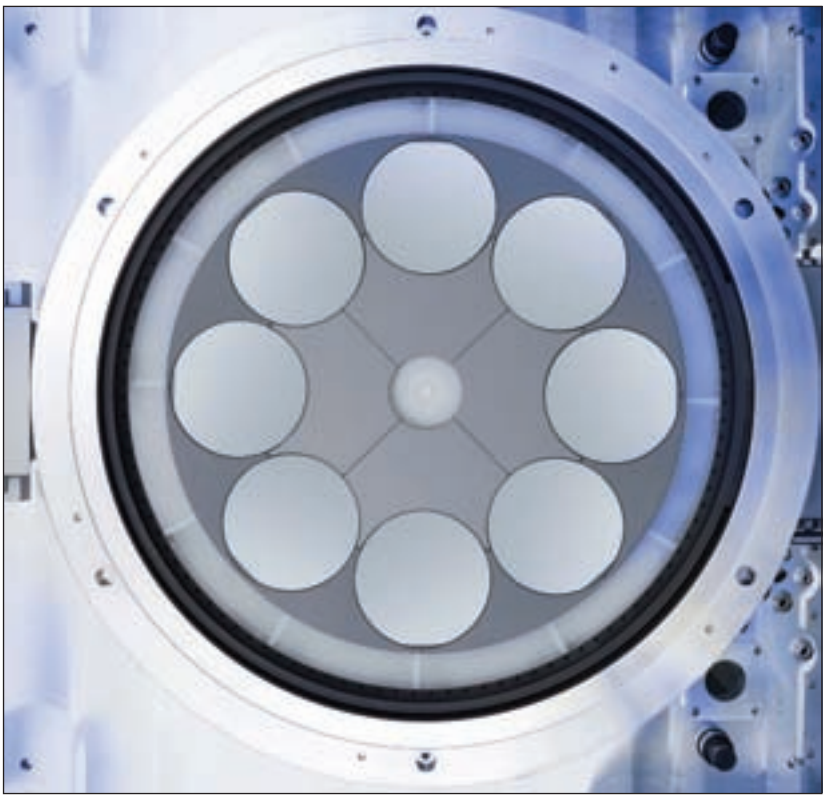


Figure 1: The proportion of chips that must be discarded due to 'edge loss' diminishes as wafer sizes increase

Our substrates are also being consumed in a second significant market for sapphire – silicon-on-sapphire (SoS) RFICs. Sales of SoS RFIC chips are ramping up, because they combine high RF performance with low power consumption, a small form factor, and significantly reduced crosstalk in antenna applications that are pervasive in smart phones and other consumer devices. Sapphire is highly insulating, which helps the fabrication of devices that are fast, frugal, and offer high levels of isolation. In the last few years, SoS RFICs have gained a significant share of the smart phone antenna chip market, especially in the rapidly growing LTE networks, and they are now being marketed for other applications within these devices.

Vertical integration

Vertical integration holds the key to our cost structure and the reliable supply of high-quality products. This integrated approach influences every step in the growth of sapphire crystals and their processing into wafers. Our end-to-end manufacturing capability, with strong intellectual property at each step of the manufacturing process, produces an advantageous cost structure and



Leading MOCVD tool makers, such as Aixtron, offer multi-wafer reactors with a variety of configurations. Loading the reactors with 6-inch wafers, rather than 2-inch wafers, leads to more efficient use of gases and pre-cursors. Credit: Aixtron

provides better control of product quality and delivery schedules. Vertical integration is also central to our ability to grow larger and larger sapphire and be the first firm to market with large-diameter sapphire wafers. To date, we have shipped more than 400,000 6-inch wafers.

One of the great strengths of our vertically integrated approach is that we have the materials on hand to meet our customers' expectations. Production begins with the processing of powdered Al_2O_3 to yield purified, 'densified' material, which is then fed into the furnace to produce a large sapphire crystal or boule. Recently, we started a transition to on-premise processing of Al_2O_3.

Processing our material in-house gives us greater control of our raw material supply, reduces our costs and enables us to ensure the quality of our starting materials for making sapphire crystals. If we were not able to do this, we would have to rely on commercially purchased crackle, which can be highly expensive and subject to an unreliable, fluctuating supply. Even high purity crackle can be plagued with impurities from transition metals such as silicon, chromium and titanium, resulting in lower quality sapphire boules. For example, the addition of small amounts of titanium can lead to a pink boule – titanium and chromium give the red sapphires found in nature their 'ruby' red colour.

The processed Al_2O_3 produced in-house is fed into custom-built, proprietary furnaces, named ES2-XLG3.0. We make these furnaces for less than half the cost of merchant furnaces. These growth tools, which have all been recently upgraded, are installed in our facilities in Batavia, Franklin Park and Bensenville, Illinois, where we maintain tight control over this valuable intellectual property.

Our customized furnaces are equipped with automation for monitoring all the vital functions and crystal growth rates. This is the key to greater yield consistency. Our proprietary ES2 crystal growth methodology is automated, requiring operator intervention only at pre-set points during the growth process. Thanks to this, it requires less operator intervention than competing methods – with our approach, the operator must be present for less than 10 percent of total cycle time. The primary role of the technician is to initiate crystal growth.

Crystal Growth

During the last 11 years, we have refined our ES2 growth process that is based on the Kyropoulos method (see box "Building on the Kyropoulos method" for details of this growth technology). Our now-perfected methodology involves a top-seeded approach that allows a clear, contaminant-free sapphire crystal to grow unconstrained. Thanks to this, growth is stress-free and defect densities are incredibly low. We employ a master seed crystal, made from one of our own high-quality boules, over and over again to produce consistently high-quality material.

Additional advantages stemming from our furnace design and growth process include: A low thermal gradient; *in-situ* annealing; minimal bubble formation, due to no crystal rotation; and continual monitoring of the entire growth process, which is possible with a weight sensor. Thanks to this impressive set of attributes, it is possible to routinely yield material with very little stress and a low dislocation density, which is of the order of 10-100 defects cm^{-2}. This is far lower than that found in sapphire formed by either the Czochralski method or the heat exchanger method, which both yield defect densities of 1000-10,000 cm^{-2}. High crystal quality with a high yield is even possible when scaling the growth of bulk crystal. The mass of our boules has steadily increased from 30 kg to 85 kg and then to 200 kg.

Finishing steps

Processing our crystals into substrates involves high-precision core drilling, wafer slicing, surface lapping, large diameter polishing and wafer cleaning. We have strong intellectual property in

In early 2011 we opened a facility at Penang, Malaysia, that is used to carry out most of our finishing processes. Operating from this location helps to reduce costs, and it is near to LED chip manufacturers in Asia. We believe that this facility will enable us to reduce the costs associated with making a 6-inch wafer by 20 percent – so far, we have got halfway towards that goal, and we expect to hit this target by summer 2013

many aspects of the finishing processes, including a recently awarded patent for *in-situ* orientation technology. This allows us to fulfil the differing needs of our customers in the LED, SoS/RFIC and optical markets. These clients all have specific, distinct requirements for the crystal planar orientation of the sapphire products used in their applications.

Two of the key benefits of our new orientation process are enhanced precision associated with sapphire planar orientation, and the elimination of time-consuming steps, because orientation is performed at the fabrication tool. Recently, we have also been awarded a patent for our lapping technology. This is associated with platens that are continuously self-conditioned and self-optimized to maintain high performance. Efficiencies resulting from this technology will translate into savings for our customers.

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Patterns for the future

Engineers in our research and development team are now focusing on the fabrication of patterned sapphire substrates. Today, many LED chipmakers etch a pattern into the sapphire substrate, prior to MOCVD growth, to increase light extraction efficiency from this device.

This year we will give our customers the opportunity to eliminate this step by doing it for them. If they take up this opportunity, they can devote more time to their core technology. Patterns etched into the sapphire vary from LED maker to LED maker, so we will offer them their own bespoke design, a step that will bring us closer to them. Patterned substrates are already available from several suppliers, but wafer sizes tend to be small. In contrast, we will focus on the production of large diameter substrates, which are more challenging to process. This means that our provision of them adds greater value.

Our move to providing patterned sapphire is in keeping with our general philosophy: As sapphire and LED chip manufacturing evolve, we will continue to invest in capabilities that provide ever-increasing value to this industry. We already employ industry-leading expertise at every stage of sapphire production, which begins with raw materials and goes right through to wafer finishing. This vertically integrated approach, working in tandem with a deep understanding of our customers' manufacturing processes, delivers two major benefits to our business: It contributes to excellence in quality and reliability; and it draws us closer to our key customers.

Building on the Kyropoulos process

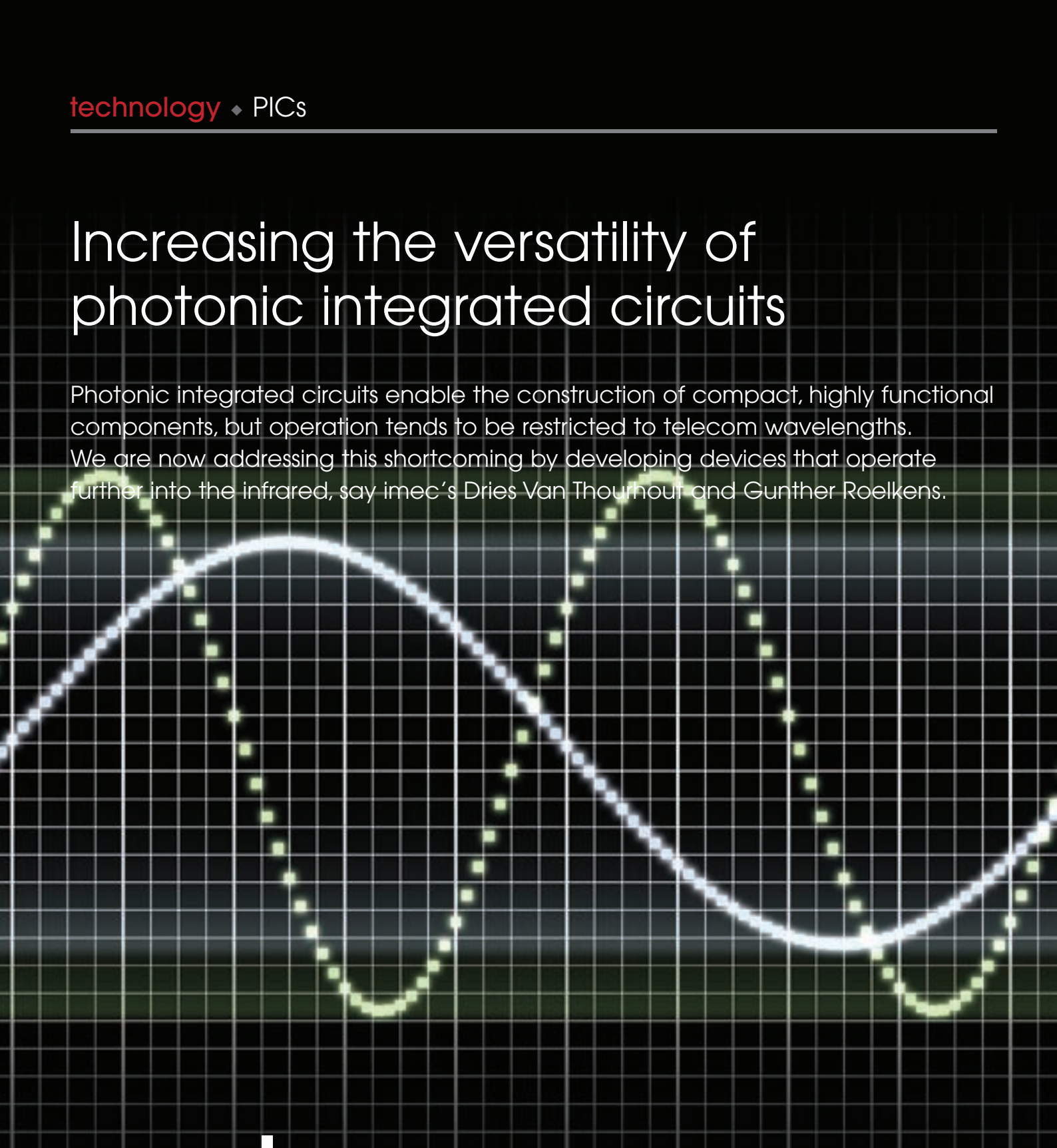
Rubicon employs a sapphire growth process based of the Kyropoulos method. This well-established technique involves placing pure alumina raw material in a crucible and heating it so that it melts. The sapphire crystal is formed on the seed, from the top down. The crystal solidifies as it is very slowly pulled up, with the thermal gradient tightly controlled, to form a free and natural shape as the crystal grows unconstrained.

The Kyropoulos technique is ideal for materials with low thermal conductivity and a high degree of thermal expansion, the combination of which can make crystal material vulnerable to various imperfections unless grown and cooled in a low-stress environment.

With this highly controlled thermal-gradient, the Kyropoulos method yields large-diameter boules of very high optical quality due to high purity. The resulting boules can be cut to any crystallographic orientation or plane.

Increasing the versatility of photonic integrated circuits

Photonic integrated circuits enable the construction of compact, highly functional components, but operation tends to be restricted to telecom wavelengths. We are now addressing this shortcoming by developing devices that operate further into the infrared, say imec's Dries Van Thourhout and Gunther Roelkens.



If you want to combine several functions on a single chip, you can build an integrated circuit (IC). In its electronic form this device is now incredibly mature, but the same cannot be said for its photonic counterpart. That's partly because more than 95 percent of electronic ICs are made in silicon, while a vast and varied array of materials are employed for fabricating optical PICs, including III-Vs, polymers, glass and $LiNbO_3$. This diversity in materials has diminished the advantages that come with scaling, and accounts for this class of ICs' relatively low degree of integration and suboptimal performance.

These weaknesses have been known for many years, and since the 1990s several research groups have tried to address this by turning to silicon as a substrate for making these optical circuits. Its attributes include optically transparency in the telecommunications window (1300 nm and 1500 nm),

plus a very high index contrast with the surrounding air or glass, which enables extremely compact circuits. What's more, optical PICs can be fabricated with the same set of tools as those used to manufacture their electronic cousins. This means that PIC production can take advantage of the installed manufacturing base, spurring the development of new types of circuits that combine higher degrees of integration with lower costs, higher performance and even co-integration with electronics.

During the last decade this new waveguide platform has been integrated with high performance passive circuitry and filters, low loss optical switches, high-speed optical modulators and germanium-based photodetectors. However, due to its indirect bandgap, it is incredibly difficult to obtain direct light generation from silicon. The most promising structures for generating light emission are silicon nanocrystals and strained germanium, and both of these are the subject of intense investigation. However, these devices are vastly inferior to conventional devices built from III-Vs.

To address this situation, our team at imec – and also other research groups, such as those based at CEA-LETI, France, and the University of California, Santa Barbara (UCSB) – have developed technologies for taking high-quality III-V epitaxial layers grown on a native substrate and transferring them to silicon wafers. With this approach we have formed circuits operating at telecom wavelengths that unite single-wavelength lasers and detector arrays, both containing InP-based active layers, with high-precision silicon nanophotonics wavelength demultiplexers.

In addition, more recently we have highlighted the true versatility of this approach by also integrating GaSb-related materials on silicon: This has led to the first ever demonstration of waveguide-based spectrometers operating above 2 μm.

Wafer bonding

The heart of our integration process is the bonding of III-V die or wafers to silicon with an adhesive layer – we use the thermosetting polymer DVS-BCB, which is available from Dow Chemical (see Figure 1). We have spent several years optimizing this bonding process, and it is now possible to reliably bond with intermediate adhesive layers less than 50 nm-thick, while realizing within wafer and wafer-to-wafer accuracy below 3 nm. With our technology we can perform wafer-to-wafer bonding, die-to-wafer bonding, and even simultaneous bonding of dies with different thicknesses.

We are not the only group to have developed a bonding technology. Researchers at UCSB use direct bonding after oxygen plasma activation to attach one material to another, while engineers at CEA-LETI employ a technique that they describe as molecular bonding, which is based on the mating of two oxide-clad wafers. Both these approaches have

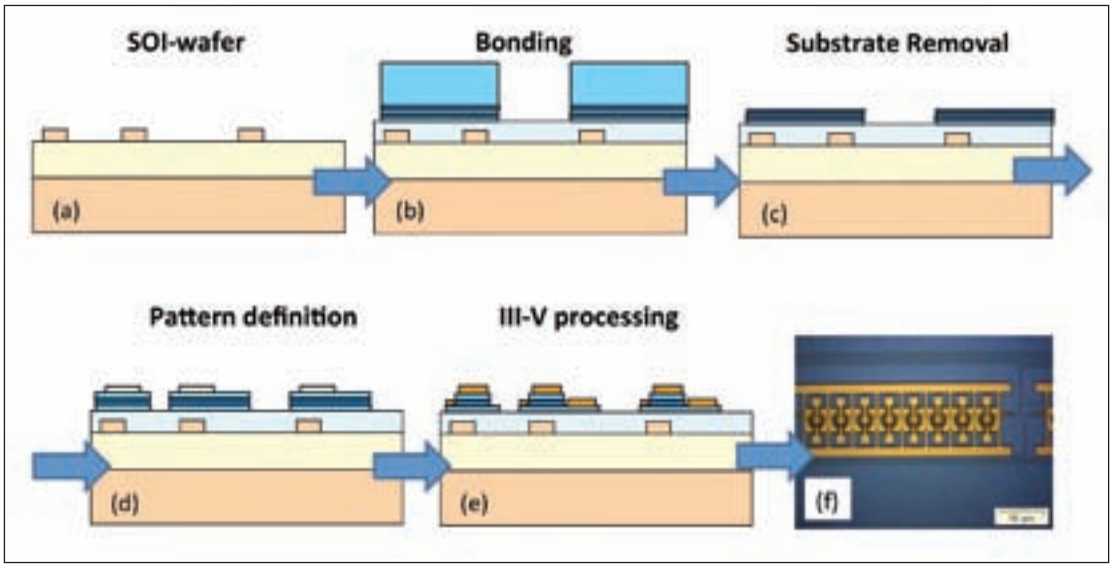


Figure 1. Illustration of the bonding process. The starting point is the processed SOI-wafer (a) with silicon waveguides. For building more advanced PICs this wafer may also already contain active devices such as modulators and germanium detectors. Next, dies or wafers of unprocessed III-V material are bonded on top, with the epitaxial layers oriented towards the silicon waveguides (b). Then the substrate is removed using grinding and or wet/chemical etching, such that only a thin stack with the active layers remains on the silicon wafer (c). This wafer can now be further processed using standard wafer-scale processing techniques such as deep UV lithography, mesa etching (d) and metallization (e), resulting in finished chips as shown in (f)

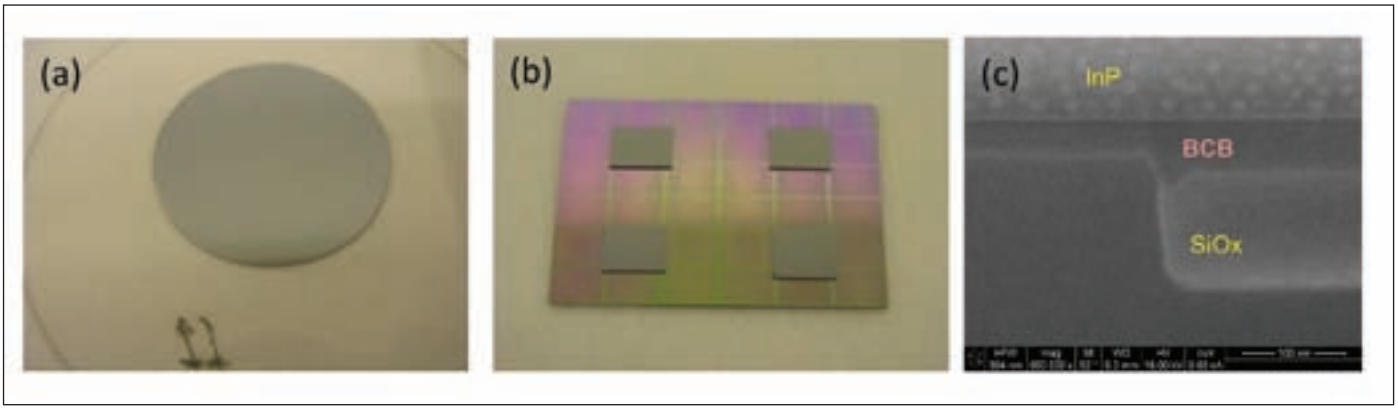


Figure 2 a) Bonded wafer, in this case on a transparent Pyrex wafer, allowing us to inspect the interface, showing no defects in this case b) Multiple bonded InP dies on a patterned SOI substrate c) Cross-section of bonded InP wafer on silicon waveguide

the advantage of avoiding a polymer layer in the stack, but they are more sensitive to surface roughness and contamination. Note that in all cases the overall integration philosophy remains the same.

Once the materials have adhered to one another, the substrate of the bonded material is removed to leave a high-quality III-V epitaxial layer on the silicon platform. The thickness of this III-V structure can range from less than 100 nm to 2 μm – its value should reflect the target application. From that point onwards, fabrication can exploit standard waferscale processes. This means that the accuracy of alignment between III-V devices and silicon waveguides is determined by lithographic processes. These deliver far tighter tolerances than the flip-chip process used for integrating prefabricated devices on top of a wafer.

Making lasers ...

Our device development began with the fabrication of telecom-wavelength lasers based on InP and related material. We constructed a portfolio of emitters, ranging from simple Fabry-Pérot lasers to single-longitudinal-mode, DFB-type lasers – with the grating defined in the silicon layer – and more complex devices, such as tuneable lasers. The latter, which featured advanced filters in the silicon layer to provide wavelength-selective feedback, have typical threshold currents of 25-50 mA and deliver output powers up to 10 mW.

One of the biggest challenges associated with the fabrication of PICs incorporating lasers is realising efficient coupling of light out of this device and into silicon. This can be achieved with the 'hybrid laser', a design originally proposed by UCSB, which maintains the optical mode within the silicon waveguide – its evanescent tail extends into the III-V gain layers on top. We have adopted this approach to build a DFB laser using our BCB-bonding process (see Figure 3). This device contains eight InGaAlAs based quantum wells, optimized for emission at 1.3 μm.

Another, more common approach for us is to concentrate light into the III-V layers and couple it back to the silicon layer using evanescent tapers. By creating suitable structures in the silicon layer, it

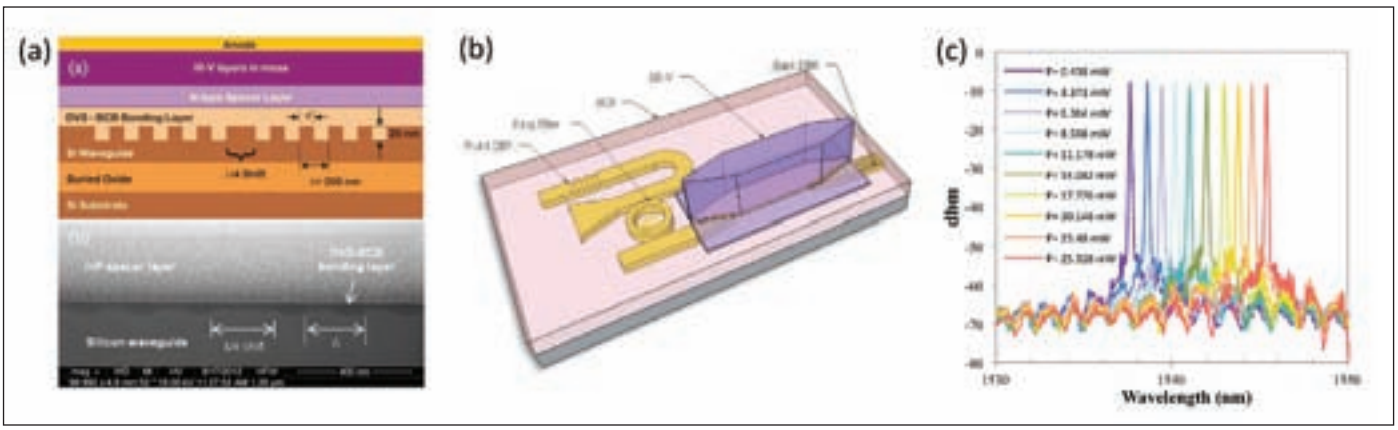


Figure 3. Ultra-dense wavelength demultiplexer chip developed in the EU-funded project BOOM. a) Top view of chip. b) Eye diagram for detector under 10 Gbit/s operation. c) Full optical to electrical response of the device

is possible to have wavelength-selective-feedback, leading to single-mode operation. We have helped to build this type of structure in an EU project called HELIOS, working in partnership with CEA-Leti and III-V lab, France, who provided silicon waveguide circuits and III-V processing, respectively (see Figure 3).

A ring resonator and a grating-based mirror in the silicon layer form the laser cavity, and the III-V layer provides the needed gain. The device delivers up to 10 mW, has threshold currents below 40 mA, and features a side-mode suppression in excess of 30dB. Tuning the ring resonator – in this case via the thermo-optic effect – enables tuning of the wavelength by typically between 5 nm and 10 nm.

...and detectors

We can also integrate InGaAs-based detectors with our silicon photonic circuits. Our involvement in the EU-project BOOM has required this, because this programme requires an optical label detector. One of the goals of this project is to label optical data packets with an inband wavelength code, which has to be extracted from the packet and sent to a routing unit. This allows full optical routing of IP-packets, without decreasing the spectral efficiency of the system. The label extractor consists of an optical demultiplexer with very high resolution – 12.5 GHz – fabricated on our silicon photonics platform and integrated with high efficiency photodetectors.

It has been very challenging to reach the required resolution, with success only possible after an in-depth study of silicon micro-ring resonators. This analysis revealed that the required specifications could be reached with single ring-resonator-based filters. These resonators have integrated resistors, which allow fine-tuning of the wavelength channels (bottom electrodes) through the thermo-optic effect. They are connected to evanescently coupled InGaAs photodetectors using heterogeneous integration technology developed by INTEC, imec's associated laboratory at Ghent University.

The efficiency of these detectors is almost 1 A/W, and they can operate at a speed of 5 Gbit/s, considerably higher than the 1 Gbit/s specification set forward at the start of the project. Engineers at Fraunhofer IZM group in Berlin have helped to package this device, which is now ready for operation in a system test bed.

Heading further into the infrared

Our efforts at developing PICs started with the development of devices operating at telecom wavelengths. We are now expanding the spectral range of the devices that can be made, because this allows circuits to serve different applications. For example, devices operating in the short-wave (SWIR) and mid-wave (MWIR) infrared wavelength ranges, which span 2 μm to 8 μm, could be used for spectroscopic sensing. That's because there are numerous gas, liquid and solid absorption features in this spectral domain.

To date, there have been very few, if any, complex PICs that have been built to work in this spectral range. Progress has been hampered by difficulties associated with developing an integration process that is fully monolithic – in other words, one that is

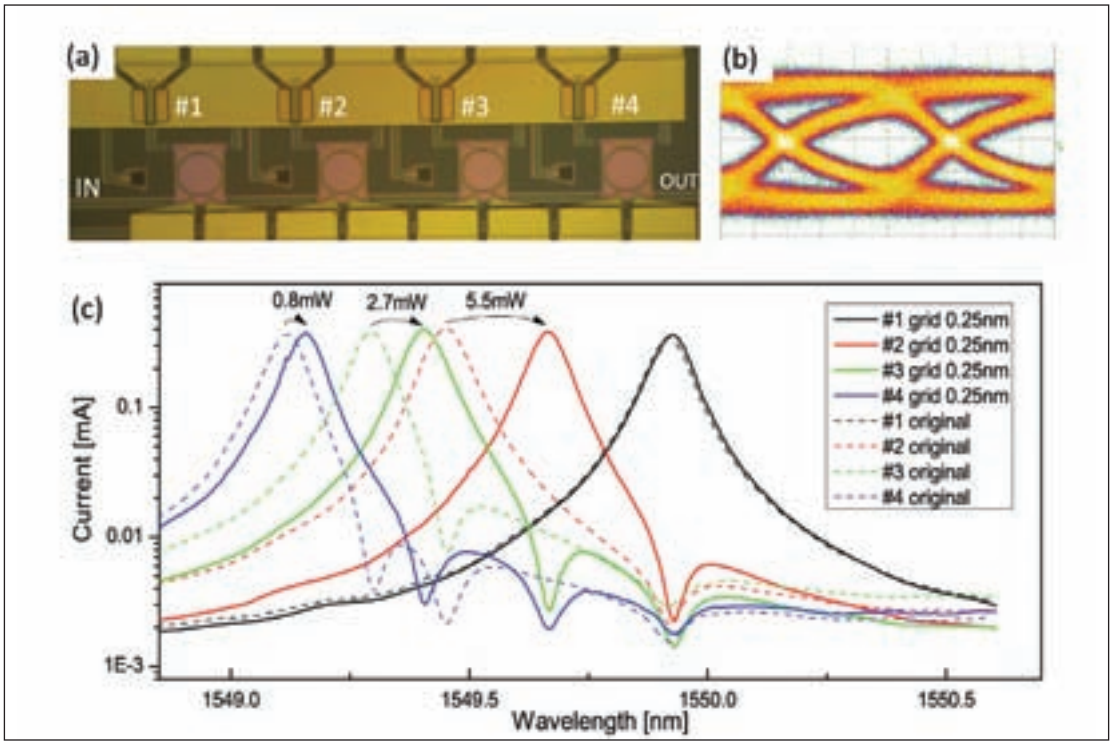


Figure 4 a) Hybrid DFB-laser. b) Schematic of III-V silicon tunable laser. c) Spectral response of III-V silicon tunable laser, for different values of tuning power on an integrated ring resonator

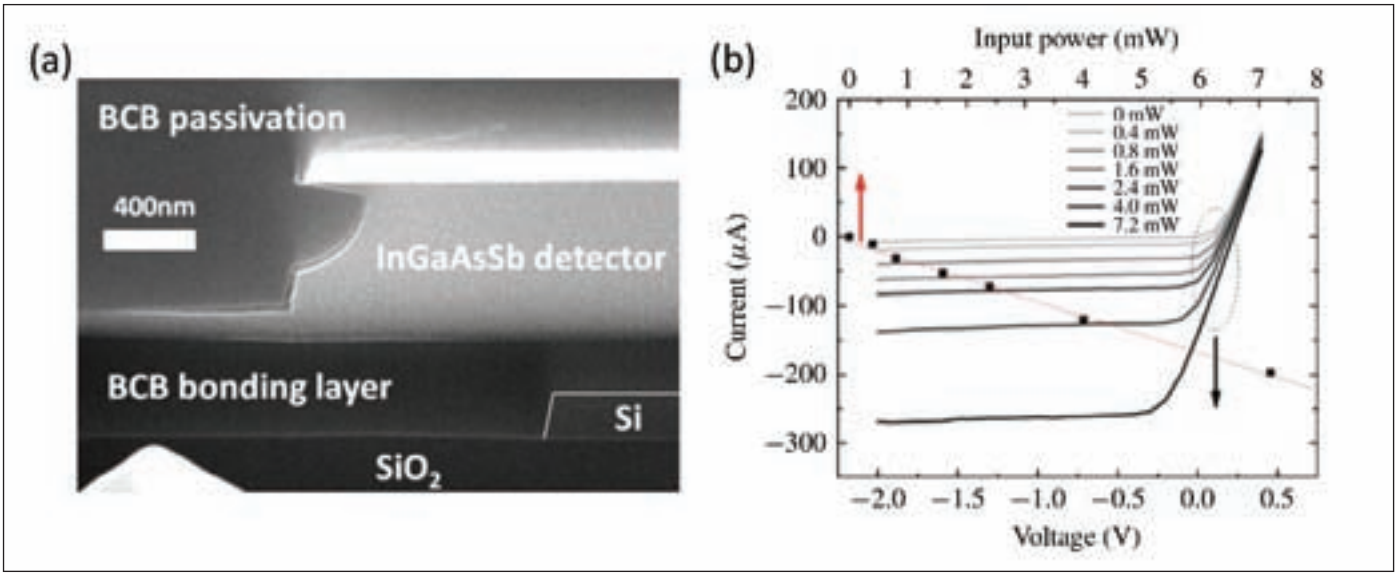


Figure 5 a) Cross-section of evanescently coupled InGaAsSb-detector integrated on a silicon waveguide. b) Current-voltage and current-power characteristics for this detector under illumination at 2.25 μm

based completely on III-V semiconductors. We try to address the lack of progress in this area by employing our heterogeneous integration process to develop such circuits. One of the strengths of silicon photonics is its broad transparency window, which stretches from 1 μm to 4 μm. Thanks to this, it should be possible to realize integrated spectroscopic systems combining active III-V devices and silicon-on-insulator passive circuits. Such systems could be incredibly compact, highly affordable and superior to existing products in terms of selectivity and sensitivity.

Fabrication of these systems requires integration of short-wave and mid-wave infrared light sources and photodetectors on top of the silicon waveguide circuit. Our first step towards this was to demonstrate efficient detectors integrated with a silicon-based integrated spectrometer circuit. The detector built for this, which was bonded to a silicon waveguide circuit, had an epilayer stack featuring a 500 nm-thick $Ga_{0.79}In_{0.21}As_{0.19}Sb_{0.81}$ layer as the intrinsic absorbing region (see Figure 5). Antimonide layers were grown by the Institut d'Electronique du Sud from the university of Montpellier.

Evanescently coupled detectors fabricated in this way produce a responsivity of 1.4 A/W at 2.3 μm, which is close to the theoretical limit. The detectors have been united with an integrated spectrometer and efficient demultiplexing in up to 16 channels with a separation of a few nanometres was obtained. We believe this is the first demonstration of a complex PIC operating in this wavelength range. Our next goal is to demonstrate lasers coupled to silicon waveguides operating at these longer wavelengths.

In short, thanks to our development of wafer bonding techniques, we have developed a powerful process for integrating a wide range of III-V active devices on silicon integrated photonic circuits. Our efforts began by demonstrating complex lasers and detectors operating in the telecom range, and now we are starting to unleash the true versatility of the process by pioneering the development of integrated spectrometers working at wavelengths above 2 μm.

Goals for the coming months are improving various aspects of device performance, including thermal behavior, and fabricating lasers operating in the SWIR wavelength range.

This work has only been possible through the collaboration with many partners within Europe, in particular CEA-LETI, III-V labs, TU/e and IES Montpellier. The work was supported by the EU-projects HELIOS, BOOM, inSPECTRA and MIRACLE.

Further reading

Nature Photonics focus issue on Silicon photonics, August 2010 ***4*** *491*
G. Roelkens et al. III-V/silicon photonics for on-chip and inter-chip optical interconnects, Laser & Photonics reviews p.DOI: 10.1002/lpor.200900033 (2010

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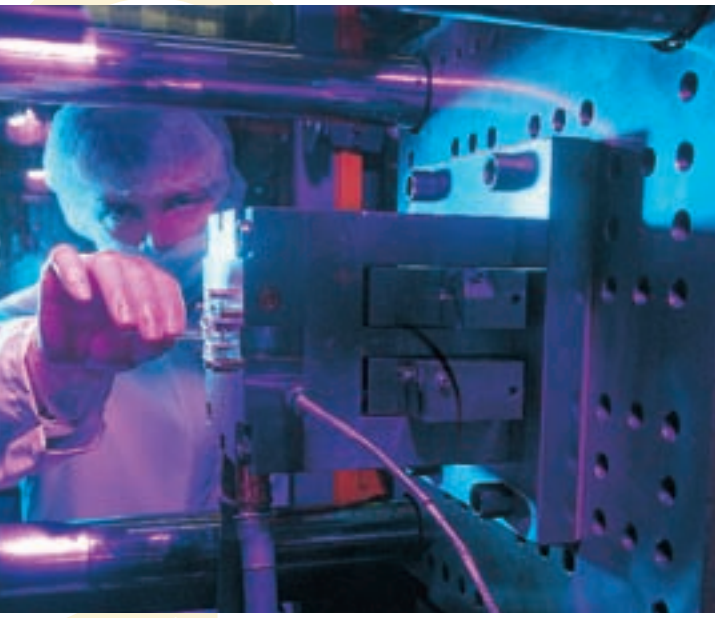



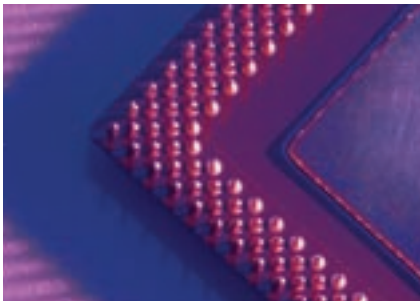

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Kyma eyes new opportunities

Diversification lies at the heart of Kyma Technologies' vision for its future. It first made a name for itself as a leading supplier of wide bandgap materials, but it is now expanding its offerings and has started to provide plasma vapour deposition (PVD) equipment and photoconductive switches, explains the company's chief executive officer, Keith Evans.

When you hear the name Kyma Technologies, I bet you think of bulk GaN. But that's not the only product developed by our team at Raleigh, NC. In addition to being a provider of high-quality HVPE-grown GaN materials, we offer a diverse and growing portfolio of products, including materials, equipment and devices.

Three of our most important product offerings are discussed in this feature: AlN templates for LEDs and power electronics; PVD crystal growth systems for fabricating AlN templates; and a novel, photoconductive GaN switch for optically isolated, rapid switching at high powers.

AlN templates

The first of these, our AlN templates, consist of a thin layer of this crystalline wide bandgap material, grown on either sapphire or silicon. AlN deposition is carried out with a patented, proprietary process called PVDNC - PVD of NanoColumns. This creates AlN crystalline layers with a defined nanostructure, consisting of a very dense array of AlN nanocolumns with a dislocation density that is very low – and possibly zero. According to atomic force microscopy and cross-sectional transmission electron microscopy measurements, the typical diameter of these nanocolumns ranges from 40 nm to 80 nm, and they have a very smooth surface with low root-mean-square roughness. Between the nanocolumns, which are oriented along the c+ axis, the AlN is of lower crystalline quality.

4-inch, 6-inch and 10-inch diameter AlN on sapphire templates produced by Kyma Technologies using its patented and proprietary PVDND technology

We routinely deposit our AlN nanocolumns on both flat and patterned sapphire substrates. The AlN templates that result enable our customers to form GaN with higher quality earlier in the buffer layer than they would get if they used just sapphire. Realizing a better buffer earlier brings two major benefits: Producers of epiwafers and devices can thin their GaN buffer, saving time and ultimately bosting throughput and reducing cost; or engineers can maintain the thickness of the buffer, leading to a lower defect density in the buffer and device active regions.

Our collaborators at John Muth's group at North Carolina State University (NCSU) have documented the improvement in thermal conductivity in GaN as the defect density is reduced. That means that our PVD AlN template customers attain higher thermal conductivity GaN buffer layers faster during their buffer layer growth. Since the device active region for most devices replicates the structural quality of the top portion of the buffer layer, we can conclude that the entire device wafer and especially the device active region has lower thermal impedance, always a desirable attribute for a device epiwafer. The higher thermal conductivity of the GaN buffers and device active regions resulting from our AlN templates have enabled our customers to report higher LED yield and better device performance.

It wasn't obvious that our PVDNC process would work on patterned sapphire. However, it shouldn't be that surprising that it does. After all, although today's patterned sapphire substrate topologies contain micron or many-micron sized features, they

are on a much larger length scale than our nanocolumns. The way we like to phrase this is that our PVDNC process puts a nanostructure onto the microstructure of a patterned sapphire substrate.

We have strong IP covering our growth technology, which is based on forming nanocolumnar III-N layers by PVD. When NCSU researchers Gerald Cuomo and Mark Williams founded our company, they brought their PVD technology with them. NCSU then licensed key patents to us, and we have strengthened our IP with additional patents – together they cover several important aspects of growth technology and equipment design relating to AlN PVD.

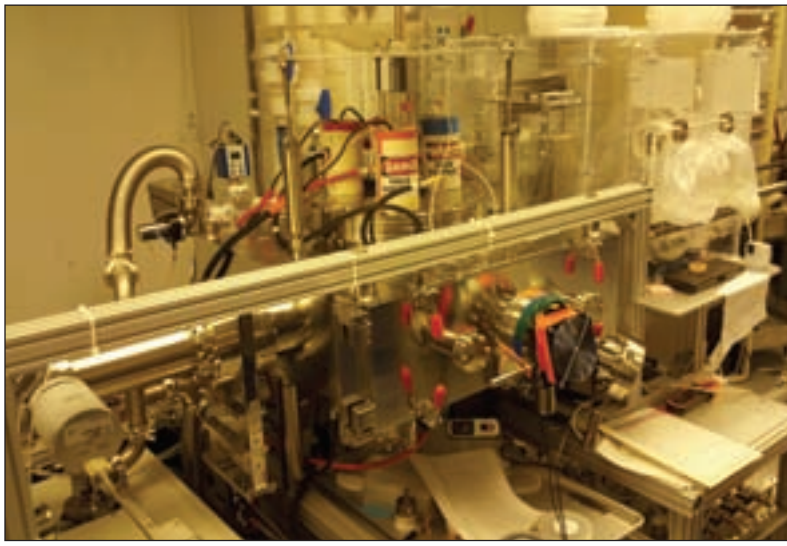
For many years, we kept our PVDNC AlN template growth process under wraps. During that time, we learnt and refined how to use it to improve our HVPE process for growing GaN. As with MOCVD growth of LEDs, defect density falls and film uniformity increases when HVPE-grown GaN layers are formed on top of our AlN template. What's more, with this approach we don't have to perform a two-step buffer layer growth, making our process faster while simultaneously providing added IP protection for our HVPE GaN growth processes.

Marketing templates

When the market for sapphire substrates for LEDs took off around 2005, we decided to launch our PVD-grown AlN templates. This was our first addition to our bulk-GaN products, and it marked the beginning of our transition to a more diversified product portfolio. At the outset, LED manufacturers were very reluctant to evaluate our material. A stigma surrounded PVD growth for epitaxial growth applications, and it did not help matters that our AlN layer characteristics were markedly different from most of the MOCVD-grown AlN-on-sapphire materials being used in many of the commercial LED recipes. But persistence on our part paid off, and a handful of companies in Taiwan and the US gave them a try.

Initially, these templates did not work well for the chipmakers, because the AlN layer was too thick. So we devoted time and effort to optimizing the thickness of AlN and its growth conditions, working in partnerships with a few companies. Although each firm settled on a different optimal thickness, their preferred values were quite similar. That didn't surprise us, but we were caught off-guard when we found that these LED makers had their best results using buffer layers that were far thinner than the ones we used in-house for our own trials. We quickly migrated to these thinner AlN buffers, and very positive reports followed from our customers.

We have subsequently mulled over possible explanations behind the benefit of employing a thinner AlN buffer. We cannot divulge many details regarding our conclusions, but we can reveal that the benefits are not limited to LEDs, and extend to any application involving MOCVD growth of a GaN buffer layer on top of the template. A great strength of the PVDNC process is its scalability. Until about two years ago, we carried out our growth on small-scale PVDNC equipment built in-house a decade ago. However, as our sales started to climb, we needed more capacity and a more robust platform, so we talked to commercial PVD tool suppliers. Our conversations with them were not that helpful. None had ever built a PVD tool operating in the growth window that our process required, and after attempts at forming creative partnerships, we concluded that it would be best to go it alone. This has yielded significant success: Our homebuilt, higher-capacity tool may not be fully automated, but it has produced thousands of templates, and it has also enabled us to demonstrate growth of AlN on 12-inch silicon and on 10-inch sapphire. We are now in the process of further automating this tool, as well as actively developing plans for a larger platform.



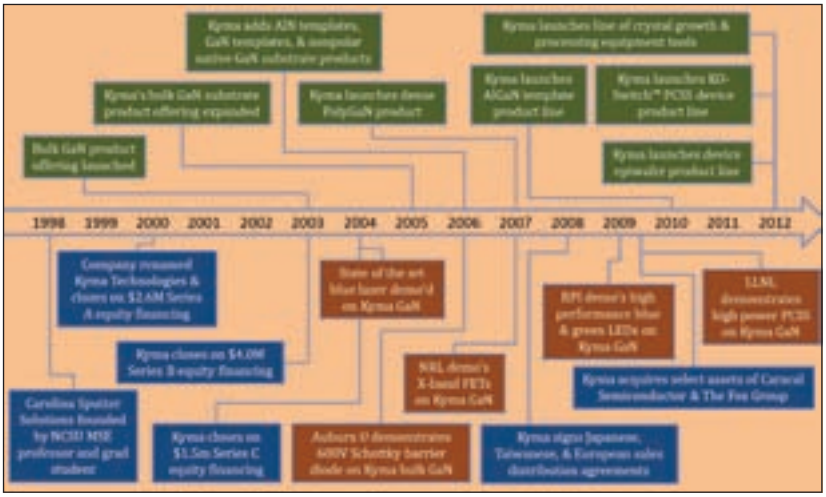
Kyma's PVD growth systems

PVD tools

As we worked hard to increase our AlN template sales, we found that many customers wanted to make these engineered substrates in-house. Often they asked us if we could supply them with PVD tools. Deciding if we would fulfil their wishes was very tricky, due to our heritage as a material company that employed proprietary growth tools and refined deposition technologies to give ourselves a competitive edge.

Could we allow all this knowledge to enter the market place? Our view was that we could. We believe that it is important for us to listen to the views of our customers and act in their interests, and we fully recognize that expansion into the equipment market is an excellent commercial opportunity for us. Process engineers that use our equipment discover that growth times are very short, thanks to a fairly fast growth process and the need for a relatively thin buffer of AlN to ensure optimal device performance.

We see PVDNC growth cycle times shrinking to below 20 minutes as we mature the equipment platform. Thanks to these short deposition times, the addition of AlN costs much less than the purchase of sapphire. Our first tool to market can be configured in many ways: 19 x 2-inch, 3 x 4-inch, or single wafer growth on substrates with diameters ranging from 6-inch to 12-inch. We are now working on a bigger tool, which we expect to support multiple 6-inch wafers and have the capacity to produce more



Kyma's major breakthrough in materials, growth tools and products

than 40 x 2-inch wafers in a single growth run.
Both tools are highly automated, with cassettes and multi-wafer platters enabling up to 24 hours of growth on dozens of platters of wafers without operator intervention. Market response to these products is positive, and we are now evaluating the outsourcing of manufacturing, in order to support an anticipated hike in shipments of dozens of PVDNC growth systems during the next few years.

From materials to devices

Last September, we passed another important milestone – the launch of our first device. It's a photoconductive semiconductor switch (PCSS), and its most important attribute is that it is the highest power semiconductor switch of its size with a sub-nanosecond response time. When naming this switch, we intentionally went for a *double entendre*: 'Kyma Optical' and 'Knock Out'. The latter is deserved, because we have knocked out some of our own electronics when scrutinizing it in our high-speed switch testing facility!

This happens because when high electrical power is switched at such speed, electromagnetic radiation is generated with frequencies above 1 GHz. We are still learning about the details of the waveform but expect that a broadband pulse is generated with frequencies as high as 10 GHz or higher. Such an electromagnetic pulse can induce currents in nearby electronics. If the induced currents are high enough, the equipment can fail irreversibly. At lower currents or durations, the equipment may just need a reboot, which we have done many times.

Our motivation for developing the KO-Switch can be traced back as far as 2006, when we read a paper written by scientists at Lawrence Livermore National Laboratory: *Wide bandgap extrinsic photoconductive switches*. In this, they compared the performance of a PCSS made from GaN with one built from SiC. The impression we had after reading the paper was that GaN can be superior to SiC in this arena, because it enables the fabrication of devices that respond more quickly and have a lower on-state resistance. We were very excited about the potential for GaN PCSS, and we explored many avenues that might allow us to supply materials or devices into a larger programme. Unfortunately, our initial efforts bore no fruit, and at times we felt that SiC had won the day – at least, for a while. That's not surprising, given that SiC wafers are larger, more plentiful and cheaper than our specially grown KO-GaN. Despite this setback, we persisted, and we were rewarded for our efforts. We won a couple of modest US DoD contracts to build our own PCSS devices with support from the Air Force Research Laboratory, and these switches have produced very promising results. It took us very little time to beat the values for standoff voltage, on-resistance, and switching current reported by LNLL, and now, even though this work is still in its infancy, we can switch over 10 kV and 10 kA in less than 1 ns with very low on-resistance. The testing of our switch has involved a high performance YAG laser equipped with an optical parametric oscillator and frequency doublers. This allows us to probe our device with a broad range of excitation wavelengths and pulse energies. We find that this switch has a very broad spectral response, which bodes extremely well for ultimate implementation using commercial, off-the-shelf fibre lasers and diode lasers.

Applications for our switch include electric circuit fault protection, low jitter pulsed power, and support of several applications in the commercial, defence, and homeland security sectors. Our first KO-switches were built as part of a government-sponsored R&D programme, and we are still delivering devices under DoD support. Several devices have been sold this year, and we are now in discussions with several key corporate and government players. They are all interested in exploring this technology for US defence and homeland security applications.

What's next?

One of the biggest benefits of diversification, whether it is achieved organically or by acquisition, is that it leads to an expansion of our core competencies. In turn, this inevitably leads to new product opportunities, which sometimes draw on a portfolio of in-house expertise. In our case, this has happened with the KO-Switch. We are committed to growing the business associated with our existing products, while continually seeking out new commercial opportunities.

This year our goals are: To increase our PVD AlN template manufacturing capacity; get our equipment products into the market; and surpass certain performance milestones with our KO-Switch, which would make a compelling case for its insertion into several demanding applications. On top of this, we are aggressively pursuing the development of several new products in partnership with Duke University and others. Watch out for exciting new product announcements during the remainder of this year.

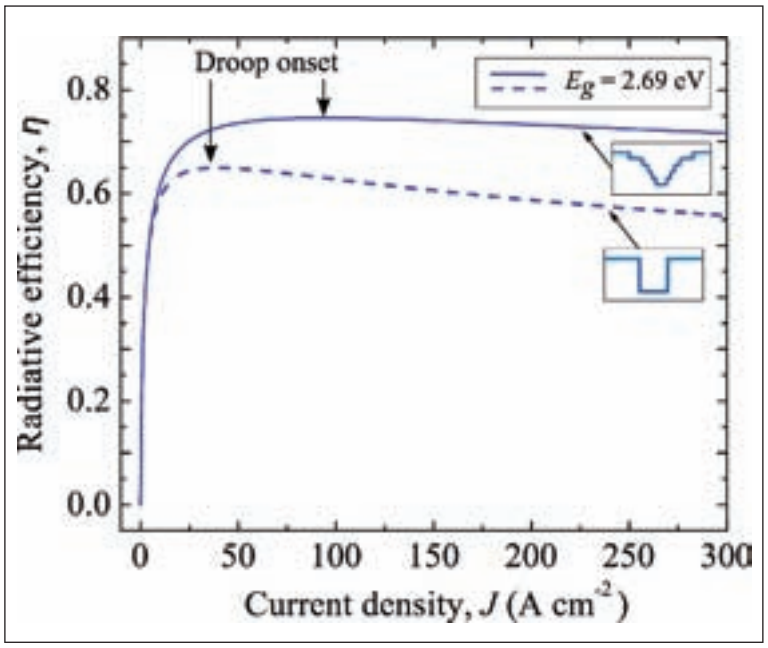
We thank the Air Force Research Laboratory for supporting our construction of a high speed switch testing facility.

LED droop: Direct Auger gets the blame

Direct Auger recombination causes droop, but its impact can be diminished by inserting graded layers into quantum wells to smooth the confining potentials

THE DEBATE over the origin of LED droop has taken yet another twist, with a partnership between researchers at Technion-Israel Institute of Technology and the US Naval Research Laboratory claiming that direct Auger recombination is to blame.

This view is at odds with that of many other theorists, who account for droop – the reduction in light efficiency as current is cranked up – with either more complex forms of Auger recombination or models involving defects.



Calculations by a partnership between at Technion-Israel Institute of Technology and the US Naval Research Laboratory show that a 'softer' potential reduces Auger recombination, leading to an increase in LED efficiency

For example, Chris Van de Walle's computational science group at the University of California, Santa Barbara, claims that the primary causes of droop are Auger-related processes involving phonons and alloy disorder. And a partnership between researchers at Boston University and Politecnico di Torino, Italy, argue that although Auger-related processes contribute to droop, carrier leakage, compositional fluctuations and threading dislocations may also play significant roles.

These differences over the cause of droop stem from differences in the structures under study, according to Roman Vaxenburg from Technion-Israel Institute of Technology. He has his co-workers have looked at quantum well structures, while others have focused on calculations for bulk material.

"In general, in bulk material, Auger recombination is not efficient due to strict energy and momentum conservation requirements," explains Vaxenburg. "On the contrary, in quantum-confined systems, such as quantum wells, the momentum conservation requirement is lifted and Auger processes are enhanced." Values calculated by the US-Israeli team for the Auger coefficient in quantum wells are in the range 10^{-31} - 10^{-30} cm^6 s^{-1}.

The structures studied by this team feature symmetric quantum wells, which are found in non-polar LEDs. That does not mean, however, that their findings offer no insights into the vast majority of devices made today – polar LEDs grown on *c*-plane sapphire. "We expect that the Auger rate will be further accelerated in quantum wells grown in the polar direction," says Vaxenburg.

For their calculations, he and his co-workers use the well-established Pidgeon and Brown model which was proposed in the 1960s. This is often used for calculating the characteristics of direct bandgap semiconductors with a band-edge at the Gamma point of the Brillouin zone.

"It takes into account the eight band-edge sub-bands," explains Vaxenburg. "Adding more bands will only accelerate the rate of Auger recombination, because it will increase the density of final states."

The code employed for these calculations has been written from scratch. It is a few tens of thousands of lines long, and when it is run on a powerful personal computer, it takes 8-10 hours to calculate the total Auger recombination rate for a given quantum well.

Auger rates have been calculated in a wide variety of InGaN/GaN quantum well structures with different confining potentials. One class of structures features a conventional active region, with $In_{0.25}Ga_{0.75}N$ barriers surrounding a GaN quantum well with a thickness of either 1.5 nm, 2.0 nm, 2.2 nm or 2.5 nm.

Other types of structure under study feature 'softer' potentials, resulting from the insertion of layers with intermediate compositions.

The conclusions of the team should not be questioned due to their assumption of zero temperature. "At temperatures higher than zero, the Auger rate is expected to accelerate even further," says Vaxenburg.

Calculations reveal that using 11 layers to form a quantum well, rather than the conventional number, 3, can lead to a three-fold reduction in the Auger recombination rate. This is claimed to spur a 20 percent increase in LED efficiency, shift droop onset to a higher current density, and reduce the droop development rate at higher current densities.

The next goal for the team is to extend their model to include piezolelectric polarization.

R. Vaxenburg *et. al.* App. Phys. Lett. **102** 031120 (2013)

Tandem solar cells are set to benefit from surface activated bonding

Surface activated bonding of GaAs and silicon substrates can yield high-quality heterojunctions.

The surface-activated bonding tool involves the bombardment of substrates by a beam of fast argon atoms

A JAPANESE PARTNERSHIP between Osaka City University and NTT Photonics Laboratories has shown that surface-activated bonding is a promising approach to fabricating novel heterojunctions. This can be used in several devices, including tandem solar cells built from GaAs and silicon.

Surface activated bonding, which begins by firing fast beams of argon atoms onto surfaces, has a significant advantage over conventional wafer bonding: It does not require a heating step to form high-quality electrical junctions.

Studies by researchers at UCLA have revealed that the electrical properties of a conventionally bonded GaAs/GaAs interface are strongly influenced by pre-bonding surface treatments and post-bonding annealing.

"They claimed that annealing in the range of 400 °C to 600 °C was essential for realising excellent characteristics," explains Naoteru Shigewaka from Osaka City University.

According to him, this annealing step has its downsides: It takes time; it may drive the diffusion of impurities through interfaces; and it can create mechanical defects, due to differences in substrate thermal expansion coefficients.

Shigewaka and his co-workers have used surface activated bonding to form a GaAs-silicon heterojunction. This has been probed by current-voltage and capacitance-voltage measurements and scrutinized by field emission scanning electron microscopy and energy dispersive X-ray spectroscopy.

Devices were formed by taking a boron-doped silicon substrate and a silicon-doped GaAs substrate (resistivities of 0.1 Ωm and 0.002 Ωm, respectively, and carrier concentrations and 2.4 x 10^{17}cm^{-3} and 1.1 x 10^{18}cm^{-3}, respectively) and cleaning them with acetone and ethanol in an ultrasonic bath for 5 minutes. After drying under nitrogen, substrates were loaded into a surface-activated bonding tool and their surfaces were activated by an argon fast atom beam.

After this step, pressing the substrates together for 60 s united them, and then Al/Ni/Au and AuGe/Ni/Ti/Au stacks were evaporated on the silicon and GaAs substrates, respectively. Rapid thermal annealing at 400 °C formed ohmic contacts.

Imaging with a field-emission scanning electron microscope showed that no structural defects, such as cracks, were present at the interface. What's more, the level of oxygen found in the interface is similar to that in the GaAs substrate, according to energy dispersive spectroscopy.

Plots of current as a function of voltage showed that the device had rectifying properties similar to those in conventional *p-n* junctions. For this heterojunction, the onset for the forward bias voltage was 0.38 V. Capacitance-voltage measurements enabled calculations for the depletion layers. They are estimated to be 84 nm in silicon and 18 nm in GaAs.

Two other features found in the current-voltage characteristics are an increase in current at higher values of reverse bias, and a gradient in these plots that shows very little variation with temperature.

The researchers say that this behaviour can be explained with a trap-assisted tunnelling model, which incorporates a trap energy of 0.1 eV.Thanks to the lack of any signs of oxygen at the interface, the team is arguing that its surface-activated bonding promises to enable the fabrication of high-quality, novel devices.

They are now processing tandem cell structures formed by surface-activated bonding.

J. Liang *et. al.* Appl. Phys. Express **6** 021801 (2013)

Tiny LEDs produce intense, directional emission

Multiple markets beckon for substrate-emitting, miniature LEDs

A RESEARCH TEAM led by engineers at Tyndall National Institute, Ireland, has fabricated tiny, blue-emitting LEDs featuring parabolic mirrors.

The collaboration, which involves InfiniLED of Cork, Ireland, and the University of Cambridge, claims that its novel LEDs – which emit an intense, relatively narrow beam of light – are suitable for a wide range of applications. They include sub-millimetre-scale projectors for spatially controlled stimulation of cells, optical fibre systems for the delivery of light to remote locations, and forms of LED-based data communication using plastic optical fibre.

Lead author of the paper detailing this class of LED, Brian Corbett from Tyndall National Institute, believes that this tiny, parabolically shaped device is unique: "It solves many problems with getting light out of LEDs, but with the added advantages of pixellation, low divergence, low crosstalk and high bandwidth."

He and his co-workers from Tyndall reported a similar device based on GaAs in 2008, when they were trying to increase light extraction from an LED.

"We were inspired by classical optics and parabolic reflectors," explains Corbett, who admits that approximations have to be made when it comes to real devices. "We have a truncated parabola and the light source is planar."

Fabrication of the team's devices begins with MOCVD growth of LED structures on free-standing, *n*-doped GaN substrates. These consist of a 2 μm-thick, silicon-doped layer; five compressively strained 1.5 nm-thick InGaN quantum wells separated by 9.6 nm-thick GaN barriers; and a 99 nm-thick magnesium-doped layer that included a heavily doped contact layer.

Devices were fabricated using a 8 μm-diameter, partially reflective palladium discs that also provided *p*-type contacts. Etching with an inductively coupled plasma to a depth of 6.3 μm formed individual mesas with 20 μm diameters.

Controlled resist erosion during the etching process produced the desired mesa shape and the addition of a SiO_2 film enabled passivation of the sidewalls. A bonding metal provided a contact to either individual LEDs or clusters of 14, and after the substrate was thinned to 100 μm, an 80 μm-thick layer of SiO_2 was added to form an anti-reflection coating.

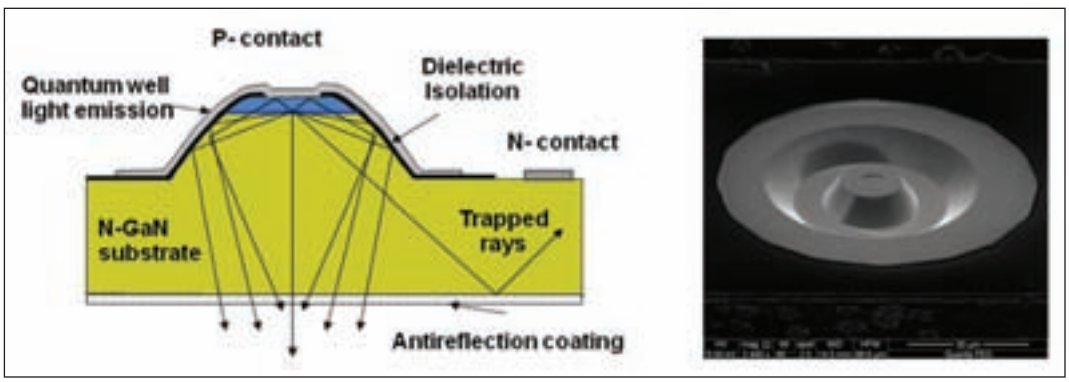
The substrate for these devices, GaN, is much more expensive than sapphire, the common platform for making LEDs. However, Corbett believes that this additional cost is acceptable, because savings can be made elsewhere: "Packaging costs are generally the greatest. Our LED is not only optically efficient, but also thermally efficient, thus reducing the need to deal with those aspects, so you will save considerably when you consider the full application." And Corbett expects GaN substrate costs to fall, due to the on-going development of this material.

A single LED emitting at 470 nm produced four times the power of an unshaped contact when the light was collected with a lens with a numerical aperture of 0.5 (collection angles of ±30°). Driven at 10 mA, which corresponds to a current density of 20 kA cm^{-2}, the LED produced 0.25 mW. It can be driven at higher current densities, but droops kicks in, reducing light emission efficiency. According to the team, it may be possible to combat this by adding a current-blocking layer to the device.

The team has also studied the characteristics of a cluster of 14 LEDs. They produce a leakage current of just 5 nA at 2.1 V, suggesting that there are no weaknesses related to surface recombination or shunt leakage.Data transmission capabilities of the team's microLEDs have also been investigated. Measurements revealed that an LED with its output collected by a lens and coupled into a plastic optical fibre had a small signal bandwidth of 500 MHz, while studies of a cluster of 14 devices sending data through several centimetres of free space showed that it was possible to transmit signals at error-free data rates up to 500 Mbit/s.

Corbett explained that the team is now using these LEDs to excite neural cells within the EU-funded Optoneuro project. "With our partners there, we are making arrays of CMOS-driven addressable elements. We plan to extend the size of the array." He expects that many new applications will emerge for this class of LED, due to the precision associated with this light source.

P. Maasant *et. al.* Appl. Phys. Express **6** 022102 (2013)



Tiny LEDs built into the substrate can feature parabolic mirrors that increase light extraction and enable directed emission from the device.

Gold-free GaN-on-silicon HEMTs

CMOS-compatible contacts realise the lowest specific contact resistivity

RESEARCHERS from Nanyang Technological University, Singapore have demonstrated 0.15 μm gate-length AlGaN/GaN HEMTs with direct-current and microwave performances. The team, led by Ng Geok Ing, say that this is the first microwave performance GaN-on-silicon HEMTs with improved ohmic contact using a CMOS-compatible non-gold metal stack. The Si/Ta-based ohmic contact exhibited the lowest contact resistance (R_c = 0.24 Ωmm) ever reported thus far with a smooth surface morphology.

This work demonstrates the feasibility of achieving high performance GaN-on-silicon HEMTs using a non-gold metal stack approach which is compatible to the CMOS process in large-volume silicon manufacturing lines. Fabricated GaN HEMTs exhibited a maximum drain current density of 830 mA/mm, a maximum extrinsic transconductance of 250 mS/mm, and a threshold voltage of -3.75 V. The measured current gain cut-off frequency and maximum oscillation frequency are 39 GHz. Devices also achieved a breakdown voltage of 90 V with a minimum drain current collapse of less than 10 percent for a gate-drain spacing of 1.7 μm. The device's Johnson's figure of merit is in the range 3.51 THz.V to 3.83 THz.V, which is comparable to other reported GaN HEMTs on silicon with a conventional III-V gold-based ohmic contact process.

MOCVD growth formed the GaN HEMT structure: A 2-nm thick GaN cap layer, 18-nm thick $Al_{0.26}Ga_{0.74}N$ barrier, 800-nm thick GaN buffer and 1.4-μm thick transition layer on 4 inch silicon (111) (resistivity > 6000 Ωcm). The grown structure exhibited room temperature two-dimensional electron gas mobility of 1450 $cm^2 V^{-1}s^{-1}$ and sheet carrier density of 1.1 x 10^{13} cm^{-2}. An optimised Ta/Si-based ohmic contact metal scheme (Ta/Si/Ti/Al/Ni/Ta) revealed a repeated low R_c value of 0.24 Ωmm (standard deviation of 0.07 Ωmm) out of 3 separate runs with an average specific contact resistivity of 1.25 x 10^{-6} Ωcm^2.

This is believed to be the lowest ever value reported for CMOS-compatible non-gold ohmic contacts for conventional GaN HEMTs on silicon. It is lower than that of recessed ohmic contacts. With reference to the conventional gold-based ohmic contact, the CMOS-compatible non-gold ohmic metal stack provides a smooth surface morphology with good edge definition (see Figure 1).

This simple ohmic scheme also avoids the need to use other complicated techniques such as an ohmic recess or a regrown ohmic contact, which will complicate the manufacturing process. The fabricated devices have also exhibited very low current collapse (less than 10 percent) at gate- and drain-quiescent biases (V_{gs0} = -8 V, V_{ds0} = 10 V). Further device improvement can be realised by optimising the GaN HEMT epi-structure and by reducing the device parasitics.

S. Arulkumaran *et al*, Applied Physics Express **6** 016501 (2013)

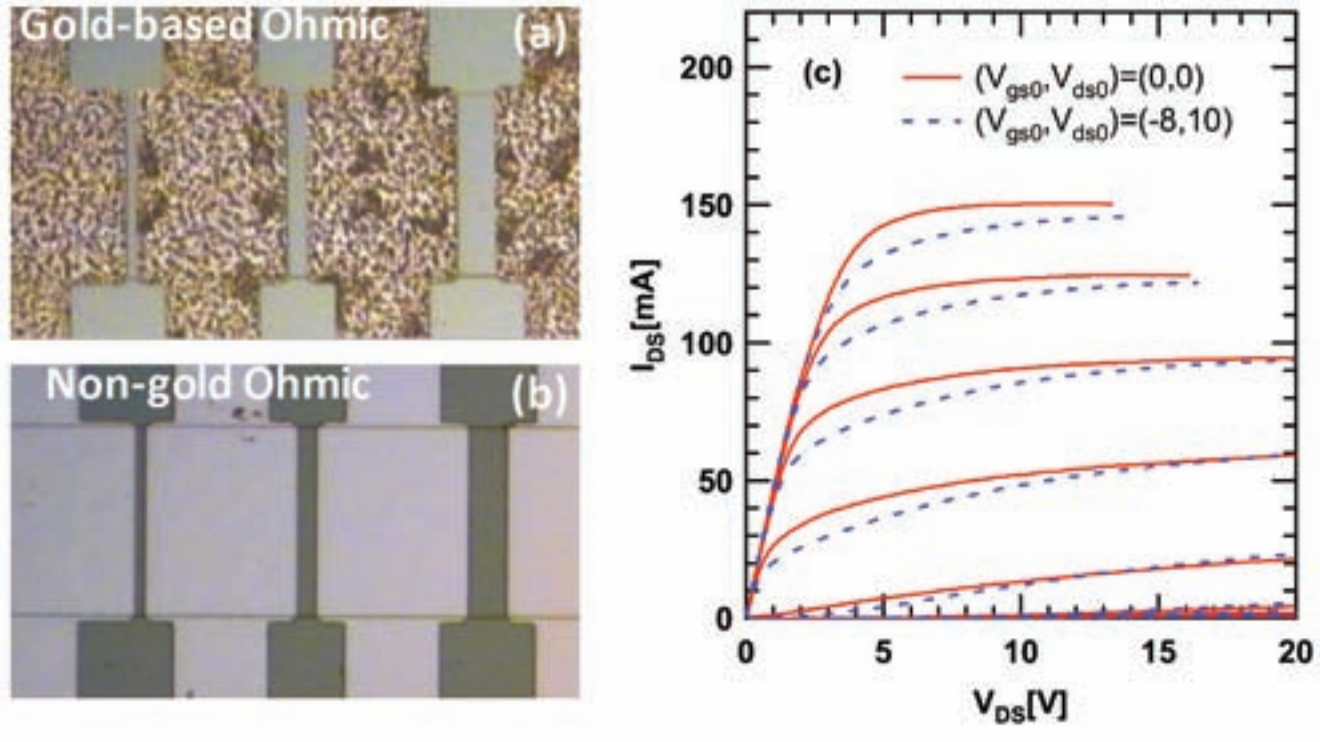


Figure 1 (a) Conventional III-V gold-based Ohmic contact with rough morphology, (b) Non-gold Ohmic contact with smooth surface morphology (c) Pulsed (pulse width = 200 ns; pulse period = 1 ms) I_{DS}-V_{DS} characteristics of fabricated GaN HEMTs on silicon using CMOS compatible non-gold metal stack

Solar cell anti-reflection coatings reach new heights

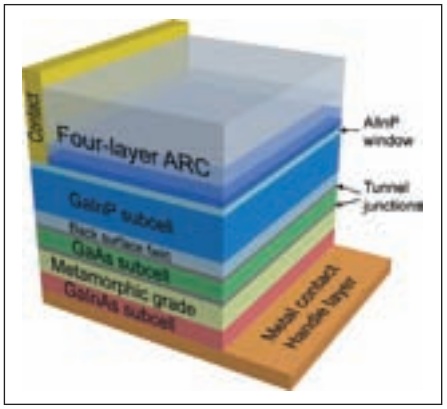
A multilayer coating realizes omnidirectional, broadband antireflection

A TEAM OF RESEARCHERS from Rensselaer Polytechnic Institute (RPI), Magnolia Solar, Inc. and Pohang University of Science and Technology have demonstrated a novel multilayer antireflection (AR) coating utilizing tailored- and low-refractive index technology.

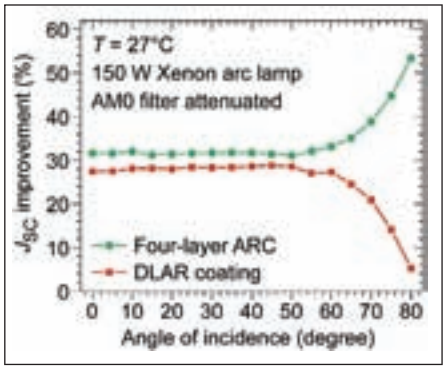
This novel multilayer AR coating exceeds the performance of the widely employed double-layer AR (DLAR) coating on state-of-the-art inverted metamorphic triple-junction solar cells. According to the team, the multijunction solar cell gains over 4 percent in efficiency when the industry-standard DLAR coating is replaced with an optimized four-layer AR coating.

"The measured reflectance reduction and omnidirectional photovoltaic performance enhancement of the four-layer AR coating are to our knowledge, the largest ever reported in the literature of solar cell devices," writes the team in its paper.

Considering that the solar spectrum is an intrinsically broadband spectrum, such broadband characteristics of the AR coating are undoubtedly beneficial for high power conversion efficiency. Furthermore, omnidirectional AR characteristics have become important for the rapidly expanding terrestrial application of solar cells. This is because solar irradiance



Carefully designed four-layer step-graded thin film realizes favourable antireflective interference of light for wavelength range of 350 nm to 1600 nm, and angle-of-incidence range of 0 degree to 80 degree



Four-layer AR coating beats DLAR coating at all angle-of-incidences on a state-of-the-art inverted metamorphic triple-junction solar cell

received by non-tracking solar cells in terrestrial applications usually has a wide range of incident angles. Both broadband and omnidirectional AR characteristics are attainable by four-layer AR coatings, as demonstrated by the RPI-led team.

The excellent broadband and omnidirectional AR characteristics of the four-layer AR coating are achieved through refractive index matching at multiple layer interfaces. By using tailored and low-refractive index nanoporous silica layers, the team has greatly reduced the refractive index contrast at the semiconductor / AR coating / air interfaces. Through a multilayer design methodology powered by a genetic algorithm optimisation, favourable antireflective properties over a specified wavelength range and angle-of-incidence range were found. Two porous layers of the four-layer AR coating were fabricated by oblique-angle deposition of bulk silica thereby resulting in films with refractive indices of 1.32 and 1.11. This is less than the refractive index of silica. The two dense layers lying below nanoporous silica were fabricated by co-deposition of silica / titanium dioxide using sputtering.

Although silica is chosen for the implementation of nanoporous layers of the four-layer AR coating, other oxides, such as alumina, may be explored in order to capture the entire spectrum of solar irradiance, according to team member Xing Yan. This is because alumina shows no absorption over a wider band than silica, and almost the same tailorability as nanoporous silica. According to the photocurrent measurements performed by the team, DLAR coating cannot compete with four-layer AR coating at normal incidence. When DLAR coating improves the short-circuit current density (JSC) over an uncoated triple-junction solar cell by 27.5 percent, four-layer AR coating improves by 31.6 percent.

At a grazing angle of incidence, four-layer AR coating significantly exceeds DLAR coating in AR performance. The JSC improvement of four-layer AR coating at 80° is 53.3 percent, whereas the JSC improvement of DLAR coating is only 5.3 percent. The angle-of-incidence (0° - 80°) averaged photocurrent enhancement of the four-layer AR coating amounts to 34.4 percent, compared to 25.3 percent for DLAR coating.

How does this tailored- and low-refractive index AR coating technology compare with continuously graded AR coatings, such as biomimetic antireflective subwavelength structures? According to the team, their multilayer AR coating technology may even outperform subwavelength structures, in several aspects. Due to a layer-by-layer deposition process, the structure profile of a multilayer AR coating can be precisely controlled.

"The tailorability and optimization of such a customizable approach readily lends itself to the incorporation of the AR coating design into solar cell device structures for application-specific requirements," writes the RPI-led team in their paper.

According to Jaehee Cho and Fred Schubert, it will be of interest to investigate the viability of applying this novel AR coating on surface-textured devices in the future. They will also investigate innovative fabrication methods for depositing low-refractive index AR coatings on curved surfaces, such as a hemispherical lens.

X. Yan *et. al.* Adv. Funct. Mater. **23** 583 (2013)

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News Digest Contents

LEDs

A novel spectroscopy to enhance optical devices

A new technique developed by university researchers could lead to better LEDs, solar cells, and other devices that use layered nanomaterials

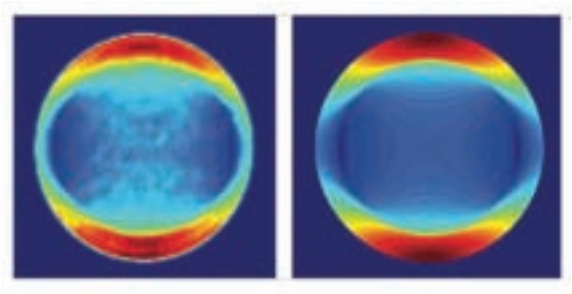
Understanding the source and orientation of light in light-emitting thin films, is now possible with energy-momentum spectroscopy.

This could lead to improvements in optical device performance.

A multi-university research team has used this new spectroscopic method to gain a key insight into how light is emitted from layered nanomaterials and other thin films.

Energy-momentum spectroscopy, enables researchers to look at the light emerging from a thin film and determine whether it is coming from emitters oriented along the plane of the film or from emitters oriented perpendicular to the film.

Knowing the orientations of emitters could help engineers make better use of thin-film materials in optical devices like LEDs or solar cells.



The orientation of light emission - The angular distribution of light emission from monolayer MoS2 , left, closely matches the theoretical calculations for in-plane oriented emitters, right, indicating that light emission from MoS2 originates from in-plane oriented emitters. (Credit: Zia lab/Brown University)

The research, published online on March 3rd in *Nature Nanotechnology*, was the collaborative effort of scientists from Brown University, Case Western Reserve University, Columbia University, and the University of California - Santa Barbara.

The new technique takes advantage of a fundamental property of thin films: interference.

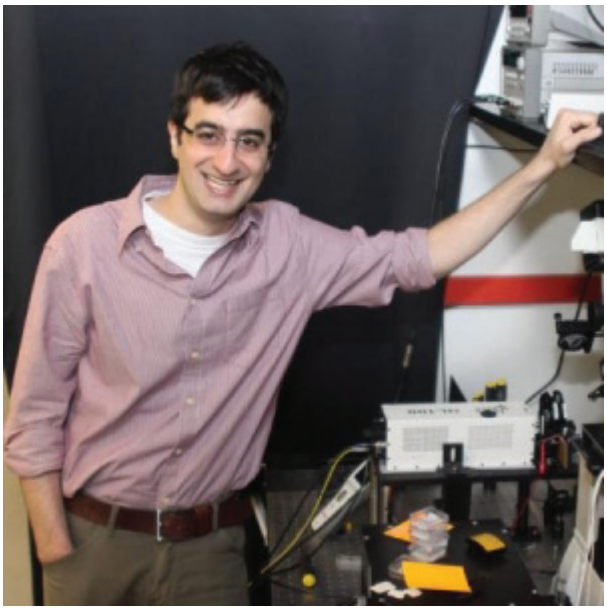
Interference effects can be seen in the rainbow colours visible on the surface of soap bubbles or oil slicks. Scientists can analyse how light constructively and destructively interferes at different angles to draw conclusions about the film itself - how thick it is, for example. This new technique takes that kind of analysis one step further for light-emitting thin films.

“The key difference in our technique is we’re looking at the energy as well as the angle and polarisation at which light is emitted,” says Rashid Zia, assistant professor of engineering at Brown University and one of the study’s lead authors. “We can relate these different angles to distinct orientations of emitters in the film. At some angles and polarisations, we see only the light emission from in-plane emitters, while at other angles and polarisations we see only light originating from out-of-plane emitters.”

The researchers demonstrated their technique on two important thin-film materials, molybdenum disulphide (MoS2) and PTCDA. Each represents a class of materials that shows promise for optical applications. MoS2 is a two-dimensional material similar to graphene, and PTCDA is an organic semiconductor. The research showed that light emission from MoS2 occurs only from in-plane emitters. In PTCDA, light comes from two distinct species of emitters, one in-plane and one out-of-plane.

Rashid Zia continues, “If you were making an LED using these layered materials and you knew that the electronic excitations were happening across an interface, then there’s a specific way you want to design the structure to get all of that light out and increase its overall efficiency.”

The same concept could apply to light-absorbing devices like solar cells. By understanding how the electronic excitations happen in the material, it could be possible to structure it in a way that converts more incoming light to electricity.



Rashid Zia

Zia also points out that once the orientation of the emitters is known, it may be possible to design structured devices that maximise those directional properties.

In most applications, thin-film materials are layered on top of each other. The orientations of emitters in each layer indicate whether electronic excitations are happening within each layer or across layers, and that has implications for how such a device should be configured.

“One of the exciting things about this research is how it

brought together people with different expertise," Zia notes. "Our group's expertise at Brown is in developing new forms of spectroscopy and studying the electronic origin of light emission. The Kymissis group at Columbia has a great deal of expertise in organic semiconductors, and the Shan group at Case Western has a great deal of expertise in layered nanomaterials. Jon Schuller, the study's first author, did a great job in bringing all this expertise together. Jon was a visiting scientist here at Brown, a postdoctoral fellow in the Energy Frontier Research Centre at Columbia, and is now a professor at UCSB."

This work is further detailed in the paper, " Orientation of luminescent excitons in layered nanomaterials," by Jon A. Schuller *et al* in *Nature Nanotechnology* (2013), published online on 3rd March 2013. DOI: 10.1038/nnano.2013.20

Funding for the work was provided by the Air Force Office of Scientific Research, the Department of Energy, the National Science Foundation, and the Nanoelectronic Research Initiative of the Semiconductor Research Corporation.

Cree's $10 LED bulb is a gamechanger

The firm's III-nitride based LED bulb is shaped like a traditional light bulb but works more efficiently and lasts 25 times longer. It provides a compact optically balanced light source within a real glass bulb to deliver warm light to consumers

Cree is launching a revolutionary series of LED bulbs at a retail price point that gives consumers a reason to switch to LED lighting.

The long-lasting Cree LED bulbs shine as brightly as comparable incandescents while saving 84 percent of the energy compared to traditional bulbs. The Cree LED bulbs are backed by a 10-year limited warranty and available exclusively at The Home Depot.

Cree LED bulb

"The Cree LED light bulb was designed to offer consumers a no-compromise lighting experience at a compelling price," says Chuck Swoboda, Cree chairman and CEO. "Over the last couple of years we recognised that the consumer is instrumental in the adoption of LED lighting, but we needed to give them a reason to switch."

"We believe this breakthrough LED bulb will, for the first time, give consumers a reason to upgrade the billions of energy-wasting light bulbs. We could not think of a better way to get this bulb into consumers' hands than through The Home Depot, a visionary partner who embraces innovation," continues Swomboda.

"As the leading retailer of energy-efficient LED lighting products, our customers look to us to provide them with the most advanced and most cost-effective lighting technologies available," comments Jeff Epstein, merchandising vice president, The Home Depot. "We diligently work with our manufacturing partners to offer consumers the most innovative alternatives that also help save money and energy. We are pleased to expand our relationship with Cree. It has enabled us to be the first in the market to offer a technologically advanced and affordable LED light bulb in the market today."

The innovative bulb is illuminated by Cree LED Filament Tower Technology and provides a compact optically balanced light source within a real glass bulb to deliver consumers the warm light they love and want. Boasting a shape that looks like a traditional light bulb, Cree LED bulbs can be placed in most lighting fixtures in the home. The new Cree LED bulb is designed to last 25,000 hours or 25 times longer than typical incandescent light bulbs - reducing the need to replace bulbs for years to come.

With a retail price of $9.97 for the warm white 40 watt (W) replacement, $12.97 for the 60W warm white replacement and $13.97 for the 60W day light, the Cree LED bulbs save 84 percent of the energy compared to traditional incandescents.

Cree LED bulbs can pay for themselves quickly and then pay consumers year after year. By replacing the incandescent bulbs with Cree LED bulbs in a home's five most frequently used light fixtures, consumers can save $61 per year on electric bills. This is based on Cree LED bulb 60W replacements at 9.5 W, $0.11 per kilowatt-hour, 25,000 hour lifetime and average usage of 6 hours per day.

Cree LED bulbs are the ideal replacement for energy-wasting 60W and 40W incandescents and compromise-laden CFL lighting. The new LED bulbs turn on instantly and are free of the mercury that is found in CFL bulbs. Unlike many low-priced LED bulbs, Cree LED bulbs are easily dimmable with most standard incandescent dimmers.

The Cree LED light bulb (60W incandescent replacement) delivers 800 lumens and consumes only 9.5W and is available in warm white (2700K) and day light (5000K) colour temperatures. The Cree LED light bulb (40W incandescent replacement) delivers 450 lumens and consumes only 6W and is available in 2700K colour temperature.

All products are available exclusively at The Home Depot.

Business Outlook Update:

For its third quarter of fiscal 2013 ending March 31st, 2013, Cree now targets incrementally higher revenue and net income. The revenue target has been increased to a range of $335 million to $350 million.

The GAAP gross margin targets remain the same as previously announced with GAAP gross margin targeted to be similar to Q2 . The GAAP gross margin targets include stock-based compensation expense of approximately $2.4 million.

Operating expenses are targeted to be approximately $2 million higher than previously announced, due to higher R&D and marketing costs to support the new product launch. The tax rate target is unchanged at 17 percent for fiscal Q3.

The GAAP net income target has been increased to a range of $18 million to $24 million, or $0.16 to $0.21 per diluted share. The GAAP net income targets are based on an estimated 116.7 million diluted weighted average shares.

Aixtron AIX G5+ wins CS Manufacturing Award 2013

The compound semiconductor industry commended the firm's gallium nitride-on-silicon (GaN-on-Si) system. The tool is designed to handle five 200 mm wafers per production run providing high throughput and high yield growth of GaN devices on large area substrates

Aixtron SE has announced that it has been awarded the 2013 Compound Semiconductor Manufacturing Award for its latest development, the AIX G5+ reactor for GaN-on-silicon epi-wafer growth.

The Award recognises key areas of innovation surrounding the chip manufacturing process from research to completed device, focusing on the people, processes and products that drive the industry forward.

Frank Schulte, Aixtron (on the right), receives the Award from Richard Stevenson, CS magazine

Editor Richard Stevenson from Compound Semiconductor (CS) magazine presented the award yesterday, March 4th, 2013 to Aixtron's Vice President Europe Frank Schulte.

"GaN-on-silicon technology promises to revolutionise power electronics and slash the cost of LEDs, spurring a lighting revolution," he commented at the award ceremony in conjunction with the CS Europe exhibition in Frankfurt, Germany. "One manufacturing tool that I am tipping to play a major role in driving both these changes is the Aixtron AIX G5+, a reactor that combines high throughput with impressive levels of uniformity."

Andreas Toennis, Chief Technology Officer at Aixtron SE, comments, "Delivering results on the leading edge of GaN-on-Si technology, we are very pleased that our achievements are recognised by the compound semiconductor industry through this prestigious prize. The AIX G5+ reactor has been specifically designed to produce GaN based devices on silicon without compromising performance or yield compared to processes on sapphire substrates."

"GaN-on-Si is a very promising technology for future power electronics applications and high brightness LED manufacturing," Frank Schulte adds.

The AIX G5+ is designed to handle five 200 mm wafers per production run providing high throughput and high yield growth of GaN devices on large area substrates.

EPIC represents photonics industry at European Commission group

European Photonic Industry Consortium (EPIC) president Drew Nelson will act as technology representative for the Photonics KET High Level Group. The group aims to foster the industrial deployment of European KETs in order to keep pace with main international competitors, restore growth, create jobs and help address today's major societal challenges

A new group was launched on 27th February to assist the European Commission in the implementation of the strategy to boost the industrial production of KETs based products in Europe.

The global market in Key Enabling Technologies (KET) is forecast to grow from about €650 billion in 2008 to over one trillion euro in 2015. World leading industries in the fields of automotive, communication, aeronautics, defence, health and energy are all intensive users of KETs.

Representing the European photonics industry, EPIC President Drew Nelson, CEO and President of epitaxial wafer supplier IQE, has been appointed as a member of the new High Level Group as technology representative for the Photonics KET.

Group inauguration by European Commissioners Antonio Tajani from DG Enterprise, Máire Geoghegan-Quinn from DG Research, and Johannes Hahn from DG Regio. Drew Nelson, President of EPIC, represents the photonics industry

"I will be a vigorous supporter and promoter of KETs at regional, national, and European level and take every opportunity to help design and implement policies to help the competitiveness of Europe through the rapid deployment of KETs," states Nelson. "I expect from the KET high level group that it is able to persuade the European Commission through evidence based examples and debate to adapt EU policies throughout each Directorate General that fully support KETs implementation throughout Europe."

The expert group advises the European Commission on KETs related policy issues, follows up the implementation of the European strategy for KETs adopted by the European Commission on 26th June 2012, and promotes the development of KETs policies by the Member States.

Carlos Lee, Director General of EPIC, is a member of the working group on "Promotion and Implementation of KETs Policies at National and Regional Level." "KETs offer a fantastic opportunity for all of Europe, we must explore and embrace its potential. Especially in Photonics, there are many opportunities ahead of us," he says.

Pike: Start-up LED lighting companies suffering

The combination of costs having fallen 50 percent in the last 18 months and the rising efficiencies of LED lamps means a boost in chip sales

A number of small start-up companies have begun offering hardware and software products for smart street lighting systems.

According to Pike Research, in this challenging emerging market, many of these start-ups have already failed, others have been acquired by larger lighting companies, and a few are flourishing on their own.

Some of the larger control and lighting companies are developing their own products for this market, which will put pressure on smaller companies that have not yet secured a reliable revenue stream.

At the same time, new lamp options have recently become available for street lights, most notably LEDs. The market for these lamps is also in a period of transition. Dramatically falling costs and rising efficiencies of LED lamps are driving up sales. Costs have fallen as much as 50 percent over the last 18 months and are expected to continue falling for years to come.

LED lamps allow for better dimming control than standard street lights, and their electronics allow for easy integration of control nodes. Rising sales of LED lamps will therefore drive up the adoption of smart street lighting systems.

Pike Research expects the market for smart street lighting to grow steadily over the remainder of this decade. Shipments of smart street lighting systems, which will be under 200 worldwide for 2012, will reach more than 1,100 in 2020. Shipments of communications nodes, meanwhile, will rise from 550,000 this year to 4.8 million in 2020.

New VP Linda Reinhard to take sapphire forward at GT

Reihard's initial focus will be on growing sapphire material and the ASF equipment business which is primarily used by the LED industry

GT Advanced Technologies has appointed Linda Reinhard as vice president, new business development and product management for the company's sapphire, DSS and HiCz products.

She will report to Dan Squiller, GT's chief operating officer. Reinhard will be responsible for leading GT's growth into new market segments and driving the product roadmap to capitalise on these new opportunities including sapphire for cover and touch screen applications.

"Linda brings deep experience and a proven track record in both product management and new business development," says Dan Squiller, GT's chief operating officer. "Linda's initial focus will be on growing our sapphire material and ASF equipment business, particularly new opportunities in the cover and touch screen markets. She has extensive experience in Asia as well as in the mobile device segment which we believe could be a significant area of opportunity for our sapphire business. Linda will also drive our product management and new business development for HiCz and our traditional PV business."

GT's Advanced Sapphire Growth Furnaces (ASF) is a production proven furnace that produces high quality sapphire material for the LED industry.

GT's ASF furnace

Reinhard received her BSEE from University of Illinois and an MBA from The Kellogg Graduate School of Management. She has over 20 years of experience with leading technology companies including Motorola, Cisco, Nokia, and H-P holding senior level positions in new business development, marketing, sales, and product management. She has lived in Asia and has extensive experience in China and Asia Pacific evangelising and introducing new products to major OEMs. Reinhard will be located in GT's headquarters in Merrimack, New Hampshire.

"Our goal for the show is to continue educating the market about the unique properties of GT's ASF-grown sapphire material for cover and touch screen applications," says Linda Reinhard, GT's vice president of business development and product management.

"ASF-grown sapphire's durability and resistance to scratching makes it ideally suited for a wide range of cover and touch screen applications from ruggedised phones, camera covers, point of sale devices and smartphone and touch screen devices. Other reinforced glass and cover screen technologies try to emulate what ASF-grown sapphire does naturally."

GT Advanced Technologies Inc. is a global provider of polysilicon production technology and sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets. The company says its products and services allow its customers to optimise their manufacturing environments and lower their cost of ownership.

Cree LEDs to slash costs by 30 percent in Mt. Pleasant Walmart

As part of a continued focus on sustainability, the US's largest retailer has selected energy-efficient LED lighting by Cree, to illuminate its Neighbourhood Market in Mt. Pleasant, Wisconsin

Cree interior lighting products, including more than 400 CS18 LED linear luminaires, will fully illuminate the Neighbourhood Market – from the sales floor and pharmacy to restrooms, vestibules and backroom areas. Cree LED lighting will also be installed in the parking lot and exterior areas of the store.

Walmart estimates that the CS18 luminaires, designed for low maintenance and long life, will save approximately 30 percent in energy costs compared to interior fluorescent lighting.

Cree interior and exterior lighting fixtures offer a long service life and are backed by a 10-year limited warranty. This substantial product lifetime enables significant maintenance reductions and energy savings for the Neighbourhood Market.

Recently ranked fifth on the 2012 Newsweek rankings for greenest U.S. retailers, Walmart's deployment of Cree LED lighting will help the company achieve its sustainability goals: to be supplied 100 percent by renewable energy, to create zero waste and to sell products that sustain people and the environment.

According to Walmart, the retailer used enough renewable energy last year to power 78,000 homes and is keeping 80 percent of its U.S. waste out of landfills.

The high-efficiency CS18 suspended LED linear luminaire uses approximately 30 percent less energy and lasts more than three times longer than standard fluorescents. The CS18 luminaire will bring a combination of performance, aesthetics and optimal light distribution to the sales floor of the Mt. Pleasant Walmart Neighbourhood Market.

"Cree LED lighting will help us advance our sustainability goals while reducing the cost of operations and also giving our customers a pleasant shopping experience," says David Redfield, senior vice president for Walmart operations. "Reducing energy consumption is the right thing to do for our natural environment, for our customers and for our business. Ultimately, the cost savings allows us to deliver on our commitment to Everyday Low Price."

"Cree has a long-standing relationship with Walmart and the continued deployment of energy-efficient lighting further establishes LEDs as the superior lighting option for retailers everywhere," adds Christopher Ruud, Cree vice president, global LED adoption. "The Mt. Pleasant location will be a great showcase of the benefits of LED lighting for the full customer experience – from the parking lot to the aisles. We're proud to support the new Neighbourhood Market right in our own backyard."

Rubicon six inch sapphire sales make up for cheaper small cores

The provider of sapphire substrates and products to the

LED, RFIC, semiconductor, and optical industries saw strong demand for six-inch polished wafers in the quarter, particularly from the LED market

Rubicon Technology, Inc. of Bensenville, IL, USAhas reported financial results for its fourth quarter ended December 31st, 2012.

The company reported fourth quarter revenue of $20 million as compared with $19.9 million in the prior quarter. Revenue from six-inch wafer sales showed another sequential increase to $17.5 million from $16.4 million in the prior quarter, a 7 percent increase.

Due to low industry pricing for two through four inch core products, the company decided to sell a limited quantity of those products in the quarter.

Raja Parvez, President and CEO of Rubicon Technology, comments, “We saw strong demand for our six-inch polished wafers in the quarter, particularly from the LED market. We continue to be the largest provider of six-inch polished wafers in the market due to our strength in both large diameter crystal growth and large diameter polishing, evidenced by the fact that we have now shipped over 400,000 polished six-inch wafers to date into the LED and SoS markets.”

While the pricing environment has not improved for two through four inch core products, Rubicon has started taking orders for those products for delivery in the first and second quarters in order to begin reducing inventory levels and maintain customer relationships. With the firm’s resumption of sales into this market, pricing has decreased further.

William Weissman, CFO of Rubicon Technology, says, “Current pricing of two through four inch core products is now below our carrying cost in finished goods and WIP inventory for those products. As a result, we recorded a $1.6 million adjustment in the period to reflect the value of those products in inventory at the current market price.”

He continues, “We believe that our competitors are now selling smaller diameter cores at cash cost in order to reduce inventory or to keep utilisation rates high. However, excess capacity in the market is gradually being absorbed and we believe the pricing environment should eventually improve. Exactly when and how quickly pricing will improve is difficult to predict.”

The company reported a sequential reduction in margins due primarily to the lower smaller diameter product pricing and resulting inventory adjustment. The loss per share in the fourth quarter was $(0.05) as compared with a diluted EPS in the third quarter of a positive $0.01 per share.

First Quarter 2013 Guidance

Commenting on the outlook for the first quarter of 2013, Parvez says, “With the accelerating growth of the general lighting sector of the LED market and with the increasing complexity of mobile devices creating greater opportunity for SoS technology, I am very excited by the longer term growth potential of the markets we serve.

However, they are evolving markets and we will likely continue to see shorter term volatility. In the first quarter, our six-inch wafer orders will be lower. Similar to what we experienced last year, our largest LED customer for six-inch wafers has excess inventory and will not likely need additional material until the second quarter. “

“Also, our SoS customer recently announced that their orders are down based on weaker than expected sales by a key end customer. However, they also expressed confidence in a strong second half of the year based on the expected introduction of new smartphone models by their end customers later in the year. As a result, six-inch revenue will be lower in the first quarter. But, we believe we will see strong orders for six-inch wafers in the second half from both the SoS and LED markets.”

Rubicon expects first quarter revenue to be approximately $8 million, down sequentially due to lower six-inch wafer sales. With the reduced sales volumes, utilisation rates will be low in both crystal growth and polishing, putting pressure on the company’s margins in the quarter. As a result, the company expects a loss per share between $(0.10) and $(0.14) in the first quarter based on 22.5 million shares outstanding and a 50 percent tax benefit.

Cree KR Series LED downlights continue to trounce fluorescents

The III-nitride LED innovator is continuing to drive the adoption of LED lighting with higher lumen outputs, new aperture and expanded options

Cree has extended the KR Series LED downlight portfolio delivering greatly improved performance at pricing to match incumbent fluorescent downlights.

With new lumen packages of up to 2650 delivered lumens, the KR Series replaces 18 to 42 watt fluorescents.

KR Series : LED Specification Downlight

Cree is further expanding the range of LED downlight applications by introducing the KR4 downlight which features an impressive, high lumen 4-inch aperture, with options similar to the 6-inch KR6 downlight.

With new standard 0 to 10V dimming, sloped ceiling and

wall wash trim options the KR Series downlights provide attractive aesthetic appeal for numerous commercial and retail applications.

"The KR Series LED downlights are ideal for new construction applications," says Greg Merritt, vice president, lighting. "And with the increased range of LED options now available at price parity to fluorescent lighting incumbents, I see no reason to ever specify a CFL downlight."

Built with Cree TrueWhite Technology, the KR Series downlight family is available in a wide range of colour temperatures (2700K, 3000K, 3500K and a new 4000K), all with over 90 CRI, enabling beautiful, efficient lighting.

To help facilitate utility rebates, the KR Series is currently in the qualification process for earning the ENERGY STAR.

The KR Series is sold through Cree lighting sales channels.

Cree shares downgraded

The firm's shares fell 0.39 percent to trade at $45.54 on Tuesday. Over the past year, the stock has been trading between $22.25 and $46.88

Cree shares were downgraded to "perform" from "outperform" by Oppenheimer based on valuation.

The brokerage, which removed price target of $42 on the stock, believes now is a good time to take money off the table.

"Cree currently trades at a 35x forward P/E multiple, a two-year high. Although we believe in the technology advantage of Cree and the long-term growth prospects of the LED lighting market, the near term may not be "all clear" to support such lofty valuation," Oppenheimer says.

The brokerage believes the stock could continue to rally over the next 3-6 months as immediate headwinds seem overblown, China orders pick up following the New Year, and spring ushers in more favourable weather for municipal and new commercial lighting.

"However, visibility remains limited and longer term competitive dynamics linger; to us, risk/reward looks balanced," Oppenheimer adds.

"Cree is still our favourite name in the LED supply chain, but valuation prompts us to take a more conservative stance and wait for a better entry point," the brokerage writes.

Cree's shift to a fixture business, and its component business fighting the commodity bug, each present unique challenges over the long haul. The brokerage sees Cree as ultimately being successful, but also don't see the risk these challenges present priced into the stock.

Aixtron appoints new general manager in Korea

The aim of the new GM is to help Korea become one of the world's major countries employing MOCVD manufacturing technology

Aixtron SE has taken on SukYoung Kim as General Manager of its subsidiary Aixtron Korea Co., Ltd.

SukYoung Kim, GM Aixtron Korea Co., Ltd.

Kim has been working in the international semiconductor industry in Korea and the USA for many years and most recently held the position of Regional President and Representative Director of Novellus Systems in Korea.

In his new position as General Manager at Aixtron Korea, he takes over strategic and operational responsibility from Eun Sook (E.S.) Choi who held this position at Aixtron Korea until now. Choi will further support Aixtron as a consultant.

Bernd Schulte, Executive Vice President and Chief Operating Officer of Aixtron SE, says, "Korea is one of the global centres of advanced high-power LED products with many important key players. I am delighted to announce the appointment of SukYoung, which demonstrates the strategic importance of Korea's significance as a key market within Aixtron."

Kim comments, "Aixtron has highly advanced technology not only in compound, but also silicon and organic semiconductors. Our target is to support our Korean customers' strategies for further development and to provide leadership across the business sector, helping Korea become one of the world's major countries employing MOCVD manufacturing technology."

Aixtron CEO quits

LED expert and ex Osram board member Martin Goetzeler will take over from Paul Hyland on March 1st, 2013

MOCVD tool manufacturer Aixtron is having a tough time.

Less than a month ago, Holger Jürgensen (deputy chairman of the supervisory board) and Karl-Hermann Kuklies (ordinary member of the supervisory board) of Aixtron, both resigned.

The firm has also recently had a round of redundancies.

Now, Aixtron SE has announced that Paul Hyland, President and CEO, will leave the company by mutual agreement with effect as of February 28th, 2013, for personal reasons.

Paul Hyland, President and CEO of Aixtron SE

The Supervisory Board has appointed Martin Goetzeler (50), an internationally experienced top manager and industry expert, as Hyland's successor. Goetzeler will join the company on March 1st, 2013.

Within the Executive Board, he will be responsible for the areas strategy, production, purchasing and logistics, investor relations and group communication.

Before his appointment Goetzeler served on the executive board of Siemens' subsidiary Osram and also held various international leadership positions within the Siemens group. He is an acknowledged expert in the LED and lighting industry.

For many years, Martin Goetzeler served as President of the European Technology Platform Photonics21, which, among other things, advises the European Commission in determining major strategic research in the area of photonics.

His extensive experience in the target markets of Aixtron will further strengthen Aixtron's technology leading position in a period of considerable market change. Goetzeler says, "I am looking forward to the task of leading Aixtron as a leading provider of semiconductor technology production solutions along the way towards industrial mass production."

He adds, "We have the opportunity to address some of the current social megatrends such as energy efficiency and intelligent networking, which are dominated by LEDs, OLEDs and power electronics. There is substantial growth potential for Aixtron in all of these areas."

Hyland comments, "I am very pleased that I had the opportunity to participate in Aixtron's route to becoming a globally acknowledged leading technology company. I am pleased to be able to hand over the CEO role to Mr. Goetzeler at this time. Mr. Goetzeler can build on a solid foundation, and he has both the leadership qualities and experience to take Aixtron successfully onto the next level."

Kim Schindelhauer, the chairman of the Supervisory Board of Aixtron SE, expressed his gratitude to Hyland for his contributions to the company and says, "Mr. Hyland has successfully managed the Company during his tenure through many ups and downs in the semiconductor industry. For this, we would like to express our great appreciation. We are delighted to have found someone like Mr. Goetzeler, a versatile manager with extensive knowledge in the high-tech market and international experience. Mr. Hyland will actively support Mr. Goetzeler in taking up his office and ensure a smooth transition."

SETi UVTOP UVC and UVB LEDs now available in SMD format

The firm has revealed a new line of surface mount devices for high-volume cost sensitive markets

Sensor Electronic Technology, Inc. (SETi) launched a new line of UVTOP products in surface mount packages at the 2013 SPIE Photonics West show.

Initial devices added to this product line will operate with peak operating wavelengths at 275nm and 310nm respectively. Additional wavelength specifications will be added to the product line in the near future.

This SMD based line of UVTOP LEDs has been developed to address high volume markets that demand lower device and assembly costs.

The ceramic package dimensions are 3.5mm x 3.5mm and are available with UV stable encapsulation, a flat glass window, or a hemispherical glass window. Windowless devices are also available.

The entire range of UVTOP LEDs will remain available in TO packages for lower volume requirements, customised specifications and for customers who prefer a through-hole package.

In 2012, SETi opened its high volume manufacturing facility for UV LEDs, driving the cost of manufacturing down. Now, by employing new high volume packaging techniques and with the use of this cost effective ceramic package, SETi is bringing the UVTOP LEDs to new mass-volume markets where the TO package is not the most effective solution.

Laytec upgrades in-situ GaN LED monitoring system

The firm's latest UV pyrometer incorporates real-time UV emissivity correction for enhanced accuracy of gallium nitride surface temperature during the growth of complex LED structures

In an ideal world, LED manufacturers would know the emission wavelength of the final device during MOCVD growth.

Today, according to the Solid State Lighting road map, the wavelength variation across a wafer should be less than 1 nm.

This means a less than 1 K (10C) variation of the GaN surface temperature during InGaN MQW growth.

LayTec's Pyro 400 is widely used for enabling fab-wide GaN surface temperature uniformity in many LED manufacturers production lines.

Meanwhile, more complex LED structures and tighter cost reduction targets need even more advanced *in-situ* metrology. Figure 1, below, shows such an example; ternary InGaN and AlGaN layers cause emissivity changes that lead to 0.7 K error of the UV pyrometry reading.

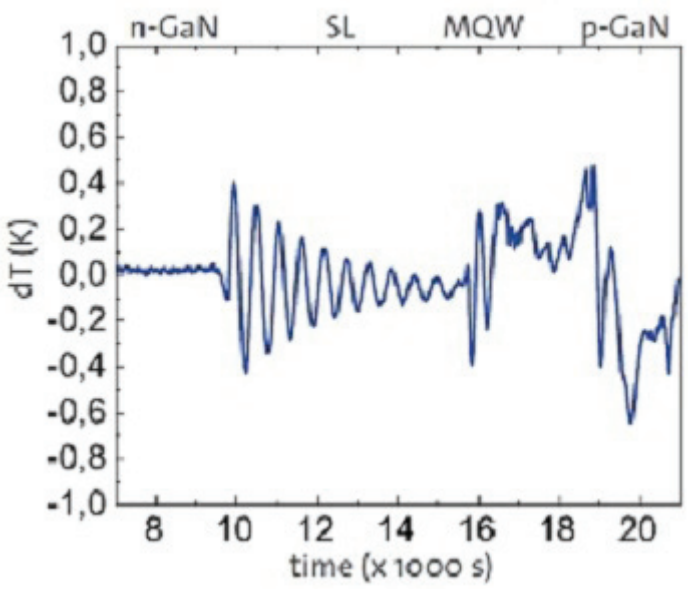


Figure 1: Effect of changing emissivity to UV pyrometer temperature reading: up to 0.7 K errors show up without emissivity correction during growth of a GaN/AlGaN-GaN-SL/ InGaNMQW/ GaN structure

LayTec's answer to this challenge is the Pyro 400 Gen 2. Along with *in-situ* UV pyrometry the new generation tool includes real-time UV emissivity correction for enhanced accuracy of GaN surface temperature during growth of more complex LED structures.

A further challenge to reliable GaN temperature control in HB-LED production is the view-port coating.

Figure 2 shows its effect just before maintenance; the UV transmission of the view-port is significantly reduced and an uncorrected UV pyrometer would give a -10 K temperature artefact. Pyro 400 Gen 2 solves this problem,too. Laytec claims the tool automatically senses and corrects these coatings and enables a long-lasting 24/7 accuracy in HB-LED emission wavelength.

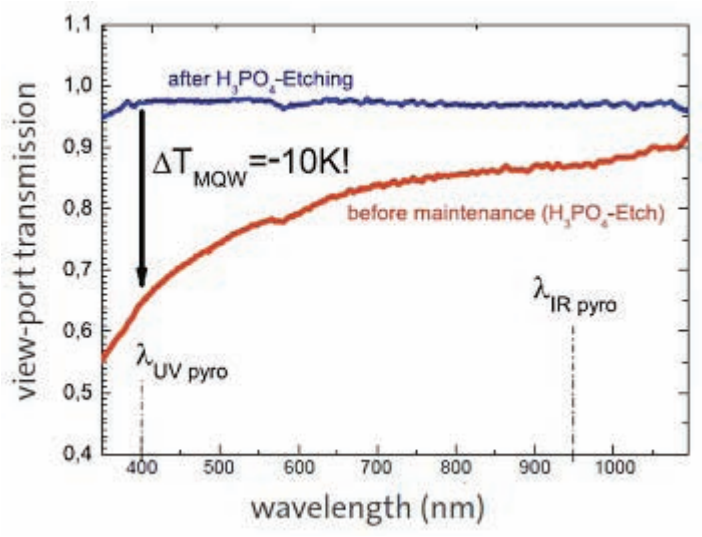


Figure 2: GaN MOCVD view-port before (red) and after maintenance (blue): the transmission at the 400nm detection wavelength of a UV pyrometer is suffering from the window coating (red). The resulting -10K artifact is avoided by Pyro 400 Gen2

Last, but not least, an assisting infrared pyrometer has been integrated into Pyro 400 Gen 2 for simultaneous monitoring of wafer pocket temperature throughout the full LED growth run.

US DOE hails Soraa GaN on GaN LEDs

The firm has been recognised for the development of high-efficiency m-plane LEDs on bulk gallium nitride substrates

Soraa has received a Lighting award from the U.S. Department of Energy (DOE) for its outstanding work in the development of high-efficiency *m*-plane LEDs grown on low-defect density bulk GaN substrates.

The company demonstrated a very high peak internal quantum efficiency (IQE of 88 percent), low efficiency droop (10 percent from 10Acm-2 to 100A.cm-2) and perfect wavelength stability (up to 200A.com-2) at a wavelength of 450nm LEDs.

"Research and development of LEDs on bulk GaN substrates is one of the critical approaches to the technological development of Solid State Lighting - a sentiment recently echoed by the National Academy of Sciences. We are pleased to recognise Soraa's pioneering work in this area," says Jim Brodrick, Manager of the U.S. DOE's Solid State Lighting Program.

"We are honoured to receive an award from the U.S. Department of Energy and it is a further testament to deep technological expertise that has made us the world's leader in the development of GaN on GaN LEDs on all planes," adds Mike Krames, CTO of Soraa.

Soraa's GaN on GaN LEDs handle more current and emit substantially more light (about ten times) per area of LED

wafer material than the conventional approach of depositing GaN layers on cheaper foreign substrates like sapphire, SiC or silicon.

The company's GaN on GaN technology leverages the advantages of the native substrate, including lower crystal defect densities (by more than a thousand times), which allow reliable operation at very high current densities, the same principle that enabled Blu-ray laser diodes.

In addition to improved crystal quality, the native substrate advantages of optical transparency and high electrical and thermal conductivity provide for a very robust, simple LED design for maximum performance. A further advantage of the GaN on GaN approach is the flexible choice of crystal growth plane, which has demonstrated advantages in high peak internal quantum efficiency and low-droop LED performance.

Lumileds unveils die-level LUXEON Flip Chip LED technology

The firm says this allows luminaire manufacturers to gain exceptional access to Philips Lumileds' technology

Philips Lumileds has developed new LUXEON Flip Chip LED devices that will enable the next generation of lighting applications by providing luminaire manufacturers with more design flexibility.

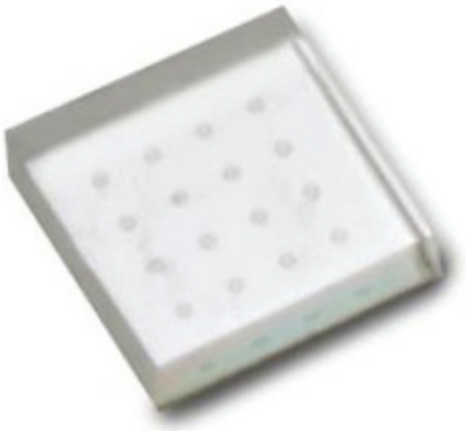
Users can now access Philips Lumileds technology through a robust LUXEON Flip Chip die format giving them greater design options than in the past.

"Now luminaire manufacturers can enjoy the best of both worlds, by either incorporating packaged LEDs as they did in the past, or by starting with the LED die and customising the phosphor and packaging to best suit their lighting application," says Pierre-Yves Lesaicherre, CEO of Philips Lumileds.

While traditional wire bonding limits the packing and power density of LEDs, LUXEON Flip Chip LEDs can be packaged closer and can be driven at a higher current density. This requires fewer emitters to achieve a higher lumen output at higher lumen densities, a capability that is especially advantageous with chip-on-board and other high-power applications.

One design advantage is large p and n bond pads that improve LUXEON Flip Chip packaging reliability

"The end result is that luminaire manufacturers can achieve higher lumens per dollar through higher lumen densities and a straightforward packaging process," notes Lesaicherre.



The robust design of Philips Lumileds LUXEON Flip Chip LED die enables LED lighting with high lumen output per dollar

Philips Lumileds introduced high-power LUXEON Flip Chips in a 1.0 mm x 1.0 mm format. As is the case with all LUXEON LEDs, these chips take advantage of Philips Lumileds' epitaxial technology, materials and design.

Osram and Evolucia LED luminaires raise heads in Mexico

Osram's ProPoint Cobrahead luminaires which employ III-nitride LEDs, use Evolucia's Aimed Optics and are now being marketed in Mexico

Osram Mexico and Evolucia have finalised an agreement whereby the companies will develop, deliver and market Osram ProPoint Cobrahead LED outdoor luminaires using Evolucia Aimed Optics.

ProPoint LED Cobrahead Luminaire

Under the agreement, the companies will work together to integrate Evolucia's Aimed Optics technology with superior LED modules and lighting controls from Osram. The combination is expected to result in one of the highest performing and highest quality LED outdoor luminaires in the industry.

"The combination of cutting edge LED technology from Osram with Evolucia's industry leading light distribution capabilities allows us to deliver high-performance and superior quality LED outdoor luminaires to our customer base," says Paolo Bortolan , Presidente y Director General - CEO of Osram Mexico.

"The new Osram ProPoint Cobrahead using Evolucia Aimed Optics outdoor luminaire delivers the perfect amount of clean white light to the target area and uses up to 62 percent less energy than traditional fixtures."

Evolucia, Inc. is a Sarasota, Florida-based company that recently won the lighting industry's coveted Best LED Street Light award, in its category, which was presented by the US Department of Energy, largely because of the proprietary Aimed Optics technology that was invented by the company's lighting design team.

Mel Interiano, Chief Executive Officer of Evolucia, adds, "We are extremely pleased to be partnering with Osram Mexico. We have invested more than $25 million in our Aimed Optics product development platform and have spent 5 years working to perfect the LED mounting angles, heat sinking and aesthetics to ensure that not only performance is at the highest level, but also that our products can be manufactured and delivered at extremely competitive prices."

Court says Intematix can still sell products in Korea

However, litigation is still continuing for the innovator of red nitride phosphor products used in LED lighting

Intematix Corporation has provided an update on its patent infringement litigation in South Korea with Mitsubishi Chemical Corporation.

The company reported that on February 5th, 2013 the Seoul Central District Court decided not to issue any enforceable ruling at this time. As such, there is no restriction on any sales or use of Intematix R or ER products in South Korea.

However, the litigation remains on-going.

"We will continue to vigorously defend ourselves in any litigation," comments Intematix General Counsel, Tom MacMitchell. "We remain confident that Intematix ultimately will be successful."

Intematix RR series red nitride products is protected by U.S. Patent No. 8,274,215, while its latest XR series of red nitride products are based on an entirely different structure.

Cree LED lighting illuminates Petty's Garage

Partnering with Greenleaf Energy Solutions, Petty's Garage installed Cree's LED lighting, featuring Cree's TrueWhite technology

Nicknamed "The King" of NASCAR, Richard Petty has endorsed Cree LED lighting after enthusiastically transforming his 100,000 square-foot garage with LED fixtures by Cree,

More than 700 Cree LED luminaires now illuminate the Petty's Garage complex, which specialises in the restoration of high-performance vehicles, stock cars, drag racers and Petty signature cars.

According to Greenleaf Energy Solutions, when compared with the previous fluorescents, the installation reduces lighting energy usage more than 50 percent and decreases the number of light fixtures needed by 10 percent.

"We know that Cree produces the best LED technology in the world," says Stephen Moffitt, energy consultant, Greenleaf Energy Solutions. "Cree was the clear choice for Petty's Garage."

"Cree LED lighting delivers the quality of light we need for the work in our garage, allowing us to focus on our business of redoing cars," continues Petty. "We turned these lights on, and they made our cars and shop look brand new. There's really only one word to describe Cree's lights – wow."

Cree CR24 LED troffers were installed in the main production facility with LR24 LED troffers and CS18 LED linear luminaires featured throughout the complex. The next stage of the installation will bring Cree Edge security and floodlights and LEDway streetlights to the property.

"High-quality, long-lasting LED lighting dramatically enhances the auto restoration experience at Petty's Garage," adds Tami Timperio, vice president of communications, lighting at Cree. "Our LED troffers feature industry-leading Cree TrueWhite Technology with 90 CRI that really makes cars pop. Designed to deliver lifetimes of more than 50,000 hours, Cree's LED troffers can virtually eliminate the time and expense associated with replacing fixtures for auto dealers and shop owners."

Cree showcased its LED lighting products at the National Auto Dealers Association Convention and Expo 2013 in Orlando at the weekend. "The King" signed autographs and photos with attendees at the Cree booth.

Cree takes on Mike McDevitt as Chief Financial Officer

McDevitt brings more than two decades of finance and operations leadership and has served as Vice President and Interim CFO of the company since May 22nd, 2012

Cree has appointed Mike McDevitt as Executive Vice President and Chief Financial Officer (CFO), which became effective last week.

“Mike is an invaluable member of the Cree team and I am very pleased to announce his appointment as CFO,” says Chuck Swoboda, Cree chairman and CEO. “After conducting an exhaustive national search, we realised Mike is the best candidate for the job. Mike’s proven leadership will help Cree drive innovation and accelerated adoption of LED lighting.”

Prior to his appointment as Interim CFO, McDevitt held several key leadership roles at Cree including Director of Sales Operations from 2011-2012, Director of Financial Planning from 2005-2011 and Corporate Controller from 2002-2005.

Soraa sponsors Strategies Unlimited LED Lighting Plugfest

For 14 years, Strategies in Light has been dedicated to providing the LED and lighting industry with an unparalleled standard of excellence in quality conference programming

In an effort to remove barriers to the rapid adoption of LED lighting, Soraa will sponsor a Lighting PlugFest in conjunction with Strategies Unlimited at its annual Strategies in Light conference in Santa Clara, California.

Incompatibility between LED lamps and fixtures with existing control gear and dimmers designed for traditional light sources- incandescent, halogen, or fluorescent -is one of the biggest hurdles facing the lighting industry today.

PlugFests are a mainstay for the IT and consumer electronics industries- Soraa was the first to adapt the practice to the lighting industry, launching the first ever PlugFest in New York City in December 2012. Lighting PlugFest gives lighting designers and specifiers, manufacturers, and end users the opportunity to test products and identify underlying compatibility issues.

“Soraa has been an innovator in Solid State Lighting, launching a revolution in everything from substrates to LED chips to lamps. Lighting PlugFest is a unique opportunity to bring SSL revolution to be on par with the IT world,” says Ella Shum, Director of Research at Strategies Unlimited. “Today, when we use a smartphone and a PC, we don’t think about how they communicate with each other. It should be the same for SSL lighting.”

Soraa will manage and run the testing using a custom-built testing panel comprised of an array of commonly used transformers and dimmers and Soraa’s 12VAC LED MR16 lamps. The panel can also accommodate participating companies’ transformers, dimmers, and 12VAC or 120VAC (E26 only) LED lamps or fixtures.

“Manufacturers benefit because Lighting PlugFest addresses compatibility - an obstacle to widespread LED lamp adoption; designers benefit because they can specify with confidence; and end users benefit because they will know that product combinations work,”comments Eric Kim, CEO of Soraa. “This event is all about ensuring a positive LED lighting user experience.”

Strategies Unlimited offers comprehensive coverage of high-brightness LEDs and LED lighting, lasers and other photonic products and systems, biomedical imaging systems and image sensors, compound semiconductor materials and specialty electronics market sectors.

Soraa says its full spectrum GaN on GaN LED lamps have superior colour rendering and beam characteristics compared to lamps using LEDs created from non-native substrates. Founded in 2008, Soraa is located in Fremont California, where it manufactures its GaN on GaN LEDs in the company’s facility.

Bridgelux appoints Bradley J. Bullington as CEO

Also, Bill Watkins, who nurtured and developed GaN on Silicon will become chairman of the board of directors

Bridgelux has appointed Bradley J. Bullington, the company’s former Vice President, Strategy and Corporate Development and General Manager, Technology Solutions, as Chief Executive Officer.

William Watkins has moved up to Chairman of the Board of Directors, having served as CEO of the company from January, 2010 until taking this new role.

Bullington joined Bridgelux from Seagate in 2010, where he worked with Watkins, and has been responsible for the company’s overall business strategy and all corporate and market development activities. These include strategic partnerships and joint venture development, technology licensing, capital formation and the legal function. He also ran Bridgelux’s Technology Solutions business.

“Brad has driven Bridgelux’s strategic direction and corporate development initiatives since joining the Company when I came aboard,” says Watkins. “I look forward to working with him to ensure a smooth transition, as well as going forward as Bridgelux enters its next phase of growth.”

“Bill has restructured and recapitalised the company, nurtured and developed our leadership position in GaN on Silicon, and significantly strengthened Bridgelux’s position in the rapidly growing global lighting market,” adds Alan Salzman, CEO and Managing Partner of VantagePoint Capital Partners.

“The Board is thrilled that Bridgelux will continue to benefit from Bill’s tremendous knowledge, expertise, and guidance as the Company moves ahead. We also look forward to working with Brad as he continues to build on Bridgelux’s leadership in the solid state lighting industry.”

Prior to joining Bridgelux, Bullington held executive strategy, corporate and business development roles at Seagate

Technology from 2006 to 2009.

Bullington held similar positions at Maxtor Corporation, where he was also a founding member of Maxtor's Branded Products Group (BPG), an industry pioneer in the external storage solutions market.

Prior to entering the data storage industry, he was a management consultant for A.T. Kearney, where he served a range of clients focused on issues of strategy and operations in the software and technology hardware, aerospace, retail and financial services industries.

He began his professional services career at Deloitte & Touche.

Bullington received his B.A. in Business Administration, with a Certificate of International Studies in Business, from the University of Washington.

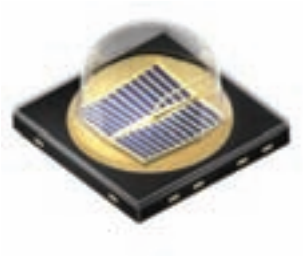
Osram introduces LED for security applications

The firm says its infrared Oslon black SFH 4725S is a secret agent in more ways than one

Osram Opto Semiconductors says its latest light has a wavelength of 940 nanometres (nm), making it virtually invisible to the human eye.

But also its black package reflects almost no ambient light whatsoever.

Together with a high optical output of almost one watt, this infrared LED from Osram is suited for covert surveillance.



The Oslon black SFH 4725

Concealed security systems – such as those installed in banks, on machinery and at border controls – need to be designed so they are unobtrusive.

This is a major challenge for infrared illumination in such applications because the 850 nm LEDs that are most often used here appear as weak dots of red light especially in dark environments.

The solution is to switch to a wavelength of 940 nm, which the human eye is 130 times less likely to notice. Camera sensors however can easily detect this invisible radiation.

The Oslon black SFH 4725S is suited to components for such applications. This compact infrared LED provides 940 nm light with the high optical output of 980 milliwatts from an operating current of 1 amp.

Behind this, high performance lies the Nanostack technology in which Osram has succeeded in providing two emission centres in one chip, almost doubling the light output. The SFH 4725S achieves a radiant intensity of 450 mW/sr at an emission angle of 90 degrees and therefore provides excellent illumination over the area being monitored.

Radiant intensity (measured in milliwatts per steradiant) indicates the light output within a solid angle segment and therefore defines the intensity of the light beam.

The black package ensures that the component is completely concealed behind the camera lens. "The 940 nm SFH 4725S is a further addition to our Oslon black series for the security sector, which already includes 850 nm versions with standard and Nanostack chips," says Jörg Heerlein, Head of Product

Osrsam says the compact Oslon is currently one of the most powerful versions for both visible and infrared illumination.

Measuring 3.85 x 3.85 x 2.29 mm, the infrared Oslon components are among the smallest IREDs with around 1 W optical power. I also has a beam angle of +/-45°.

"Users with experience in constructing visible lighting units can transfer their know-how and their processes directly to the infrared Oslon," adds Heerlein.

The market is also full of lenses that designers can use to shape the beam from the IRED to meet their specific requirements.

Record-breaking antireflection coating on solar cells

A new development could significantly improve the performance of solar cells, LEDs and photodetectors

A team of researchers from Rensselaer Polytechnic Institute (RPI), Magnolia Solar, Inc. and Pohang University of Science and Technology have demonstrated a novel antireflection (AR) coating.

It beats the widely employed double-layer AR (DLAR) coating on state-of-the-art triple-junction solar cells.

The scientists demonstrated that the solar cells investigated gain over 4 percent in efficiency when replacing the industry-standard DLAR with an optimised four-layer AR coating.

Considering that the solar spectrum is an intrinsically broadband spectrum, such broadband characteristics of the AR coating are undoubtedly beneficial for high power conversion efficiency.

What's more, omnidirectional AR characteristics have become important for the rapidly expanding terrestrial application of solar cells. This is because solar irradiance in terrestrial applications usually has a large range of incident angles for non-tracking solar cells.

Both broadband and omnidirectional AR characteristics are attainable by four-layer AR coatings, as demonstrated by the RPI-led team.

RPI says that the excellent broadband and omnidirectional AR characteristics of the four-layer AR coating are achieved through solving the problem of refractive index matching at multiple layer interfaces.

By using tailored and low-refractive index nanoporous silica layers, the team has greatly reduced the refractive index contrast at the semiconductor / AR coating / air interfaces.

Through a multilayer design methodology powered by a genetic algorithm optimisation, favourable antireflective properties over a specified wavelength range and angle-of-incidence range were found.

Two porous layers of the four-layer AR coating were fabricated by oblique-angle deposition of silica thereby resulting in films with refractive indices of 1.32 and 1.11. This is less than the refractive index of silica. The other two layers are dense and were fabricated by co-deposition of silica / titania using sputtering.

According to the photocurrent measurements performed by the team, the angle-of-incidence (0°- 80°) averaged photocurrent enhancement (over an uncoated triple-junction solar cell) of the four-layer AR coating amounts to 34.4 percent. The enhancement of a DLAR coating is only 25.3 percent.

In the future, the team members Jaehee Cho and E. Fred Schubert, will integrate this novel AR coating technology on surface-textured devices.

They will also investigate innovative fabrication methods for depositing low-refractive index AR coatings on curved surfaces, such as a hemispherical lens.

Further details of this research are described in the paper, "Enhanced Omnidirectional Photovoltaic Performance of Solar Cells Using Multiple-Discrete-Layer Tailored - and Low-Refractive Index Anti-Reflection Coatings," by X. Yan *et al* in *Advanced Functional Materials*, 23, 583 (2013).

PhotonStar to host major LED lighting event

The III-V nitride firm will be instrumental in this global sustainable design event

PhotonStar LED Group plc, a British designer and manufacturer of smart LED lighting solutions, will be the primary sponsor this year for EcoBuild's 300m2 lighting feature "Evolution of Light".

With a visitor count of 60,000, it is a key event on the global architectural calendar.

The "Evolution of Light" feature, housed inside three giant connected domes, will take visitors on a dynamic audio visual journey through light, providing visitors with essential information about our biological lighting needs, lighting energy challenges, and lighting in the future connected world.

The feature will demonstrate the latest ChromaWhite dynamic lighting solutions from PhotonStar controlled by Pharos lighting controllers.

Representatives from key industry bodies and other manufacturers will be supporting PhotonStar and contributing to the feature to provide the very best educational experience.

Visitors will be able to interact with the installations through their smartphones and can ask questions or talk to professionals with knowledge and experience of all aspects of lighting.

A comprehensive seminar programme will also run throughout the exhibition, educating visitors about the most pertinent issues affecting the lighting industry, and setting out many of the possibilities for the future. This educational programme will be delivered by PhotonStar and other experts in the lighting industry, who will provide trusted advice and responsible solutions.

Separating the core and shell of CdSe quantum dots

LEDs, solar cells and sensors could benefit from a new technology to study the interface between the core and shell of quantum dots composed of CdTe based materials

The J. William Fulbright College of Arts & Sciences at the University of Arkansas, has received a $650,000 award from the National Science Foundation.

Colin Heyes, an assistant professor in the department of chemistry and biochemistry in the institute was instrumental in receiving the award.

The Faculty Early Career Development Program award was given to further his investigation of the interfaces between the core and shell of colloidal quantum dots.

Colloidal quantum dots are microscopic semiconductor crystals

that are grown in solution.

Adding a shell to the core quantum dot provides a way to control the functionality of these crystals, which can be used to emit light for biomedical imaging, LEDs and spectroscopy or photocurrents for solar cells and chemical sensors.

The research will help scientists better understand the relationship between the structure of the quantum dot and its functionality.

“All of these modern applications rely on the same fundamental electronic processes within quantum dots,” Heyes says. “Our work will provide a better understanding of how to control these crystals to eventually build brighter, faster, longer-lasting and more efficient products.”

Heyes studies the interfacial chemistry between the core, shell and ligands of colloidal quantum dots. Ligands sit on the shell surface and “hold” the colloidal quantum dots in solution; they also provide a chemical connection to the “outside world” so that quantum dots can attach to biological cells, solar cells or act as chemical sensors.

There is a lack of fundamental understanding about the structural properties of the core-shell and shell-ligand interfaces.

Scientists can observe the boundary between the core and shell materials using powerful electron microscopes, but they do not yet understand how the nature of the structural mismatches between the two materials affects their optical and electrical properties.

These mismatches create “holes” or “trap states” that result in losing control of excitons, which are electrons that have been energetically excited. The inability to control excitons result in energy lost as heat rather than converted into useful energy, such as light or electrical currents.

The NSF grant will expand Heyes’ investigation of how the optical and electrical properties of quantum dots are related to the core-shell and shell-ligand interfaces at the single quantum dot level.

Understanding single quantum dots is necessary to advance miniaturised optoelectronics and single molecule fluorescence applications. His research team has produced preliminary data demonstrating that as these interfaces are systematically varied, the optical properties of single quantum dots can be tuned.

“We hypothesise that understanding the relationship between the structures of the core-shell or shell-ligand interfaces and the trap states will allow us to more precisely control these excitons that underlie the optical and electrical properties,” Heyes says.

Heyes’ team will focus specifically on understanding how the trap states are formed and how they contribute to the optical and electronic properties with the eventual goal of avoiding their formation altogether.

The grant will support Heyes’ research in this area for the next five years and will encourage and promote the participation of graduate, undergraduate and minority students. As part of the grant, a two-week, hands-on workshop will be held each summer on the U of A campus.

Students from the university and from institutions in Arkansas and Oklahoma will perform research experiments in Heyes’ lab to promote and foster their interest in chemistry and nanomaterial science for eventual careers in the fields of science, technology, engineering and maths.

Telecoms

Opel makes breakthrough with POET based n- and p-transistors

The result builds on the previous GaAs (gallium arsenide) based VCSEL milestone. It is a further verification that III-Vs can compete with silicon CMOS in WDM capable optoelectronic devices and functions, FETs and bipolar devices

Opel Technologies has achieved Milestone 4 in its Planar Optoelectronic Technology (POET), achieving radio frequency and microwave operation of both *n*-channel and *p*-channel transistors.

With this achievement, POET extends the capability of its unique monolithic platform to cover integration of a complete range of wavelength-division multiplexed (WDM) capable optoelectronic devices and functions.

This is in addition to complementary electronics based on *n*-channel and *p*-channel transistors as either field effect transistors (FETs) or bipolar devices.

For this milestone, 3inch POET wafers fabricated at BAE Systems (Nashua, NH) yielded submicron *n*-channel and micron-sized *p*-channel transistors operating at frequencies of 42 GHz and 3 GHz respectively. These operating frequencies are expected to be improved even further in the short term to up to 300-350 GHz range for the *n*-channel device.

Peter Copetti, Executive Director of Opel, notes, "Following the success of our Vertical Cavity Surface Emitting Laser milestone achieved recently, this result further verifies POET's electronic and optical monolithic compatibility, a key advantage of POET as a silicon CMOS replacement. Our on-chip optical generation and detection capability is unique in the semiconductor industry."

Progress on Taylor's work at the Opel lab had been delayed by damage sustained to key equipment during a multi-day power outage caused by Tropical Storm Sandy in late October 2012. However, the rebuild is expected to be completed next week, and the company expects the affected equipment will be recalibrated and operational again by the end of March 2013.

Copetti adds, "Given the calibre of the POET team, we are confident that the lost time will be made up so that it will not have a material impact on the milestone target dates."

At the successful conclusion of the recent private placement fundraising, approximately $1.3 million in new capital equipment was ordered to upgrade the R&D facility capabilities. The company has completed all necessary site infrastructure upgrades and is awaiting the arrival of the new equipment.

Opel expects the new equipment will be installed, calibrated, and commissioned by the end of June, 2013.

By enabling increased speed, density, reliability, power efficiency, and much lower bill-of-materials and assembly costs, POET provides a new technology direction and opportunity for the semiconductor industry.

POET will allow continued advances of semiconductor device performance and capabilities for many years, overcoming the current power and speed bottlenecks of silicon-based circuits,. Opel believes it will change the future development roadmaps of a broad range of semiconductor applications including mobile devices, computer servers, storage arrays, imaging equipment, networking equipment, transportation systems, and test and measurement instruments.

Infinera's 100Gb/s platform connects subsea Mediterranean network

The firm's InP (indium phosphide) based DTN-X platform will provide links between Italy, Greece, Turkey, Israel and Cyprus

MedNautilus has deployed the Infinera DTN-X platform across the Mediterranean to increase capacity on its subsea network and deliver up to 100Gb/s international connectivity services.

The Mediterranean operations of the Telecom Italia Sparkle Group, MedNautilus, operates the largest protected submarine cable network in the Mediterranean connecting Italy, Greece, Turkey, Israel and Cyprus, and serves the growing capacity needs of the region.

The Infinera DTN-X solution enables MedNautilus to upgrade its network quickly in response to customers' demands as the platform simplifies the management of long-haul terrestrial and submarine networks.

"MedNautilus now operates the first submarine cable network in Europe able to provide up to 100Gb/s international connectivity services with a solution that ensures top quality and efficiency standards," says Mario Pirro, Sparkle's EVP Technology.

"The market in the region is demanding faster and more advanced services and with the Infinera DTN-X solution for the provision of 100Gb/s services, we are able to provide the capacity we need in order to meet the fast growing requirements of our customers throughout the markets covered by our backbone."

"We are pleased that MedNautilus selected us to build out one of the regions fastest growing networks," comments Chris Champion, VP EMEA Sales for Infinera. "The simplicity of the DTN-X allows us to upgrade any backbone quickly, enabling our customers to deploy services faster while offering outstanding reliability."

Infinera says its DTN-X platform is the first to deliver up to 500 Gb/s long-haul super-channels based on Photonic Integrated Circuits (PICs) and the FlexCoherent Processor, scaling transport capacity without scaling operational complexity. With coherent long haul reach for submarine links, the Infinera

DTN-X platform seamlessly integrates terrestrial and subsea applications for network operators.

EPIC represents photonics industry at European Commission group

European Photonic Industry Consortium (EPIC) president Drew Nelson will act as technology representative for the Photonics KET High Level Group. The group aims to foster the industrial deployment of European KETs in order to keep pace with main international competitors, restore growth, create jobs and help address today's major societal challenges

A new group was launched on 27th February to assist the European Commission in the implementation of the strategy to boost the industrial production of KETs based products in Europe.

The global market in Key Enabling Technologies (KET) is forecast to grow from about €650 billion in 2008 to over one trillion euro in 2015. World leading industries in the fields of automotive, communication, aeronautics, defence, health and energy are all intensive users of KETs.

Representing the European photonics industry, EPIC President Drew Nelson, CEO and President of epitaxial wafer supplier IQE, has been appointed as a member of the new High Level Group as technology representative for the Photonics KET.

Group inauguration by European Commissioners Antonio Tajani from DG Enterprise, Máire Geoghegan-Quinn from DG Research, and Johannes Hahn from DG Regio. Drew Nelson, President of EPIC, represents the photonics industry

"I will be a vigorous supporter and promoter of KETs at regional, national, and European level and take every opportunity to help design and implement policies to help the competitiveness of Europe through the rapid deployment of KETs," states Nelson. "I expect from the KET high level group that it is able to persuade the European Commission through evidence based examples and debate to adapt EU policies throughout each Directorate General that fully support KETs implementation throughout Europe."

The expert group advises the European Commission on KETs related policy issues, follows up the implementation of the European strategy for KETs adopted by the European Commission on 26th June 2012, and promotes the development of KETs policies by the Member States.

Carlos Lee, Director General of EPIC, is a member of the working group on "Promotion and Implementation of KETs Policies at National and Regional Level." "KETs offer a fantastic opportunity for all of Europe, we must explore and embrace its potential. Especially in Photonics, there are many opportunities ahead of us," he says.

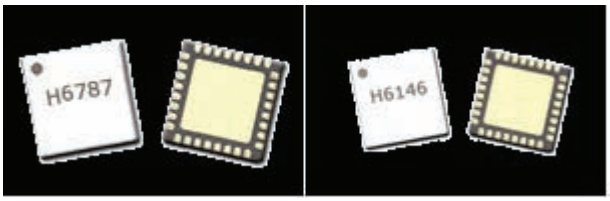
GaAs MMIC I/Q converters for microwave radio revealed by Hittite

The gallium arsenide devices are suited to 38 GHz & 42 GHz applications

Hittite Microwave Corporation has launched several new, highly integrated I/Q upconverter and downconverter products.

They cover the licensed 38 GHz and 42 GHz bands in microwave radios for cellular backhaul radio links.

The HMC6787ALC5A and the HMC6146BLC5A are GaAs MMIC I/Q variable gain upconverters which form a competitive and cost-effective microwave radio transmitter solution which has been designed to meet or exceed all of the performance criteria required for modern high capacity QAM microwave radios.



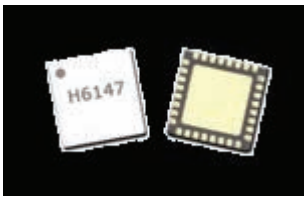
The HMC6787ALC5A operates from 37 to 40 GHz and provides a small signal conversion gain of 10 dB with 17 dBc of sideband rejection, and 13 dB of gain control.

The HMC6146BLC5A operates from 40 to 44 GHz and provides a small signal conversion gain of 12 dB with 25 dBc of sideband rejection, and 17 dB of gain control.

Both devices utilise a RF variable gain amplifier preceded by an I/Q mixer where the LO is driven by a x2 multiplier. IF1 and IF2 mixer inputs are provided and an external 90 degree hybrid is needed to select the required sideband.

The I/Q upconverters feature high output IP3 of +27 dBm, 2LO/RF isolation of 15 dB, and also meet the requirements of VSAT/Satcom transmitter terminals covering the EHF frequency band.

The HMC6147ALC5A is a GaAs MMIC I/Q downconverter which is ideal for replacing the front end receiver section of 38 GHz and 42 GHz microwave radio designs.



The HMC6147ALC5A provides a small signal conversion gain of 13 dB with 25 dBc of image rejection and utilises a low noise amplifier to drive the I/Q mixer where the LO is driven by a x2 multiplier. IF1 and IF2 mixer inputs are provided and an external 90 degree hybrid is needed to select the required sideband. The HMC6147ALC5A I/Q downconverter also features a very low noise figure of less than 3.5 dB and typical input IP3 of 2 dBm.

The I/Q mixer design topology used for the HMC6787ALC5A , HMC6146BLC5A and the HMC6147ALC5A is provide a big advantage because it reduces the need for filtering of the unwanted sidebands.

All three devices are claimed to provide a much smaller alternative to hybrid-style single sideband converter assemblies, and they eliminate the need for wire bonding by allowing the use of surface mount manufacturing techniques.

The HMC6787ALC5A , HMC6146BLC5A and the HMC6147ALC5A are housed in compact, 5 x 5 mm RoHS compliant SMT packages.

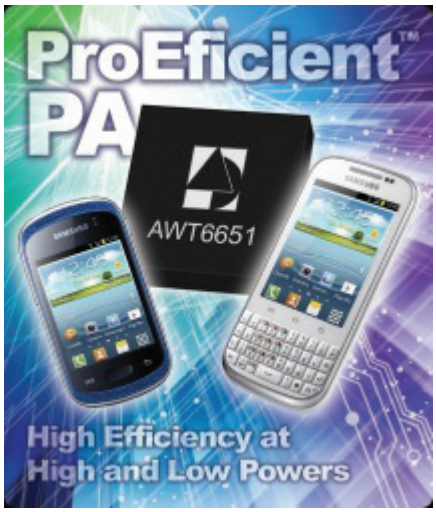
Samples and evaluation PC boards for all SMT packaged products are available from stock and can be ordered via the company's e-commerce site or via direct purchase order.

Anadigics InGaP PAs help extend Samsung battery-life

The firm is shipping production volumes of its AWT6651 ProEficient indium gallium phosphide power amplifier to Samsung Electronics for the Galaxy Music Duos and Chat

Samsung's Galaxy Music Duos S6012 features a 3-inch touch screen, 850 MHz processor, and 4 GB of storage. The Galaxy Chat B5330 offers a QWERTY keyboard, 3-inch touch screen, and 850 MHz processor. Both phones include Android 4.0 Ice Cream Sandwich operating system.

"Anadigics' ProEficient and ProEficient-Plus power amplifiers provide the industry's best combination of efficiency, current consumption, and linearity to help extend battery-life and maintain stable, high throughput 4G connectivity," says Michael Canonico, senior vice president of Worldwide Sales at Anadigics.



"The selection of the AWT6651 for the Galaxy Music Duos and Chat not only exemplifies the tremendous real-world performance advantages offered by our ProEficient solutions, but also the strength of the relationship that we have forged with Samsung Electronics. We look forward to continued close collaboration with Samsung in the design of next-generation mobile devices that further the user experience," continues Canonico.

Anadigics' ProEficient PAs use the company's exclusive InGaP-Plus technology to achieve outstanding efficiency at high and low power modes to extend 3G and 4G battery-life without the use of a DC-DC converter.

These PAs are also optimised for use with average power tracking (APT) to further increase efficiency and reduce current consumption at medium and low operating powers.

Apart from outstanding efficiency, Anadigics says its ProEficient power amplifiers deliver exceptional linearity to ensure a stable connection for clear voice and high-speed data.

With excellent efficiency in both low and high power modes, the Proeficient PAs have a very low quiescent current to extend battery-life. They come in a compact 3 mm x 3 mm package with internal voltage regulation and integrated DC blocks on the RF ports to reduce PCB space requirements.

Superb linearity helps to maintain stable, high-throughput 3G / 4G connections. Finally, RF matching is optimised for output power, efficiency, and linearity in a 50-Ohm system.

RFMD reveals GaAs entry solutions for 2G & 3G smartphones

The firm's newest products include GaAs (gallium arsenide) - and silicon-based power amplifiers and transmit modules

RF Micro Devices, Inc. has expanded its entry solutions product portfolio to include multiple new solutions for 2G and

3G entry smartphones.

The new RF solutions are designed to solve the increasingly complex RF requirements of entry-level 2G and 3G smartphones related to cost, band count, and thermal dissipation.

RFMD believes it is uniquely positioned with a complete portfolio of GaAs and silicon-based RF solutions for the entry smartphone segment.

The company's newest entry solutions include GaAs- and silicon-based power amplifiers and transmit modules for 2G and 3G entry smartphones, enabling RFMD to deliver complete RF reference designs, from the transceiver to the antenna.

RFMD intends to expand its entry solution product portfolio in calendar 2013 to include fully integrated silicon-based multimode power amplifiers and multimode transmit modules, bringing unprecedented levels of integration to the entry and mid-tier smartphone segments.

Industry analysts estimate quarterly shipments of entry smartphones will reach record levels, as new smartphone models proliferate across all tiers and as entry smartphone prices drop below $100.

Leading manufacturers of entry smartphones are leveraging RFMD's entry solutions product portfolio to achieve the optimum balance of cost, performance and flexibility while satisfying critical requirements for quality and reliability in high-volume manufacturing.

RFMD is enabling the rapid growth in the entry smartphone segment by providing a complete suite of GaAs- and silicon-based 2G and 3G solutions optimised for the cost, size and performance requirements of entry devices. RFMD's entry solutions product portfolio is compatible with all leading baseband chipset providers, including Qualcomm, Intel, Broadcom, Mediatek, Spreadtrum and others.

Firecomms meets escalating demand for fibre optics in China

With a new appointment and distribution agreement, the company is extending its presence in China

Firecomms, a provider of fibre optic solutions and optical transceivers, has appointed a new Director of Sales and Marketing for its new sales office in Shanghai.

The firm has also signed a distribution agreement with DongTing Technologies Shenzhen Co. to meet the increased demand for its products in China.

"Continued investment in public infrastructure and production automation has led to significant growth in China's renewable energy, transportation and industrial automation markets; applications that require a broad array of rugged and reliable fibre optic solutions," says Hugh Hennessy, Firecomms' Vice President and Sales and Marketing.

"This trend, together with our new LC terminated solutions and RedLinkÂ® range of Avago Versatile Link compatible components, requires us to significantly expand our footprint in China to meet the growing demand for our products."

Hennessy adds, "Not only are we pleased to announce the opening of a new regional sales office in Shanghai, we're very excited to announce the appointment of Weikang Jiang to the newly created role of Director of Sales and Marketing for the Greater China region. Formerly at Avago Technologies' Industrial Fibre Product division, Jiang brings a wealth of experience to the organisation and is highly respected in the industrial fibre marketplace."

Jiang will drive the expansion of Firecomms' presence in the wider Chinese marketplace and, from Firecomms' new regional sales office in Shanghai, will serve customers in Greater China through direct sales and regional distributors.

DongTing Technologies, the company's newest distributor, has a proven track record in serving industrial customers, a key industry for Firecomms fibre optic transceivers. From its headquarters in Shenzhen, DongTing Technologies serves customers throughout China.

"Offering a perfectly aligned synergy with our product portfolio and excellent coverage throughout Mainland China, DongTing Technologies is an ideal partner in the fast-growing industrial fibre market," says Jiang. "DongTing Technologies' extensive experience working with customers in the power, automation and transportation industries is a big advantage as these are key markets for Firecomms fibre optical transceivers."

"DongTing is pleased to leverage our abundant resources in different territories to bring Firecomms optical solutions to our strategic accounts and new customers in our key industrial markets," says Fred CAI, General Manager of DongTing Technologies. "The broad usage of Firecomms products also will enable us to explore new and growing market segments throughout Mainland China."

Firecomms' line of fibre optical transceivers includes RedLink, a series of DC-capable transmitters and receivers for industrial command and control applications that are drop-in compatible with the Versatile Link range of products, LC connectors, and OptoLock plugless fibre optic transceivers.

In addition to its industrial fibre optic transceivers, Firecomms offers an accompanying line of cable assembly solutions to enable quick field installations without extensive training.

Skyworks wins SkyOne contracts

The highly integrated front-end solution for advanced mobile applications incorporates Skyworks' GaAs, SOI, SiGe and CMOS processes

Skyworks Solutions has announced that several leading OEMs and smartphone providers are leveraging the company's highly customisable, fully optimised SkyOne front-end solution.

The SkyOne platform, which integrates all RF and analogue content between the transceiver and antenna, reduces complexity, size and time-to-market for customers with demanding architectures for advanced mobile applications.

Skyworks says that SkyOne is the world's first semiconductor device to condense multiband power amplifiers and high throw switches along with all associated filtering, duplexing and control functionality into a single, ultra-compact package--all in less than half the area of the industry's most advanced approach.

The platform utilises Skyworks' full technology portfolio and advanced multichip module capabilities including proprietary shielding and packaging.

At the same time, the solution is claimed to provide the world's best linearity and power added efficiency for smart RF integration. As a result, SkyOne offers smartphone, tablet and ultrabook OEMs improved efficiency, drastically reduced RF paths, ease of implementation and a scalable platform as bands increasingly proliferate worldwide.

"Consumer demand for increasingly thinner mobile platforms with increased talk and data access time is creating unprecedented analogue and RF complexity as well as harmonic coexistence issues. Skyworks is delighted to solve this system challenge with our breakthrough SkyOne platform," says Liam K. Griffin, executive vice president and corporate general manager at Skyworks.

"SkyOne is a proven architecture that optimises performance beyond what is possible with existing approaches and incorporates all 2G, 3G and 4G/LTE protocols enabling seamless global roaming and extended battery life. Incorporating Skyworks' arsenal of tested and patented technologies and leveraging GaAs, SOI, SiGe and CMOS processes, SkyOne can be modulated and customised depending upon the system requirements and roadmaps of each OEM," adds Griffin.

SkyOne solutions incorporate the SKY77619, Skyworks' high efficiency, multimode power amplifier module already in volume production with multiple customers. What's more, the highly flexible solution contains a common footprint that can be implemented by all of the world's carriers and in various regions. Skyworks will be sampling third generation solutions next month and is already developing fifth generation architectures with multiple OEMs.

Sampling now, these second generation, hybrid, multimode, multiband, patented front-end modules with low insertion loss support 2.5/3G/4G handsets and operate efficiently in quad-band GSM, GPRS, EDGE, WCDMA, HSPA and LTE modes.

The ultra compact, 7 x 9.8 x 1.05 millimetre packaged FEMs consist of a GSM800/EGSM900 power amplifier block (PA), a DCS1800/PCS1900 PA block, separate WCDMA blocks operating in the low and high bands, logic control block for multiple power control levels as well as band-enable functions in cellular and universal mobile telecommunications system.

Radio frequency I/O ports are internally matched to minimise external components while extremely low leakage current maximizes handset standby time. The InGaP/GaAs die and passive components are mounted on a multi-layer laminate substrate and the assembly encapsulated in plastic overmold.

SKY78010 (Bands I, II, IV, V, VIII)

SKY78011 (Bands I, II, III, V, VIII)

Anadigics adds another InGaP PA to its small-cell family

The new indium gallium phosphide based power amplifier is suited to WCDMA / LTE applications for picocells, enterprise-class femtocells, and CPE

Anadigics, a developer of radio frequency (RF) solutions, has introduced the AWB7224 small-cell power amplifier (PA).

The firm claims its AWB7224 is optimised to deliver an industry-leading combination of efficiency, linearity, output power and thermal characteristics for WCDMA, HSPA, and LTE small-cell base stations operating in the 728 to 768 MHz frequency band.

Manufacturers are able to leverage this performance to develop infrastructure solutions that consume less power, and provide higher throughput and greater coverage.

"Anadigics continues to expand its family of small-cell power amplifiers to target the 3G and 4G frequency bands most used in dense population areas," says Glenn Eswein , director of product marketing for infrastructure products at Anadigics. "The rapid increase in wireless data consumption, especially in urban and campus settings, places tremendous pressure on existing wireless infrastructure. Our solutions enable the design of high throughput, reliable, and compact small-cell base stations that offer service providers an economical and

pragmatic path to expand broadband network coverage."

Anadigics' small-cell wireless infrastructure power amplifiers leverage the Company's patented InGaP-Plus technology and advanced design architectures to deliver world-class performance and integration.

The AWB7224 offers 13 percent efficiency to minimise power requirements and provide flexibility in selecting network power systems. With exceptional linearity of -47 dBc ACPR at +27 dBm output power, and 29 dB of RF gain, the AWB7224 enables high throughput data rates with a wide coverage area. The complete family of small-cell power amplifiers is available in a compact, low profile 7 mm x 7 mm x 1.3 mm surface mount package with integrated RF matching to reduce PCB space requirements.

½-Watt Linear Small-Cell Infrastructure Amplifiers:

Product	Frequency Band	Output Power	Efficiency	Gain
AWB7125	860 to 894 MHz	+24.5 dBm	14.5%	30 dB
AWB7129	925 to 960 MHz	+24.5 dBm	15%	30 dB
AWB7123	1930 to 1990 MHz	+24.5 dBm	17%	31 dB
AWB7127	2110 to 2170 MHz	+24.5 dBm	18%	30 dB
AWB7128	2545 to 2690 MHz	+24.5 dBm	16%	28 dB

¼-Watt Linear Small-Cell Infrastructure Amplifiers:

Product	Frequency Band	Output Power	Efficiency	Gain
AWB7224	728 to 768 MHz	+27 dBm	13%	29 dB
AWB7225	860 to 894 MHz	+27 dBm	13%	29 dB
AWB7223	1930 to 1995 MHz	+27 dBm	14%	29 dB
AWB7227	2110 to 2170 MHz	+27 dBm	14%	29 dB
AWB7228	2545 to 2690 MHz	+27 dBm	14%	27 dB

Engineering samples of the AWB7224 are available now for qualified programs.

Avantes advances its Fibre Optic Multiplexers

The firm has revealed a new range of broadband fibres, which combine the advantages of high OH solarisation resistant fibre for the UV with low OH fibre for the NIR

Manufacturer of fibre optic spectroscopy instruments and systems, Avantes, has released a new generation of Fibre Optic Multiplexers (FOMs).

They are faster, more reliable and quieter than ever before. The FOM easily integrates to Avantes' advanced spectroscopy software AvaSoft.

Avantes FOM

Fibre Optic Multiplexers enable single or multiple light sources and spectrometers to make multi-point serial measurements. This new generation now features USB 2.0, complete integration into AvaSoft and full Avantes DLL support.

All next generation Fibre Optic Multiplexers are supplied with the new broadband fibres exclusive to Avantes. Broadband fibres combine the advantages of high OH solarisation resistant fibre for the UV with low OH fibre for the NIR.

Broadband fibre is a huge leap forward for fibre optic spectroscopy applications which have historically been forced to choose between UV/VIS and NIR fibre or combine two types of fibre into an assembly making it more costly and complex.

Benno Oderkerk, founder and CEO of Avantes says, "Our Fibre Optic Multiplexers see a wide variety of usage in our customer base. The great advantage is the flexibility in which measurements can be done. Furthermore, the extensive programming possibilities mean that even in setups with different integration times, the Avantes FOM will allow a suitable setting."

The FOM is available in three different versions: 1 x 16, 2 x 8 and 4 x 4. As standard, they are supplied with 400µm fibre optic cables. Any other diameter is available on request.

InP innovator Albis Opto is up and coming

Following a management buyout, Albis Optoelectronics is resurfacing as one of the renowned industry brands for high performance indium phosphide photodetector products

The change of company name to Albis Optoelectronics, previously used by the entity from 2003 to 2008, designates the final step in the separation from Enablence Technologies Inc.

The management buyout was initiated by local management, coordinated by industry veteran Joerg Wieland and supported by a strong team of European private investors.

During the past 5 years, demand for our photodiode products has grown steadily with an average growth rate of 35 percent year over year. As we see the enormous potential of our

technology, we are obviously very excited to be masters again of our own business", says Vincent Grundlehner, CEO.

The management buyout allows for the execution of a number of growth initiatives such as an expanded product portfolio, a higher level of production automation as well as a strengthening of customer support functions.

The investors backing the company, bring in a broad industry network and share the long-term focus to expand the global reach of the company. "As seasoned technology entrepreneurs, we understand the value of a strong management team combined with a solid balance sheet", says Falk Strascheg, one of the most experienced and successful private equity investors in Germany. "Considering the operational success of the company throughout the past ten years, we gladly took a substantial stake in Albis Optoelectronics."

Albis Optoelectronics is a designer, developer and manufacturer of high-speed PIN and APD photodiodes for fibre optic datacom and telecom applications. The firm's product portfolio supports 10G, 40G and 100G communication links as well as analogue microwave applications. The Zurich based fabrication facilities offer full in-house production from front-end to back-end.

The focal investment area of Falk Strascheg is private equity and venture capital. As an entrepreneurially-minded, active investor, Falk Strascheg invests in young, innovative technology businesses with strong growth potential. His investments in currently more than 25 companies cover, among others, the electronics, laser and semiconductor sectors, information and web technology as well as new media and the cleantech field.

VIS & Illinois Uni's 850nm GaAs based VCSEL travels 25 Gbit/s over 1km

VI Systems has worked with the American university to develop a VCSEL which is suited for use in the next generation of datacom and computercom standards

Researchers have demonstrated a novel Single Mode Photonic Crystal VCSEL, suitable for error-free 25 Gbit/s data transmission over 1km of multi mode fibre at very low received optical power. .

VI Systems GmbH and the Department of Electrical and Computer Engineering at the University of Illinois, USA demonstrated, jointly, at the Photonics West Conference, a novel Single Mode Photonic Crystal VCSEL (vertical cavity surface emitting laser).

The photonic crystal (PC) VCSEL is manufactured from a proprietary VI System's wafer which was processed at the University of Illinois at Urbana-Champaign with a defined photolithographic pattern of holes in the top mirror. This process results in a single mode emission of the VCSEL at 850nm wavelength.

The PC VCSEL operating at low current density of 5.4kA / cm2 enables -3dB bandwidth of 18GHz. Error free optical data transmission at 25 Gbit/s over 1-km OM4 multimode fibre has been realised at 1km distances at very low received power of only 70µW at the Department of Solid State Physics at the Technical University of Berlin, Germany, with a high speed photoreceiver module from VI Systems.

Single-mode VCSELs extend the reach over multimode fibre by eliminating the impact of chromatic dispersion of glass at 850nm wavelength, which is particularly important for ultrahigh transmission bit rates within the next generation of datacom and computercom standards.

Target applications are data transmission inside of large data centres, supercomputer clusters and racks of telecom equipment at ultrahigh bit data rates.

1km transmission at very low received power allows cost and energy-efficient 850nm VCSEL-based links to extend to longer distances thus saving space, cost and energy consumption in all major applications.

Infinera InP PICs demonstrate 500 Gb/s transmission in Russia

The firm used its indium phospide based DTN-X platform and worked with FSUE ZNIIS to perform the super-channel trial

Infinera, a provider of Digital Optical Networks, has completed its first ultra-long-haul lab trial in Russia.

To perform the trial, the firm collaborated with FSUE ZNIIS, Russia's Central Science and Research Telecommunications Institute and the integrator of the latest technological advances in telecommunications in Russia.

Infinera says this trial demonstrates the firm's ability to supply scalable, efficient and high capacity optical networking solutions to meet the needs of service providers in Russia.

The DTN-X trial with FSUE ZNIIS took place at ZNIIS' Techno Park in Moscow, successfully demonstrating 8 Terabits per second (Tb/s) of DWDM capacity across 1,175 kilometres. The network configuration provided flexible service add/drop and non-blocking OTN-switching capabilities and enabled a variety of different types of traffic demands including high speed 100 Gigabit Ethernet services (Gb/E), 40 Gb/E as well as widely used 10 Gb/E and 10 Gb/s SDH services.

The trial was based on Infinera's DTN-X platform, using 500 Gb/s super-channels and integrated non-blocking OTN-switching. The all-in-one solution helps service providers steadily grow their network capacity up to 8 Tb/s.

"We are impressed by Infinera and the DTN-X solution, especially by its ability to quickly deploy and launch a DWDM line to demonstrate long-haul transmission," says. Svetlana Yarlykova, Scientific Director at FSUE ZNIIS. "The equipment

was easy to operate. We are confident that Russian service providers will see the value in Infinera's next generation solution, offering an architecture that's simple and reliable due to photonic integration."

"We are pleased to complete this trial with ZNIIS," adds Chris Champion, vice president EMEA sales. "The success of this demonstration is a milestone for Infinera. We demonstrated that our next generation DWDM optical networking solution, the Infinera DTN-X, is certified and available to the Russian market."

Infinera claims the DTN-X is the first to deliver 500 Gb/s long-haul super-channels based on Photonic Integrated Circuits (PICs) and the FlexCoherent Processor, scaling transport capacity without scaling operational complexity.

Integra introduces 100MHz - 1GHz GaN HEMT

The gallium nitride module is suited to Broadband applications

Integra Technologies has launched the IGN0110UM100, a dual-lead packaged GaN high electron mobility transistor (HEMT).

This device is designed for Broadband applications operating over the 100MHz – 1GHz instantaneous frequency band.

Under CW conditions it supplies a minimum of 100 watts of output power with 12dB gain. Specified operation is with Class AB bias. It is also operable under a wide range of pulse widths and duty factors. It operates with spectral purity into all phases of 3:1 output load VSWR.

All devices are 100 percent screened for large signal RF parameters in a fixed tuned broadband matching circuit / test fixture. Integra says the use of external tuners is not permitted during screening.

M/A-COM Tech launches GaAs LNA for V-sat, radar and microwave

The gallium arsenide amplifier is claimed to offer excellent performance for easy and efficient implementation in X-band applications

M/A-COM Technology Solutions has introduced an X-Band extension to its Low Noise Amplifier (LNA) family.

The MAAL-010528 is designed for customers who need a quick LNA solution for V-sat, radar and microwave applications.

MAAL-010528

This LNA delivers higher gain and linearity performance over the 8.0 to 12.0 GHz frequency band than many competing parts, providing customers with system advantages for their LNA requirements.

Packaged in a compact 3 x 3mm PQFN surface mount and having a single, positive bias supply, the device allows customers a simple and elegant LNA solution.

The MAAL-010528 GaAs MMIC LNA provides a nominal gain of 20dB with excellent gain flatness, high OIP3 linearity of 26 dBm, and a mid-band noise figure supply of 1.6dB.

The part features a self-bias architecture which requires the customer to apply only a single positive supply. In addition, the device is internally matched to 50 Ω input/output. M/A-COM Tech says this makes the MAAL-010528 well suited for multiple radar and communication applications.

"The MAAL-010528 is ideal for customers looking for low noise figure and high linearity for their X-Band Solutions", says Paul Beasly, Product Manager. "The excellent performance and very small, fully matched PQFN package make this LNA a simple and elegant solution for multiple applications."

Jenoptik experiences surge in demand for GaP devices

The gallium phosphide based microoptic products are primarily used in the medical industry

Microlenses, microlens arrays, and diffractive optics are used for homogenisation of laser beams for laser eye surgery and

aesthetic skin treatment.

They create multi-spot arrays for ophthalmic diagnostics, for collimating and shaping laser beams for surgical applications, and for imaging applications such as optical coherence tomography and scanning confocal microscopy.

Recent advances in near infrared (NIR) and mid-wavelength infrared (MWIR) quantum cascade and fibre lasers in conjunction with new diagnostic and treatment approaches are placing new demands on microoptics for these applications.

These needs include a broad NIR - MWIR transmission, high numerical aperture (NA), and small form factor for minimally invasive applications.

Jenoptik´s Grayscale lithographically fabricated GaP microlenses and microlens arrays meet these demands with:

1) A broad wavelength range from 600 nm beyond 5 µm

2) A high refractive index of 3.1 allowing a single element lens or lens array with NA's up to 0.85.

3) Complex surface shapes providing for beam collimation and circularization of high divergence diode lasers with a single element.

Scanning confocal microscopy and minimally invasive optical coherence tomography are two examples where a single GaP microlens or microlens array can be used to extend the wavelength range over traditional GRIN and silicon lenses.

Jenoptik's says it fabricates complex aspheric elements with high numerical aperture also provide for better imaging performance when compared with GRIN lens based systems.

What's more, standard manufacturing processes are available for a range of different optical materials such as SiO2, GaAs, CaF2, Al2O3, ZnS, ZnSe, Ge, and chalcogenide glass.

RF Electronics

Cree and Acal BFi to increase GaN RF sales in Europe

The LED and gallium nitride RF specialist and design and engineering innovator are uniting to accelerate the adoption of Cree's RF technology

Cree and Acal BFi have signed a franchise agreement to increase the sale of Cree RF components in Italy, Spain, Germany, Poland, Czech Republic, The Netherlands, Norway, Sweden, Hungary and Luxembourg.

Acal BFi was founded through its design expertise and engineering knowledge. The firm works closely with its suppliers as a technical partner to help solve its' customers design challenges.

"GaN is increasingly recognised as a key technology in bringing about improved efficiency and reducing overall systems costs. Cree and Acal BFi have joined forces to accelerate bringing this advantage to a wider market" says Tom Dekker, World Sales and Marketing Director for RF Technology at Cree.

"Acal BFi has an excellent reputation with a strong technical team able to support this specialised technology. This agreement further strengthens a sales network that has built a reputation for excellence in customer support. We look forward to accelerating adoption of Cree GaN HEMT as the RF technology of choice throughout Europe," adds Dekker.

"A partnership with the leading innovator in the key area of GaN RF allows Acal BFi to increase its offer of advanced solutions at the very forefront of technology. Acal BFi's experienced engineering team across Europe provides our customers with the design support and product knowledge needed to take advantage of this innovative technology," concludes Lee Austin, Business Development Director, Acal BFi Communications Division.

Lasers

IPG Photonics strengthens management team

Three new appointments have been made to enhance IPG's strategic marketing, acquisition and global sales initiatives of its laser products

IPG Photonics Corporation has appointed three senior management appointments focused on strengthening the company's worldwide sales and marketing efforts.

Trevor Ness has been promoted to Senior Vice President Worldwide Sales and Marketing and will continue to supervise the Asian operations. Also, David Gray was appointed Vice President - Strategic Development & Systems Solutions; and Yuri Erokhin was appointed Vice President - Strategic Marketing.

"We are strengthening our management team with three experienced professionals who have demonstrated their expertise and success in helping to expand business opportunities and grow sales," says Valentin Gapontsev, IPG Photonics' Chief Executive Officer.

"Trevor Ness has been successful at IPG in establishing strong relationships with OEMs in Asia, as well as improving service and the effectiveness of the sales force there. David Gray has a proven track record of driving rapid growth through organic product development, strategic acquisitions and operational execution. Yuri Erokhin has a strong scientific background that he has applied to the development of sophisticated marketing strategies to identify and secure new business opportunities. We look forward to their combined contributions as we enhance our product portfolio, enter new applications and geographies and generate profitable long-term growth."

Trevor Ness joined IPG in January 2011 as Vice President - Asian Operations, and successfully managed double digit growth in China, Japan and Korea. Prior to 2011, he served as Director of GSI Precision Technologies China at GSI Group, where he was responsible for all business activity in China, including manufacturing, sales, service and market development.

From 1997 until 2005, Ness served in various senior management sales and operations roles in the UK and Asia with GSIL Asia Pacific, Westwind Japan, and Westwind Air Bearings Ltd. Ness earned a BSc in Geology from Imperial College London, an HNC in Production Engineering from Bournemouth University, and an MBA (Technology Management) from The Open University.

David Gray joins IPG from GT Advanced Technologies, where he served in multiple roles, most recently as its Chief Strategy & New Business Officer. Prior to that, he served as a senior M&A advisor to the photonics and electronics markets with Alliant Partners and Broadview.

Early in his career, Gray also co-founded Aspect International, Inc., and served as a senior engineer with Raychem in its display products group. David earned a Ph.D. in Chemical Engineering from Massachusetts Institute of Technology, an MBA from Stanford University Graduate School of Business, and a B.S. in Chemical Engineering from Carnegie-Mellon University.

Yuri Erokhin joins IPG from Applied Materials/Varian Semiconductor Equipment where he has worked since 2003 and served as Senior Director, Strategic Marketing since 2006. Prior to working at Applied Materials, he was Vice President of Wafer Technology at IBIS Technology Corp. From 1995 to 2000, Erokhin was at Axcelis Technologies Corp., where he was Director of Process Technology.

Before that, Erokhin worked as a research scientist at various institutions since 1980. Erokhin earned an M.S. with Honors in Quantum Electronics (Lasers) from the Moscow Physical-Technical Institute and a Ph.D. in Microelectronics Technology from the Russian Academy of Sciences, Moscow.

IPG Photonics Corporation is a developer and manufacturer of high-power fibre lasers and amplifiers. Founded in 1990, IPG pioneered the development and commercialisation of optical fibre-based lasers for use in diverse applications, primarily materials processing.

Oclaro contracts 4 and 8 beam red laser diodes

The breakthrough improves printing quality in III-V laser diodes

Oclaro has announced significant advancements in its red laser diodes.

The company has reduced the size of its 4 beam red laser diodes by 75 percent (from TO9.0mm to TO5.6mm) and 8 beam red laser diodes by 80 percent (from TO16.0 to TO9.0mm.)

These significant reductions will enable customers designing laser beam printers (LBPs) and multi-function printers (MFPs) to design smaller and more compact printers or to utilise the extra space for adding more features and functionality.

What's more, Oclaro has significantly improved the printing quality of its red laser diodes by modifying their structure to produce what it claims is the smallest and most precise laser beam available from any red laser diode in the industry.

To achieve the size reductions and improve the printing quality of its red laser diodes, Oclaro leveraged its 30 years of laser diode expertise. To date, Oclaro says no other company has achieved these size reductions or has been able to deliver this level of laser beam precision (known as low droop and small deviation).

As a result of both of these innovations, Oclaro customers will now be able to offer improved printing quality while at the same time providing more lightweight and compact designs to its customers.

"Customers designing LBP and MFP applications are under increasing pressure to improve printing quality and deliver light-weight products to customers," says Tadayuki Kanno, President, Oclaro Japan, Inc & GM, Modules & Devices Business Unit.

"Once again, Oclaro has been able to uniquely meet customers' needs by leveraging our fundamental expertise and understanding of the red laser diode design to produce the features, quality and performance that customers need to achieve a competitive advantage."

The Oclaro red beam laser diodes are ideally suited for customers designing MFPs and LPBs. The narrow beam pitch enables the customer to simplify the optics design of their printing system.

High thermal radiation design for high temperature operation, allows customers to deliver high printing quality. High accuracy mounting for junction down die bonding for low droop. This also improves the printing quality of the customer's printing system.

Finally, tuning LD characteristics by new structures meet each customer's requirement to realise their printing system technology.

Solar

A novel spectroscopy to enhance optical devices

A new technique developed by university researchers could lead to better LEDs, solar cells, and other devices that use layered nanomaterials

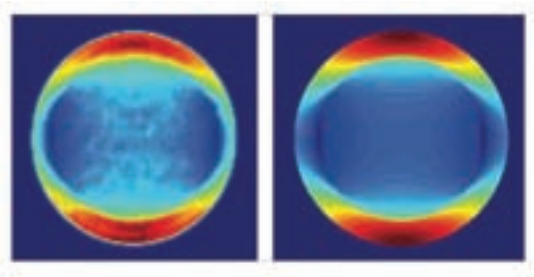
Understanding the source and orientation of light in light-emitting thin films, is now possible with energy-momentum spectroscopy.

This could lead to improvements in optical device performance.

A multi-university research team has used this new spectroscopic method to gain a key insight into how light is emitted from layered nanomaterials and other thin films.

Energy-momentum spectroscopy, enables researchers to look at the light emerging from a thin film and determine whether it is coming from emitters oriented along the plane of the film or from emitters oriented perpendicular to the film.

Knowing the orientations of emitters could help engineers make better use of thin-film materials in optical devices like LEDs or solar cells.



The orientation of light emission - The angular distribution of light emission from monolayer MoS2 , left, closely matches the theoretical calculations for in-plane oriented emitters, right, indicating that light emission from MoS2 originates from in-plane oriented emitters. (Credit: Zia lab/Brown University)

The research, published online on March 3rd in *Nature Nanotechnology*, was the collaborative effort of scientists from Brown University, Case Western Reserve University, Columbia University, and the University of California - Santa Barbara.

The new technique takes advantage of a fundamental property of thin films: interference.

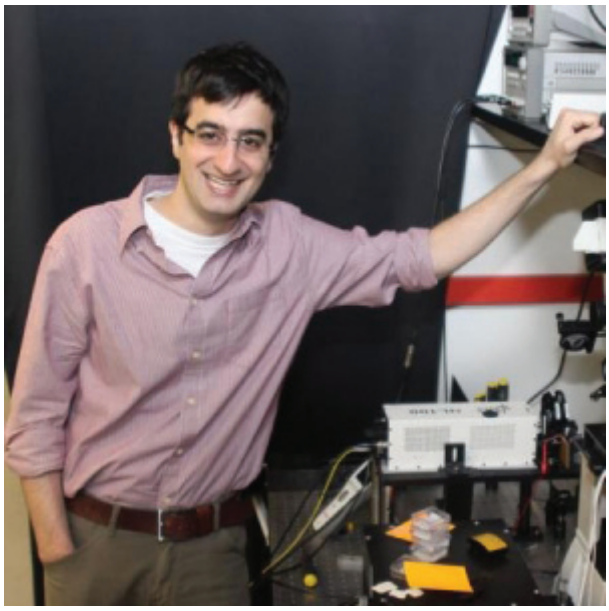
Interference effects can be seen in the rainbow colours visible on the surface of soap bubbles or oil slicks. Scientists can analyse how light constructively and destructively interferes at different angles to draw conclusions about the film itself - how thick it is, for example. This new technique takes that kind of analysis one step further for light-emitting thin films.

"The key difference in our technique is we're looking at the energy as well as the angle and polarisation at which light is emitted," says Rashid Zia, assistant professor of engineering at Brown University and one of the study's lead authors. "We can relate these different angles to distinct orientations of emitters in the film. At some angles and polarisations, we see only the light emission from in-plane emitters, while at other angles and polarisations we see only light originating from out-of-plane emitters."

The researchers demonstrated their technique on two important thin-film materials, molybdenum disulphide (MoS2) and PTCDA. Each represents a class of materials that shows promise for optical applications. MoS2 is a two-dimensional material similar to graphene, and PTCDA is an organic semiconductor. The research showed that light emission from MoS2 occurs only from in-plane emitters. In PTCDA, light comes from two distinct species of emitters, one in-plane and one out-of-plane.

Rashid Zia continues, "If you were making an LED using these layered materials and you knew that the electronic excitations were happening across an interface, then there's a specific way you want to design the structure to get all of that light out and increase its overall efficiency."

The same concept could apply to light-absorbing devices like solar cells. By understanding how the electronic excitations happen in the material, it could be possible to structure it in a way that converts more incoming light to electricity.



Rashid Zia

Zia also points out that once the orientation of the emitters is known, it may be possible to design structured devices that maximise those directional properties.

In most applications, thin-film materials are layered on top of each other. The orientations of emitters in each layer indicate whether electronic excitations are happening within each layer or across layers, and that has implications for how such a device should be configured.

"One of the exciting things about this research is how it brought together people with different expertise," Zia notes. "Our group's expertise at Brown is in developing new forms of spectroscopy and studying the electronic origin of light emission. The Kymissis group at Columbia has a great deal of expertise in organic semiconductors, and the Shan group at Case Western has a great deal of expertise in layered nanomaterials. Jon Schuller, the study's first author, did a great job in bringing all this expertise together. Jon was a visiting scientist here at Brown, a postdoctoral fellow in the Energy Frontier Research Centre at Columbia, and is now a professor at UCSB."

This work is further detailed in the paper, " Orientation of luminescent excitons in layered nanomaterials," by Jon A. Schuller *et al* in *Nature Nanotechnology* (2013), published online on 3rd March 2013. DOI: 10.1038/nnano.2013.20

Funding for the work was provided by the Air Force Office of Scientific Research, the Department of Energy, the National Science Foundation, and the Nanoelectronic Research Initiative of the Semiconductor Research Corporation.

SEMI calls for constructive action on solar trade dispute

A new white paper written by SEMI analysts contains recommendations to move beyond trade litigation and encourage an accelerated path towards dispute resolution

SEMI has released the "Global Trade War and Peace: Unified Approaches to a Global Solar Energy Solution," report.

The report is authored by SEMI and the SEMI PV Public Policy Sub-committee, which is comprised of representatives from leading solar companies with global manufacturing operations.

The report recommends three concurrent ways forward. The first is to support and promote existing efforts to unify national/ regional renewable and solar trade associations and strengthen the voice of the global industry. Industry leadership will be essential if the solar market is to advance beyond the current protectionist impasse.

Secondly, to encourage the governments of the United States, China, Europe, India, and elsewhere to initiate a dialogue that transcends short-term enforcement actions and supports clean technologies. SEMI can play a critical role in this advocacy effort, given its experience from the semiconductor disputes of the 1990s.

Last but not least, SEMI will develop an outline proposal for creating an entity similar to the World Semiconductor Council (WSC), as well as a draft implementation plan.

William Morin, senior director of government affairs at Applied Materials and one of the white paper's lead authors states, "The solar energy sector is a $100-billion-plus and growing global business characterised by fierce international competition. So it was probably inevitable that trade conflicts would arise. What should not be inevitable, however, is that these tensions continue to define the global solar landscape. The current path ultimately means the industry, consumers and the environment all lose. With leadership and long-term vision, we can turn this around."

"An end to global conflict within the PV market is both advantageous and conceivable, and there are a variety of approaches that merit consideration in achieving an industry-driven solution, from the World Semiconductor Council's model, to broad sectoral agreements in ICT and 'green goods,' to regional pacts with 21st century standards," adds Bettina Weiss, vice president for business development at SEMI.

According to the SEMI white paper, multiple avenues for amelioration can be examined including:

U.S-Japan Semiconductor Trade Agreement : Born out of the semiconductor dispute, the creation of the World Semiconductor Council (WSC) produced an elevated dialogue and a pathway forward for the semiconductor industry. Far beyond the scope of the initial U.S.-Japan agreement, this government-industry body was created to promote the semiconductor industry in a global way and to use trade as more than simply a tool for litigation.

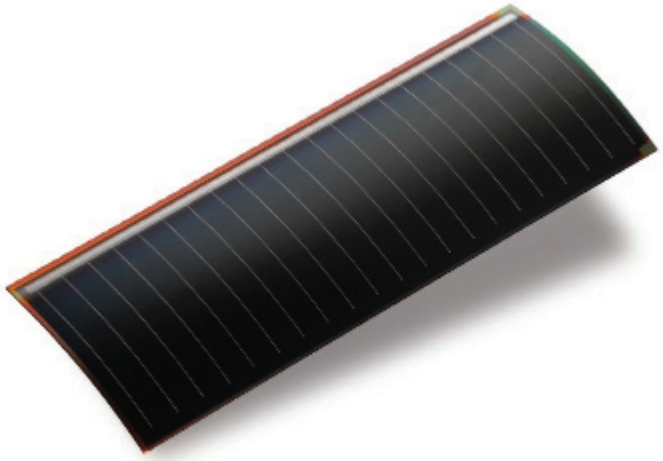
Information Technology Agreement (ITA) : Initially crafted in 1996, the ITA is a broad sectorial agreement that has allowed an annual increase of more than 10 percent for all ICT products it covers. There are currently 74 ITA participants accounting for about 97 percent of global trade in ICT products and this model is viewed as the standard bearer for plurilateral engagement.

Alta Devices III-V cell breaks record

The firm's new technology builds on its basic GaAs approach, but implements a second junction with indium gallium phosphide (InGaP) as the absorber on top of the base cell. The technology will enable significant battery life extension in mobile devices

Alta Devices says it has achieved 30.8 percent solar cell efficiency.

This new NREL (National Renewable Energy Laboratory) verified record has resulted from the company's first implementation of a new generation "dual junction" solar cell technology which augments the company's "single junction" technology.



Alta Devices solar panel

Higher efficiency directly translates into more electricity generated from smaller surface areas.

Therefore, applying Alta's highly efficient, very thin and flexible mobile power technology to consumer devices can extend the battery life of everyday products such as smartphones, tablets, keyboards, mice, remote controls, and more.

"We are changing the way solar technology is used," says Chris Norris, president and CEO of Alta Devices. "With our technology, enough energy can be generated from sunlight to effectively power devices in ways not previously possible. We are working with a number of customers who are designing their mobile products to increase battery life; and in some cases, we can provide enough energy to eliminate the need to plug into the electric grid."

To help device manufacturers understand the benefits of using Alta's material on their products, Alta has created a calculator to compute the battery life extension for a variety of consumer mobile devices; it is available on the firm's website. According to the calculator, a typical outdoor worker could realise 80 percent more battery life each day for their mobile phone. Or a student can get over 60 percent more battery life for his or her tablet device. These results can be achieved with minimal weight or form-factor penalty on the device design.

Alta's Second Generation Technology

"Alta Devices has been setting efficiency records since 2010. This new dual junction record at 30.8 percent is a testament to our technology and our world-class team. It's also an important step toward our target of 38 percent efficient cells," continues Norris. "We continue to redefine the boundaries of what is possible with solar power."

Alta Devices pioneered the world's highest efficiency single junction solar technology by using a number of breakthrough approaches to implementing GaAs for solar cells. The company's new dual junction technology builds on that basic GaAs approach, but implements a second junction (or layer) with InGaP as the absorber on top of the base cell.

Because InGaP uses high-energy photons more efficiently, the new dual junction cell generates more electricity from the same amount of light than a single junction device.

Alta Devices is currently shipping its single junction products.

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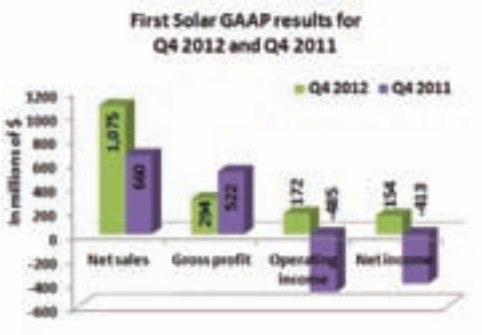
First Solar converts loss to profit in Q4 2012

Despite a turnaround in quarterly profits, reversing the loss of a year ago, the cadmium telluride cell manufacturer's shares fell 8 percent. This could be after the company remained tight-lipped about an earnings and sales outlook for 2013

CdTe panel manufacturer First Solar has announced financial results for the quarter and year ended December 31st. 2012.

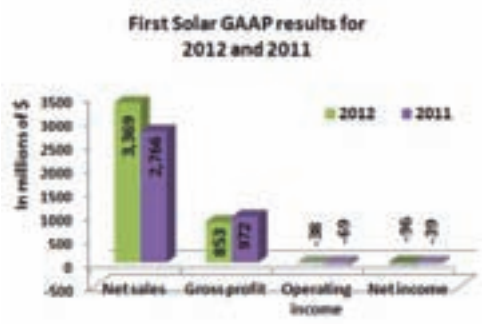
Net sales were a record $1.1 billion in the quarter, an increase of $236 million from the third quarter of 2012 and $415 million from the fourth quarter of 2011. The increase in net sales from the third quarter of 2012 was primarily due to increased revenue recognition for the Topaz project, and an increase in third-party module sales.

The company reported fourth quarter GAAP net income per fully diluted share of $1.74, compared to $1.00 in the third quarter of 2012 and a loss of $4.78 in the fourth quarter of 2011, which included $454 million in pre-tax goodwill impairment and restructuring charges. The fourth quarter of 2012 was impacted by pre-tax charges of $25 million (reducing EPS by $0.30), relating to previously announced restructuring actions.



Net sales for 2012 were $3.4 billion, up 22 percent from 2011.

First Solar reported a full-year GAAP loss of $1.11 per share for 2012, including the impact of pre-tax charges of $529 million (reducing EPS by $5.99), relating to previously announced restructuring actions and costs in excess of normal warranty.



Cash and Marketable Securities at the end of 2012 were $1 billion, up from $717 million at the end of the third quarter of 2012. Cash flows from operations were $328 million in the fourth quarter, and $762 million for the full-year 2012.

Q1 2013 Outlook

The company expects net sales to be in the range $650 to $750 million and a gross margin of 25 to 27 percent. First Solar also an OPEX of $90 to $100 million, an operating income of $70 to $100 million and a tax rate between 11 and 13 percent. EPS of $0.70 to $0.90 per fully diluted share, a cash flow from operations of up to $100 million and a CAPEX of $80 to $100 million are also anticipated.

"Despite a very challenging market environment, we continued to make meaningful progress in all critical value drivers for the company," says Jim Hughes, CEO of First Solar. "We exceeded our module and balance-of-systems cost reduction targets for 2012, as announced in December 2011, further increased module efficiency and field performance, and achieved several key objectives in our strategy to develop and service new sustainable energy markets. We expect the market will remain turbulent for some time to come, but we have seen

some evidence of improvement and believe we have the right strategy in place to retain our industry leadership by providing the best value for our customers."

First Solar CdTe 18.7% efficient cell breaks record

In the future, the firm's cadmium telluride module will be optimised for volume manufacturing

First Solar says it has set a new world record for CdTe photovoltaic (PV) solar cell conversion efficiency, achieving 18.7 percent cell efficiency.

The tests were conducted by the U.S. Department of Energy's National Renewable Energy Laboratory (NREL).

The record-setting cell was constructed at the company's Perrysburg, Ohio factory and R&D centre using processes and materials - including the glass substrate - that are designed for commercial-scale manufacturing.

First Solar's R&D team in Perrysburg, Ohio, set a new world record for CdTe solar cell efficiency, 18.7 percent, as certified by the NREL

"This achievement showcases the huge potential of CdTe compared to other PV technologies and highlights the performance gains we continue to achieve thanks to our consistent and strong investment in R&D," says Raffi Garabedian, First Solar's Chief Technology Officer.

"We are confident the advanced technologies and processes we developed for this record-setting cell will further enhance the performance of our future production modules and power plants."

First Solar has continued to transfer its success in the R&D lab into its commercial modules, increasing its average production module efficiency to 12.9 percent in the fourth quarter of 2012, up 0.7 percentage points from 12.2 percent in the fourth quarter of 2011. The company's lead line was producing modules with 13.1 percent efficiency during the fourth quarter, up from 12.6 percent in the same period a year ago.

Since it began commercial production in 2002, First Solar has produced more than 90 million of its advanced thin-film solar modules with a capacity of over 7 gigawatts (GW), enough to provide clean electricity for approximately 3.5 million homes and displace 4.7 million metric tons of CO2 annually, based on world averages.

If laid end-to-end, the modules would circle the equator nearly three times.
First Solar utilises a continuous manufacturing process which transforms a sheet of glass into a complete solar module in less than 2.5 hours, contributing to the excellent energy payback time and low carbon footprint of systems using First Solar PV.

Emcore solar panels power LDCM satellite

The orbital-built satellite will use the firm's BTJ triple-junction III-V solar cells delivering 3,750W of power at the end of life

Emcore solar panels are powering the Landsat Data Continuity Mission (LDCM) satellite that was successfully launched on February 11th, 2013 from Vandenberg Air Force Base in California.

LDCM was designed, built and tested by Orbital Sciences Corporation for NASA to support the Landsat Earth observation program that began over four decades ago. The LDCM satellite continues a 40-year legacy of seven previous satellites that have collected vital data and images of the Earth's surface and environment.

NASA and the U.S. Geological Survey (USGS) share responsibility for the LDCM program. NASA's Goddard Space Flight Centre oversaw development of the flight systems including the LDCM spacecraft and the onboard instruments, and is responsible for mission operations, launch, and in-orbit checkout.

The USGS will operate the satellite and the Landsat ground network, image-processing and archive facilities. The data collected constitutes the longest ongoing record of the Earth's surface as seen from space and benefits many industries including agriculture, geology, forestry, regional planning, education, mapping, emergency response and disaster relief.

The knowledge gained contributes to research on climate, carbon cycle, water cycle, ecosystems, biogeochemistry and changes to Earth's surface, as well as our understanding of visible human effects on land surfaces.

LDCM joins Landsat 7, which is currently in orbit. Once the spacecraft completes in-orbit testing and is operated by the USGS, it will be renamed Landsat 8, reflecting its place in a distinguished legacy of highly-productive spacecraft.

The satellite has two new spectral bands that will allow it to detect clouds on coastal zones. In addition, it will produce more than twice as many images per day than the Landsat 7. LDCM is approximately 20 feet tall with a 9-foot diameter at its widest point.

The solar array has four Emcore solar panels that will extend 32 feet from the satellite when deployed and feature high-efficiency BTJ triple-junction solar cells delivering 3,750 watts of power at End-Of-Life (EOL).

"Emcore is proud to have once again partnered with Orbital

on the deployment of critical on-orbit capability," says Brad Clevenger, General Manager of Emcore's Photovoltaics Division. "We appreciate the opportunity to contribute to this important mission for NASA and the U.S. Geological Survey and we look forward to seeing LDCM's many contributions to earth science."

AV Solar Ranch One CdTe plant achieves 100 MW

California's largest operating PV power plant will reach 230 MW once completed this year

First Solar has announced that the Antelope Valley Solar Ranch One project has achieved a peak generating capacity of 100 megawatts (MW)AC connected to the electrical grid.

The project, which is under construction in northern Los Angeles County, is currently California's largest operating photovoltaic (PV) power plant and will have a generating capacity of 230 MWAC upon completion, expected later this year.

AV Solar Ranch One is California's largest operating PV solar power plant, under construction in LA.

Cadmium telluride solar modules installed at AV Solar Ranch One

Initial construction on the solar project began in September 2011 and module installation started in June 2012, providing an average of 400 jobs during the construction phase. Power from the plant is being purchased by Pacific Gas and Electric Company under a 25-year contract.

"We are proud to achieve this important clean energy milestone for California, which was made possible by the tireless efforts of hundreds of individuals working together. We especially appreciate the support of LA County's Fifth Supervisorial District staff and the departments of Regional Planning and Public Works for their contributions to making this project a success," says Lou Moore, First Solar Senior Vice President of Engineering, Procurement and Construction.

"Unlike traditional power plants, the modular nature of PV power projects enables us to quickly add substantial volumes of clean energy to the grid throughout the construction process. This shorter 'time to energy' is another key advantage of PV solar electricity," Moore continues.

Dennis Hunter, Deputy Director of Los Angeles County Public Works, congratulated First Solar on its achievement at Antelope Valley Solar Ranch One. "We appreciated the opportunity to work with the First Solar team to reach this operational milestone."

When fully operational, the facility will generate enough power for 75,000 average California homes and will displace about 140,000 tons of carbon dioxide per year. That's equivalent to taking 30,000 cars off the road on an annual basis.

GaAs quantum dots assemble themselves

Quantum dots can self-assemble at the apex of a GaAs/AlGaAs (gallium arsenide/aluminium gallium arsenide) core/shell nanowire interface. This breakthrough could bolster quantum photonics and solar cell efficiency

Scientists from the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) and other labs have demonstrated a process where quantum dots can self-assemble at optimal locations in nanowires.

This breakthrough could improve solar cells, quantum computing, and lighting devices.

Quantum dots are tiny crystals of semiconductor a few billionths of a metre in diameter. At that size they exhibit beneficial behaviours of quantum physics such as forming electron-hole pairs and harvesting excess energy.

The researchers demonstrated how quantum dots can self-assemble at the apex of the GaAs/AlGaAs core/shell nanowire interface.

Crucially, the quantum dots, besides being highly stable, can be positioned precisely relative to the nanowire's centre. That precision, combined with the materials' ability to provide quantum confinement for both the electrons and the holes, makes the approach a potential game-changer.

Electrons and holes typically locate in the lowest energy position within the confines of high-energy materials in the nanostructures. But in the new demonstration, the electron and hole, overlapping in a near-ideal way, are confined in the quantum dot itself at high energy rather than located at the lowest energy states. In this case, that's the GaAs core. It's like hitting the bulls-eye rather than the periphery.

The quantum dots, as a result, are very bright, spectrally narrow and highly anti-bunched, displaying excellent optical properties even when they are located just a few nanometres from the surface - a feature that even surprised the scientists.

"Some Swiss scientists announced that they had achieved this, but scientists at the conference had a hard time believing it," says NREL senior scientist Jun-Wei Luo, one of the co-authors of the study.

Luo got to work constructing a quantum-dot-in-nanowire system using NREL's supercomputer and was able to demonstrate that despite the fact that the overall band edges are formed by the gallium arsenide core, the thin aluminium-rich barriers provide quantum confinement both for the electrons and the holes inside the aluminium-poor quantum dot. That explains the origin of the highly unusual optical transitions.

Several practical applications are possible. The fact that stable quantum dots can be placed very close to the surface of the nanometres raises a huge potential for their use in detecting local electric and magnetic fields. The quantum dots also could be used to charge converters for better light-harvesting, as in the case of photovoltaic cells.

This work is described in detail in the paper, "Self-assembled Quantum Dots in a Nanowire System for Quantum Photonics," by M. Heiss *et al* in *Nature Materials,* (2013). DOI:10.1038/nmat3557

The team of scientists working on the project came from universities and laboratories in Sweden, Switzerland, Spain, and the United States.

First Solar's new VP takes a shine to the Middle East

The CdTe (cadmium telluride) solar cell manufacturer is branching out in this region with the new appointment of ex GE executive, Ahmed Nada

First Solar has announced that Ahmed Nada will join the company as Vice President of Business Development for the Middle East. He will report to Christopher Burghardt, Vice President of Business Development for Europe, Middle East and Africa (EMEA).

Ahmed Nada, , First Solar VP of Business Development for the Middle East

In this new role, Nada will be based in the company's Dubai office and will lead business development activities in the region outside of Saudi Arabia, where the company is also establishing operations.

Ahmed Nada has 20 years of experience throughout the Middle East, concentrated in the energy and power industries. He joins First Solar after 14 years with General Electric. He most recently was the business executive and regional general manager of GE Oil & Gas Global Services in the Middle East.

Prior to that Nada worked at Zahid Tractors & Heavy Machinery Co, a Caterpillar distributor in Saudi Arabia, and Saudi Arabian Marketing Corp. (SAMACO).

"The Middle East is just beginning to tap its immense potential solar power generation, and Ahmed's many years of experience working with the region's leading energy companies will help us to meet the growing demand for renewable energy in the region," says Christopher Burghardt.

"Utility-scale solar power offers a compelling solution to the region's growing energy needs, and this is a great opportunity to leverage First Solar's proven technology and global experience to provide the best value to our customers here," adds Nada.

Ahmed Nada holds a Master's of Science degree in international management from HEC Lausanne University in Switzerland.

Flisom secures funding to ramp up 15 MW CIGS production plant

Apart from securing financial backing, the firm has been awarded by Empa, an unnamed Swiss investor and the firm's

existing Indian strategic investor, Tata

Flisom, a Swiss company developing technologies for manufacturing of flexible thin film CIGS solar modules, has raised a substantially large investment.

The amount of money raised has not been disclosed.

The cash will be used to further develop Flisom's CIGS technology and build a production plant with an annual capacity of 15MW in Switzerland.

Besides securing financial backing, Flisom also signed an agreement with Empa, the Swiss Federal Laboratories for Materials Science and Technology, to provide research and development support on high-efficiency flexible CIGS solar cell technology.

Flisom's third funding round was completed with participation from a Swiss investor along with the firm's existing strategic investor, Tata, one of India's largest and most respected business houses.

"This new investment marks investors' satisfaction with Flisom's progress towards the development of industrial manufacturing technology for roll-to-roll production of flexible solar modules. The 15MW plant will serve as a blueprint towards the establishment of larger-scale plants to manufacture flexible solar modules at low cost", says Flisom's interim CEO Marc Kaelin. "Flisom's technology shows strong potential in helping solar electricity become affordable."

"At Tata, we are keen to support the company in achieving its vision. Such technologies have a potential to transform many lives for the better", adds K.R.S. Jamwal, Executive Director, Tata Industries. "We admire the team and technology, based on a record setting efficiency of over 20 percent for CIGS from Empa, which we hope will be scaled up successfully. The funding will enable Flisom to purchase equipment and hire more experts to convert an innovative Swiss technology into an industrial reality."

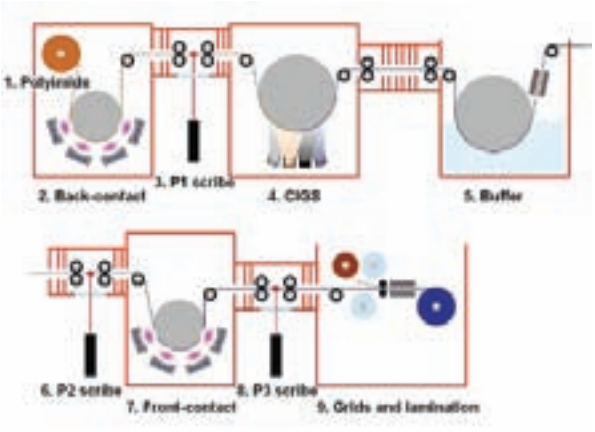
Flisom's high performance products, processes and systems could lower the price of solar electricity thanks to low material usage, economic production technology, and reduced storage, transportation and installation costs.

Markets addressable by Flisom's flexible solar module manufacturing technology include utility scale solar farms, building integrated photovoltaics (BIPV), building applied photovoltaics (BAPV), transportation, portable power and electronics.

The key is roll-to-roll manufacturing

The production technology is roll-to-roll manufacturing of flexible solar modules, involving deposition of CIGS thin films onto polymer foil.

A schematic showing the process is below:



Founded as a spin-off company from ETH Zurich (Swiss Federal Institute of Technology Zurich), Flisom has subsequently developed proprietary tools and processes for manufacturing solar modules.

After moving to Empa's Dübendorf campus, Flisom has been collaborating with Empa's Laboratory for Thin Films and Photovoltaics led by Ayodhya Nath Tiwari through various projects.

On 17th January 2013, Empa announced that its CIGS flexible solar cells achieved 20.4 percent photovoltaic conversion efficiency – a world record for CIGS technology that equals the record efficiency of polycrystalline silicon wafer solar cells.

"Scale-up for large-area solar modules and adapting these complex innovative processes for industrial manufacturability is quite a challenge and requires close collaboration between research labs and industrial partner", says Pierangelo Groening, head of the Department of Advanced Materials and Surfaces and member of the Board of Directors at Empa.

"Therefore, Empa and Flisom have signed a collaboration agreement on certain topics of flexible CIGS technology, and Empa has deputed Tiwari for a part-time involvement as senior strategic officer to support Flisom's further development, a move that is instrumental to Empa's long-term strategy to support early-stage companies with global market ambitions," continues Groening.

"This is a very special way of technology transfer – by way of sharing highly experienced staff. We expect Flisom to benefit greatly from Ayodhya Tiwari's expert knowledge and experience. I see it as sort of a kick-start for the company's new phase of development", says Empa CEO, Gian-Luca Bona.

"The success also highlights, according to Bona, Empa's strength in the field of renewable energy and, in particular, photovoltaics. We have several labs here at Empa devoted to the development of various innovative thin film technologies for solar energy generation", he adds.

"Along with the success of Flisom's capital raise, we are very impressed by the high photovoltaic conversion efficiency attained by our scientific partners at Empa", concludes Flisom interim CEO Kaelin. "We look forward to benefitting from the insights of Empa to further raise the efficiency of flexible solar modules produced using Flisom's industrial roll-to-roll vacuum

deposition technology.

III-V solar cells soar with birds

A new technology incorporating III-V solar cells and MEMS technology can be implemented in tracking birds

STMicroelectronics and the University of Amsterdam (UvA) Faculty of Science have developed a sophisticated bird-tracking system developed by the university.

The tracker contains sensors that measure both the air temperature and the internal temperature of the device. A lithium battery, charged by a highly efficient compound semiconductor triple-junction solar cell, provides power to the system, and a ZigBee transceiver manages wireless data communication to and from the device.

Multi-junction solar cells contain several *p-n* junctions. Each junction is tuned to a different wavelength of light, reducing one of the largest inherent sources of losses, and thereby increasing efficiency.

The chip also uses advanced MEMS sensing technology from ST.

Weighing as little as a 20 euro cent coin or a US quarter and smaller than a car key so as not to impede the birds› flight, the tracking systems are sophisticated data loggers that can be attached to the back of the birds. The trackers enable valuable scientific research on bird behaviour by measuring GPS position every 3 seconds.

In addition to the bird›s location, determined via the GPS, the tracker collects acceleration and direction data from ST›s digital compass that integrates low-power, high-performance motion and magnetic sensing in a miniature form factor. The MEMS chip monitors the direction and vertical/horizontal orientation of the animal and can determine the body angle of birds flying in a crosswind.

Data from the trackers is currently being shared among bird-research institutes and biologists to verify computer models that predict bird behaviour and migration patterns.

«MEMS technologies are finding their way into a broad range of applications and only ST has the breadth of technologies available to serve as a one-stop supplier,» says Benedetto Vigna, Executive Vice President and General Manager of ST›s Analogue, MEMS and Sensors Group. «The light weight, low power, and high accuracy of the MEMS make it ideal for innovative projects like UvA›s bird tracking system to study avian migration and behaviour.»

«Animals have a lot to teach us and, especially as the Earth›s climate changes, there are many projects that we can undertake to study animal behaviour and migration patterns,» adds Ir. Willem Bouten of UvA. «STMicroelectronics is a strong partner for us in developing technologies that are suitable and adaptable to researching challenging problems that could help us address the effects of global warming and land use change.

DayStar in talks to sell CIGS assets and technology to PWEI

The deal is subject to completion of Due Diligence, which has been on-going since December 2012, and the DayStar Board approval of this transaction

DayStar Technologies is negotiating the potential sale of its CIGS solar technology, equipment and patent library with PacWest (PWEI).

DayStar's President Lorne Roseborough states, "This proposed deal with PacWest would be a no lose transaction for DayStar. This strategy fits well with the company's go forward plan as disclosed in our PRE 14A."

This deal would only be for DayStar's CIGS technology assets, including its proprietary differentiated manufacturing process to produce low-cost monolithically integrated, silicon-free CIGS-on-glass modules that do address the grid-tied, ground-based Solar (PV) market as well as Building Integrated Photovoltaic (BIPV).

DayStar Technologies developed its CIGS photovoltaic module based on its proprietary one-step CIGS deposition process. The CIGS Module does addresses the construction market's need to be compatible with today's largest growth area for solar which is building integration and the most rapidly growing market for thin film Solar (BIPV).

This technology is equally of interest to PacWest Equities wholly owned subsidiary World EcoSource, a technology based company which has developed the MobileFeed and MobileFood systems, helping offset deficient worldwide food production for both animals and humans.

PacWest Equities specialises in working with underperforming companies and bringing together the resources needed for them to attain financial stability and growth. its focus is on companies showing a positive upside while struggling to bring new bio-technologies and unique products to market.

TSMC Solar CIGS module reaches 15.1 percent efficiency

The firm says this module sets a new world record for monolithic thin-film module efficiency. It was produced using the current manufacturing equipment and materials at the company's manufacturing facility in Taichung, Taiwan

TSMC Solar has announced TUV SUD and UL have confirmed that its commercial-sized (1.09 m2) latest CIGS module has achieved 15.1 percent module total area efficiency.

"In just one year our process technology has made great progress. Our champion modules now have comparable module efficiency to mainstream multi-crystalline silicon modules, demonstrating TSMC Solar's ability to realise the high-efficiency potential of our CIGS technology. Our technology's superior competitiveness comes from its high efficiency, excellent high temperature performance and intrinsic cost structure advantages," says Ying-Chen Chao, President of TSMC Solar.

TSMC Solar S-Fab production line, located in Taichung, Taiwan

"Customers appreciate our ability to continuously improve module efficiency. In addition, TS CIGS Series modules deliver up to 5 percent additional energy yield over crystalline silicon in high temperature regions." points out Stephen McKenery, TSMC Solar Worldwide Sales Head.

TSMC's solar business was founded in May 2009 and is headquartered in Taichung, Taiwan.

Record-breaking antireflection coating on solar cells

A new development could significantly improve the performance of solar cells, LEDs and photodetectors

A team of researchers from Rensselaer Polytechnic Institute (RPI), Magnolia Solar, Inc. and Pohang University of Science and Technology have demonstrated a novel antireflection (AR) coating.

It beats the widely employed double-layer AR (DLAR) coating on state-of-the-art triple-junction solar cells.
The scientists demonstrated that the solar cells investigated gain over 4 percent in efficiency when replacing the industry-standard DLAR with an optimised four-layer AR coating.

Considering that the solar spectrum is an intrinsically broadband spectrum, such broadband characteristics of the AR coating are undoubtedly beneficial for high power conversion efficiency.

What's more, omnidirectional AR characteristics have become important for the rapidly expanding terrestrial application of solar cells. This is because solar irradiance in terrestrial applications usually has a large range of incident angles for non-tracking solar cells.

Both broadband and omnidirectional AR characteristics are attainable by four-layer AR coatings, as demonstrated by the RPI-led team.

RPI says that the excellent broadband and omnidirectional AR characteristics of the four-layer AR coating are achieved through solving the problem of refractive index matching at multiple layer interfaces.

By using tailored and low-refractive index nanoporous silica layers, the team has greatly reduced the refractive index contrast at the semiconductor / AR coating / air interfaces.

Through a multilayer design methodology powered by a genetic algorithm optimisation, favourable antireflective properties over a specified wavelength range and angle-of-incidence range were found.

Two porous layers of the four-layer AR coating were fabricated by oblique-angle deposition of silica thereby resulting in films with refractive indices of 1.32 and 1.11. This is less than the refractive index of silica. The other two layers are dense and were fabricated by co-deposition of silica / titania using

sputtering.

According to the photocurrent measurements performed by the team, the angle-of-incidence (0°- 80°) averaged photocurrent enhancement (over an uncoated triple-junction solar cell) of the four-layer AR coating amounts to 34.4 percent. The enhancement of a DLAR coating is only 25.3 percent.

In the future, the team members Jaehee Cho and E. Fred Schubert, will integrate this novel AR coating technology on surface-textured devices.

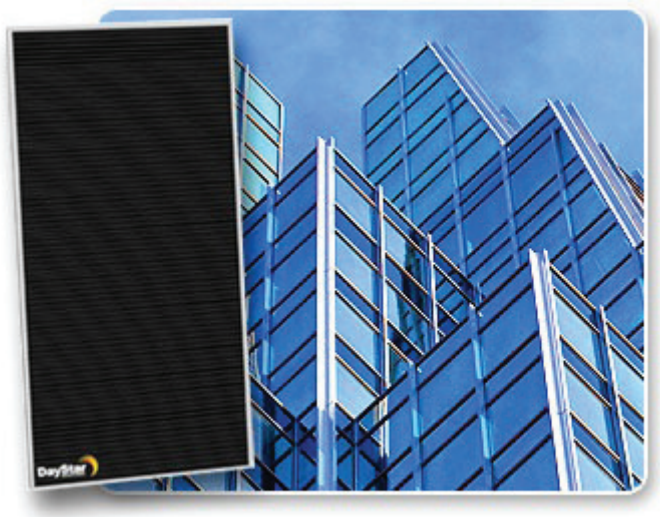
They will also investigate innovative fabrication methods for depositing low-refractive index AR coatings on curved surfaces, such as a hemispherical lens.

Further details of this research are described in the paper, "Enhanced Omnidirectional Photovoltaic Performance of Solar Cells Using Multiple-Discrete-Layer Tailored - and Low-Refractive Index Anti-Reflection Coatings," by X. Yan *et al* in *Advanced Functional Materials*, 23, 583 (2013).

DayStar invests in next generation CIGS technology

The solar firm has approved the acquisition of a 20 percent equity ownership in BC-based Premier Global Holdings Corporation

Premier has demonstrated solar cells that are the first to combine energy generation and power storage in one cell.



DayStar is to issue $12 million in preferred stock in return for the 20 percent equity ownership position in privately held Premier. The preferred can be converted to common stock at $1.60 per share, and will pay an in-kind dividend of 5 percent per annum.

According to its president, John Crawford, "Premier's photosynthesis photovoltaic (PV) promises significantly lower total solar energy costs, good performance in low lighting conditions, along with a significantly reduced footprint, and a wide range of possible form factors."

"Crawford, who served as Director of Strategic Ventures for the Energiser Holdings (ENR) before resigning to become President of Premier said he "looks forward to a successful partnership with DayStar, and its important network of affiliates and advisors throughout the world."

Lorne Roseborough, DayStar President, says this new technology represents a "fundamental change" in the business model for solar energy, and "will provide Daystar with a significant competitive advantage in its efforts to facilitate utilities and their customers in designing more cost effective and profitable renewable energy projects."

Developed at the University of British Columbia (UBC), the new technology integrates photosynthesis into the photovoltaic (PV) system permitting for the first time, simultaneous generation and storage in a single solar cell.

The system addresses the natural intermittency of Solar (PV) and can make solar power available under low or no direct sun conditions; the result is a built-in solution for reducing total demand on the local electrical grid. Each battery-like cell comes complete with two electrodes and an electrolyte.

Light is absorbed by harvesting light molecules in the electrolyte. Charges are then transferred between the excited light harvesting molecules and mediator molecules that are also in the electrolyte with nearly perfect quantum efficiency. The mediators store the harvested energy, which can then be extracted at the electrodes on demand.

According to Roseborough, "The technology will enable the deployment of units that could be built into apartments, offices, homes, and industrial sites, providing power during utility system outages and natural disasters."

Day Star views this as a long-term strategic investment, he adds, "Having assembled a team of world class engineers and system designers, and developed or co developed projects now or soon to be underway around the world using today's technology, we are very well aware the critical role new technology will play in the expansion of the solar market.

"By investing in Premier we gain access to an important piece of that future," Roseborough says, "Without committing the company to fund and manage its own research and development team."

Separating the core and shell of CdSe quantum dots

LEDs, solar cells and sensors could benefit from a new technology to study the interface between the core and shell of quantum dots composed of CdTe based materials

The J. William Fulbright College of Arts & Sciences at the University of Arkansas, has received a $650,000 award from

the National Science Foundation.

Colin Heyes, an assistant professor in the department of chemistry and biochemistry in the institute was instrumental in receiving the award.

The Faculty Early Career Development Program award was given to further his investigation of the interfaces between the core and shell of colloidal quantum dots.

Colloidal quantum dots are microscopic semiconductor crystals that are grown in solution.

Adding a shell to the core quantum dot provides a way to control the functionality of these crystals, which can be used to emit light for biomedical imaging, LEDs and spectroscopy or photocurrents for solar cells and chemical sensors.

The research will help scientists better understand the relationship between the structure of the quantum dot and its functionality.

“All of these modern applications rely on the same fundamental electronic processes within quantum dots,” Heyes says. “Our work will provide a better understanding of how to control these crystals to eventually build brighter, faster, longer-lasting and more efficient products.”

Heyes studies the interfacial chemistry between the core, shell and ligands of colloidal quantum dots. Ligands sit on the shell surface and “hold” the colloidal quantum dots in solution; they also provide a chemical connection to the “outside world” so that quantum dots can attach to biological cells, solar cells or act as chemical sensors.

There is a lack of fundamental understanding about the structural properties of the core-shell and shell-ligand interfaces.

Scientists can observe the boundary between the core and shell materials using powerful electron microscopes, but they do not yet understand how the nature of the structural mismatches between the two materials affects their optical and electrical properties.

These mismatches create “holes” or “trap states” that result in losing control of excitons, which are electrons that have been energetically excited. The inability to control excitons result in energy lost as heat rather than converted into useful energy, such as light or electrical currents.

The NSF grant will expand Heyes’ investigation of how the optical and electrical properties of quantum dots are related to the core-shell and shell-ligand interfaces at the single quantum dot level.

Understanding single quantum dots is necessary to advance miniaturised optoelectronics and single molecule fluorescence applications. His research team has produced preliminary data demonstrating that as these interfaces are systematically varied, the optical properties of single quantum dots can be tuned.

“We hypothesise that understanding the relationship between the structures of the core-shell or shell-ligand interfaces and the trap states will allow us to more precisely control these excitons that underlie the optical and electrical properties,” Heyes says.

Heyes’ team will focus specifically on understanding how the trap states are formed and how they contribute to the optical and electronic properties with the eventual goal of avoiding their formation altogether.

The grant will support Heyes’ research in this area for the next five years and will encourage and promote the participation of graduate, undergraduate and minority students. As part of the grant, a two-week, hands-on workshop will be held each summer on the U of A campus.

Students from the university and from institutions in Arkansas and Oklahoma will perform research experiments in Heyes’ lab to promote and foster their interest in chemistry and nanomaterial science for eventual careers in the fields of science, technology, engineering and maths.

First Solar buys Macho Springs Project from Element Power Solar

The CdTe solar provider says, once the task is complete, it will be the state’s largest solar power project

First Solar has acquired the 50-megawatt AC (MW) Macho Springs Solar project that Element Power Solar has developed in Luna County, New Mexico.

The solar project is expected to be completed in 2014, providing up to 400 construction jobs, and producing enough clean, renewable energy to power over 18,000 homes while displacing 40,000 tons of CO2 per year - the equivalent of taking 8,000 cars off the road.

The terms of the transaction were not disclosed.

The Macho Springs Solar project is located on land leased from the New Mexico State Land Office, and electricity from the facility will be purchased by El Paso Electric under a power purchase agreement that is subject to regulatory approvals, expected in the first half of 2013.

“We’re very excited to continue our work in New Mexico, increasing the state’s utility-scale solar generation capacity,” says Dana Diller, First Solar Vice President of U.S. Business Development.

“Element Power is pleased to once again work with the State of New Mexico, Luna County, the town of Deming and El Paso Electric to bring renewable energy and economic development to the region. The sale of Macho Springs Solar to First Solar is the result of a strong working relationship that draws on each company’s strengths,” adds Raimund Grube, COO of Element Power.

“We look forward to working with First Solar on this very important renewable energy project that will benefit all El Paso

Electric customers," comments Tom Shockley, El Paso Electric Chief Executive Officer. "We also want to thank Element Power Solar for its dedication and commitment to bringing this project to fruition."

The Macho Springs project was the result of a Request for Proposal (RFP) by El Paso Electric to include additional electric peaking resources in its current energy mix.

First Solar will construct the Macho Springs facility using its advanced thin-film CdTe PV modules. First Solar says its PV systems have the smallest carbon footprint and shortest energy payback time of any PV technology on the market today.

First Solar completed New Mexico's 30 MW Cimarron Solar facility in 2011, which is owned by Southern Company and Turner Renewable Energy. First Solar also completed 22 MW of solar projects in the state for PNM Resources, Inc. in 2011 and has been selected to build another 21.5 MW for PNM for expected completion in late 2013.

Power Electronics

GeneSiC raises the bar in high frequency and temperature applications

The silicon carbide junction transistors will increase conversion efficiency and reduce the size, weight and volume of power electronics

GeneSiC Semiconductor, a pioneer and global supplier of a broad range of SiC power semiconductors has announces the immediate availability of a family of 1700V and 1200V SiC Junction Transistors.

GeneSiC silicon carbide junction transistor

Incorporating high voltage, high frequency and high-temperature capablability, the SiC Junction Transistors will increase conversion efficiency and reduce the size/weight/volume of power electronics.

These devices are targeted for use in a wide variety of applications including server, telecom and networking power supplies, uninterruptable power supplies, solar inverters, industrial motor control systems, and downhole applications.

Junction Transistors offered by GeneSiC exhibit ultra-fast switching capability, a square reverse biased safe operation area (RBSOA), as well as temperature-independent transient energy losses and switching times.

These switches are gate-oxide free, normally-off, exhibit positive temperature co-efficient of on-resistance, and are capable of being driven by commercial, commonly available 15V IGBT gate drivers, unlike other SiC switches.

While offering compatibility with SiC JFET drivers, Junction Transistors can be easily paralleled because of their matching transient characteristics.

"As power system designers continue to push the limits of operating frequency, while still demanding high circuit efficiencies, they need SiC switches which can offer a standard of performance and production uniformity. Utilising the unique device and fabrication innovations, GeneSiC's Transistor products help designers achieve all that in a more robust solution," says Ranbir Singh, President of GeneSiC Semiconductor.

The 1700V junction transistors come in 110 mΩ (milliOhms) (GA16JT17-247), the 250 mΩ (GA08JT17-247) and the 500 mΩ (GA04JT17-247).

There are two new offerings in the 1200 V junction transistors ; the 220 mΩ (GA06JT12-247) and the 460 mΩ (GA03JT12-247).

All these devices have a Tjmax of 175oC and the turn On/Off have typical rise and fall times of less than 50 nanoseconds.

All devices are 100 percent tested to full voltage/current ratings and housed in Halogen-Free, RoHS compliant TO-247 packages. The devices are immediately available from GeneSiC's Authorised Distributors.

GeneSiC`s hybrid SiC / Silicon modules open new doors

The firm's low Inductance, higher temperature capable silicon carbide mini-modules enable 175 degree C operation are suited to industrial motors, solar inverters and power grid applications

GeneSiC Semiconductor is marketing its second generation hybrid mini-module using 1200V/100A SiC Schottky rectifiers with rugged silicon IGBTs - the GB100XCP12-227, shown

below.

The performance-price point at which this product is being released allows many power conversion applications to benefit from the reduction of the cost, size, weight and volume. GeneSiC says neither silicon IGBT, silicon rectifier solutions, nor pure SiC modules can offer all of these attributes.

The module is targeted for use in a wide variety of applications including industrial motors, solar inverters, specialised equipment and power grid applications.

The SiC Schottky/silicon IGBT mini-modules (Co-packs) offered by GeneSiC are made with silicon IGBTs that exhibit positive temperature coefficient of on-state drop, robust punchthrough design, high temperature operation and fast switching characteristics that are capable of being driven by commercial, commonly available 15V IGBT gate drivers.

The SiC rectifiers used in these Co-pack modules allow extremely low inductance packages, low on-state voltage drop of 1.9V at 100A and no reverse recovery. The SOT-227 package offers isolated baseplate, 12mm low profile design that can be used very flexibly as a standalone circuit element, high current paralleled configuration, a Phase Leg (two modules), or as a chopper circuit element.

“We listened to our key customers since the initial offering of this product almost 2 years back. This second generation 1200 V/100 A Co-pack product has a low inductance design that is suitable for high frequency, high temperature applications. The poor high temperature and reverse recovery characteristics of Silicon diodes critically limits the use of IGBTs at higher temperatures. GeneSiC’s low VF, low capacitance SiC Schottky Diodes enable this breakthrough product,” says Ranbir Singh, President of GeneSiC Semiconductor.

With a positive temperature coefficient on VF and a maximum junction temperature of 1750C, the products have typical turn-on energy losses of 23 microJoules.

All devices are fully tested to full voltage/current ratings and housed in Halogen-Free, RoHS compliant industry-standard SOT-227 packages.

The devices are immediately available from GeneSiC’s authorised distributors.

SemiSouth SiC manufacturing and test equipment to be sold off

Following the closure of the silicon carbide device manufacturer several months ago, semiconductor fabrication, electronic test , dicing and final assembly equipment are to be disposed of

Heritage Global Partners (HGP) and The Branford Group have announced their upcoming major global webcast auction sale of late model SiC semiconductor manufacturing assets and testing equipment of SemiSouth Laboratories.

SemiSouth was founded in 2001 by former Mississippi State University (MSU) faculty member Jeffrey Casady and current MSU electrical and computer engineering professor Michael Mazzola. Before its closure, the company manufactured SiC devices for high-power, high-efficiency, harsh-environment power management and conversion applications.

HGP is an asset advisory and auction services and a wholly owned subsidiary of Counsel RB Capital. The Branford Group, deals with surplus industrial machinery, equipment auctions and valuations.

The assets being sold include: semiconductor fabrication equipment, electronic test equipment, dicing equipment and final assembly equipment.

“Our upcoming sale, in partnership with The Branford Group, features SemiSouth’s wide array of SiC manufacturing and related testing equipment, representing an ideal opportunity for interested parties to take advantage of these late model state-of-the-art industry assets,” says Craig Thompson, Director of Sales at Heritage Global Partners.

“The SiC materials and electrical components being sold via our global webcast are ideal for high-power, high-efficiency, harsh-environment power management and conversion applications. Typical applications range from power conversion to variable-speed drives to high-power, harsh-environment military and aerospace applications,” adds William Gardner, President of The Branford Group.

A full listing of the items up for sale can be found online at: www.hgpauction.com and www.thebranfordgroup.com.

The global webcast auction is scheduled to begin at 10 am CT on April 4th, 2013.

Interested bidders are encouraged to attend the on-site preview April 3rd, between 9 am and 4 pm CT at 201 Research Boulevard on the campus of Mississippi State University in Starkville, Mississippi.

Aixtron AIX G5+ wins CS Manufacturing Award 2013

The compound semiconductor industry commended the firm's gallium nitride-on-silicon (GaN-on-Si) system. The tool is designed to handle five 200 mm wafers per production run providing high throughput and high yield growth of GaN devices on large area substrates

Aixtron SE has announced that it has been awarded the 2013 Compound Semiconductor Manufacturing Award for its latest development, the AIX G5+ reactor for GaN-on-silicon epi-wafer growth.

The Award recognises key areas of innovation surrounding the chip manufacturing process from research to completed device, focusing on the people, processes and products that drive the industry forward.

Frank Schulte, Aixtron (on the right), receives the Award from Richard Stevenson, CS magazine

Editor Richard Stevenson from Compound Semiconductor (CS) magazine presented the award yesterday, March 4th, 2013 to Aixtron's Vice President Europe Frank Schulte.

"GaN-on-silicon technology promises to revolutionise power electronics and slash the cost of LEDs, spurring a lighting revolution," he commented at the award ceremony in conjunction with the CS Europe exhibition in Frankfurt, Germany. "One manufacturing tool that I am tipping to play a major role in driving both these changes is the Aixtron AIX G5+, a reactor that combines high throughput with impressive levels of uniformity."

Andreas Toennis, Chief Technology Officer at Aixtron SE, comments, "Delivering results on the leading edge of GaN-on-Si technology, we are very pleased that our achievements are recognised by the compound semiconductor industry through this prestigious prize. The AIX G5+ reactor has been specifically designed to produce GaN based devices on silicon without compromising performance or yield compared to processes on sapphire substrates."

"GaN-on-Si is a very promising technology for future power electronics applications and high brightness LED manufacturing," Frank Schulte adds.

The AIX G5+ is designed to handle five 200 mm wafers per production run providing high throughput and high yield growth of GaN devices on large area substrates.

EPC to present GaN technology and applications at APEC 2013

The firm's CEO and applications experts will conduct a half-day seminar and technical presentations on gallium nitride FET technology and applications

Efficient Power Conversion Corporation (EPC), an innovator in enhancement-mode GaN on silicon (eGaN) power FETs, will be presenting an educational seminar and several application-focused technical presentations at APEC 2013.

The Applied Power Electronics and Exposition Conference (APEC) will be held in Long Beach, California from March 17th to 21st.

APEC, focuses on the practical and applied aspects of the power electronics business. It is one of the leading conferences for practicing power electronics professionals addressing a broad range of topics in the use, design, manufacture and marketing of all kinds of power electronics components and equipment.

"We are honoured that the technical review committee of APEC 2013 has selected EPC experts to conduct an educational seminar and to give technical papers focusing on GaN technology at their annual conference. This selection supports our belief that the superior performance of GaN technology has gained the interest and acceptance of power system design engineers," says Alex Lidow, EPC's co-founder and CEO.

Educational Seminar

GaN Transistors for Efficient Power Conversion
Sunday, March 17th (S.7, 2:30 p.m. - 6:00 p.m.)

Expanding on the GaN FET technology textbook written by EPC, this seminar will explain how GaN High Electron Mobility Transistors (HEMT) work. This session will discuss how to use these devices including showing the drivers, layout, and thermal considerations for high performance and high frequency power conversion. To showcase the real-world value of GaN technology, several applications including high frequency envelope tracking (ET), Intermediate Bus Converters (IBC), and wireless power transmission will be presented. The seminar will conclude with a look at the future of this emerging displacement technology.

Technical Presentations Featuring GaN FETs by EPC Experts:

Roundtable Discussion

"Wide band-gap semiconductors - Prime time or promises?"
Presenter: Alex Lidow Tuesday, March 19th (Session 2, 5pm - 6:30 pm)

Technical Sessions

"Design of a High Frequency, Low Loss eGaN Converter with Reduced Parasitic Inductances" Presenters: David Reusch, Johan Strydom Wednesday, March 20th (DC-DC Converters, 2 pm - 5:30 pm)

"Using eGaN FETs for Envelope Tracking"
Presenter: Johan Strydom Wednesday, March 20th (IS2.2.4, 8:30 am - 10:15 am)

"eGaN FETs Enable Low Power High Frequency Wireless Energy"
Presenter: Michael de Rooij Wednesday, March 20th, (IS2.2.3, 8:30 am - 10:15 am)

"eGaN FET based HF Resonant Converter"
Presenter: David Reusch Thursday, March 21st (IS1.4.5, 8:30 am. - 11:30 am

Connecting indium antimonide quantum dots

A novel spin technique has allowed scientists to move closer to creating what they say is the first viable high-speed quantum computer

Recent research offers a new spin on using nanoscale semiconductor structures to build faster computers and electronics. Literally.

University of Pittsburgh and Delft University of Technology researchers have revealed a new method that better preserves the units necessary to power lightning-fast electronics, known as qubits (pronounced CUE-bits).

The scientists explored InSb (indium antimonide) quantum dots in their study.

Hole spins, rather than electron spins, can keep quantum bits in the same physical state up to ten times longer than before, a new report by the scientists, finds.

"Previously, our group and others have used electron spins, but the problem was that they interacted with spins of nuclei, and therefore it was difficult to preserve the alignment and control of electron spins," says Sergey Frolov, assistant professor in the Department of Physics and Astronomy within Pitt's Kenneth P. Dietrich School of Arts and Sciences, who did the work as a postdoctoral fellow at Delft University of Technology in the Netherlands.

Whereas normal computing bits hold mathematical values of zero or one, quantum bits live in a hazy superposition of both states. It is this quality, said Frolov, which allows them to perform multiple calculations at once, offering exponential speed over classical computers. However, maintaining the qubit's state long enough to perform computation remains a long-standing challenge for physicists.

"To create a viable quantum computer, the demonstration of long-lived quantum bits, or qubits, is necessary," continues Frolov. "With our work, we have gotten one step closer."

The holes within hole spins, Frolov explains, are literally empty spaces left when electrons are taken out. Using extremely thin filaments called InSb nanowires, the researchers created a transistor-like device that could transform the electrons into holes.

They then precisely placed one hole in a nanoscale box called "a quantum dot" and controlled the spin of that hole using electric fields. This approach - featuring nanoscale size and a higher density of devices on an electronic chip - is far more advantageous than magnetic control, which has been typically employed until now, notes Frolov.

"Our research shows that holes, or empty spaces, can make better spin qubits than electrons for future quantum computers."

Graphic displaying spin qubits within a nanowire

"Spins are the smallest magnets in our universe. Our vision for a quantum computer is to connect thousands of spins, and now we know how to control a single spin," Frolov adds. "In the future, we'd like to scale up this concept to include multiple qubits."

This work is further described in the paper, "Electrical control over single hole spins in nanowire quantum dots," by V. S. Pribiag *et al* in *Nature Nanotechnology, (2013).* DOI:10.1038/nnano.2013.5

The research was supported by the Dutch Organisation for Fundamental Research on Matter, the Netherlands Organisation for Scientific Research, and the European Research Council.

Frolov and his Netherlands colleagues were recent winners of the 2012 Newcomb Cleveland Prize, an annual honour awarded to the author/s of the best research article/report appearing in Science, which is published weekly by the American Association for the Advancement of Science (AAAS).

GaN Systems expands UK base

The developer of gallium nitride power switching semiconductors has set up a new office in response to increasing demands and a growing base of European partners

GaN Systems has opened a new office facility located in Reading, England.

This expansion of the company's European operations will aid the firm in continuing to impact key industries, like manufacturing and automotive, where the need for clean technology power conversion applications continue to grow.

GaN Systems' head office is currently located in Ottawa, Canada.

"GaN Systems new office facility comes in response to a strong pull from our growing base of European customer partners," says Geoff Haynes, the company's UK based VP Business Development. "The company has a strong focus on collaborating across the manufacturing value chains for global power electronics markets to accelerate the adoption, and drive the cost of manufacture of GaN components. That can only be achieved through a strong local technical presence."

In addition to sales offices, the new location will include technical support and seminar facilities.

Richardson RFPD reveals GaN website resource

The website, focused exclusively on gallium nitride, includes GaN products from Empower RF Systems, M/A-COM Technology Solutions, Microsemi, Nitronex, TriQuint, and UMS

Richardson RFPD has announced the launch of a new website resource focused exclusively on GaN.

GaN technology is suited to meet today's size, weight and power ("SWaP") demands better than older technologies like GaAs, because GaN provides RF system engineers with the flexibility to achieve significantly higher power and efficiency, with lower part count, board space and resultant cost.

Several Richardson RFPD suppliers are driving innovation in the development of GaN discrete devices and modules , and the new GaN technology section of the website offers a range of power transistors, power amplifiers and switches from industry-leading manufacturers

The featured GaN products are suitable for a wide range of broadcast transmission, aerospace and defence, commercial and military avionics and radar, communications, test and measurement, small cell, and wireless infrastructure applications.

In addition to product and supplier information, the new GaN website section offers links to an extensive list of technical resources, from applications notes to brochures, selector guides, videos and white papers.

Richardson RFPD, Inc., an Arrow Electronics company, is an innovator in the RF and wireless communications, power conversion and renewable energy markets. Relationships with the industry's top component suppliers enable Richardson RFPD to meet the total engineering needs of each customer. Whether it's designing components or engineering complete solutions, Richardson RFPD's global design centres and technical sales team provide support for all aspects of customers' go to market strategy, from prototype to production.

Lattice location determines trace nitrogen dopants in SiC

A new technology is expected to contribute to the optimisation of the doping process of silicon carbide. The SC-XAFS techniques could also be applied to the analysis of other wide-gap semiconductors such as GaN (gallium nitride)

Researchers have developed an instrument for X-ray absorption fine structure (XAFS) spectroscopy equipped with a superconducting detector.

The study was conducted by Masataka Okubo and others from the Research Institute of Instrumentation Frontier of the National Institute of Advanced Industrial Science and Technology, in collaboration with the Institute of Materials Structure Science of the High Energy Accelerator Research Organisation and Ion Technology Centre Co., Ltd.

With the instrument, the researchers say they have realised, for the first time, local structure analysis of nitrogen dopants (impurity atoms at a very low concentration), which were introduced by ion plantation in SiC, a wide-gap semiconductor, and are necessary for SiC to be a*n*-type semiconductor.

Wide-gap semiconductor power devices, which enable reduction of power loss, are expected to contribute to the suppression of CO2 emissions. To produce devices using SiC, one of the typical wide-gap semiconductor materials, introduction of dopants by ion plantation is necessary for the control of electrical properties.

The dopant atoms need to be located in the particular lattice site in a crystal. However, there has not been a microstructural analysis method.

SC-XAFS was used to measure the XAFS spectra of the nitrogen dopants at a very low concentration in the SiC crystal, and the substitution site of the nitrgoen dopants was determined by comparison with a first-principle calculation. In addition to SiC, SC-XAFS can be applied to wide-gap semiconductors such as GaN and diamond, magnets for low-loss motors, spintronics devices, solar cells, etc.

The superconducting X-ray detector developed by AIST, used to identify N dopants at a very low concentration in SiC (left) and SC-XAFS installed at a beam line of Photon Factory, KEK (right)

SiC has a band gap larger than that of general semiconductors and possesses excellent properties including chemical stability, hardness, and heat resistance. Therefore, it is expected to be a next-generation energy-saving semiconductor which can function in a high-temperature environment.

In recent years, large single-crystal SiC substrates have become available and devices such as diodes and transistors appeared on the market; however, doping, which is necessary to produce devices with the semiconductor, is still imperfect, preventing SiC from fully utilising its intrinsic energy-saving properties.

Doping is a process in which a small amount of impurity is introduced (for substitution) into a crystal lattice site to form a semiconductor with electrons playing a major role in electrical conduction (*n*-type semiconductor) or with holes playing a major role in electrical conduction (*p*-type semiconductor).

SiC is a compound, and thus has a complex crystal structure, which means that doping SiC is far more difficult than doping silicon .

Since dopants should be light elements such as boron, nitrogen, aluminium, or phosphorus, there was no measurement method to study at which site in the SiC crystal they are located, namely the silicon site or the carbon site. Although transmission electron microscopy can visualise atoms, it is difficult to distinguish a trace light element from light elements constituting the matrix material.

To determine dopant lattice sites, XAFS spectroscopy is effective. X-ray fluorescence analysis allows to measure XAFS spectra of a specific element in matrices, and reveals the atomic arrangement and the chemical state around the element.

So far, however, it has been impossible to distinguish the characteristic X-ray of a light element at a very low concentration from those of the matrix elements, silicon and carbon. The lack of the analysis method has hindered the development of wide-gap semiconductors.

AIST has been developing advanced measurement technologies for industrial research and scientific studies, making them available for public use, and standardising them. As a part of these efforts, SC-XAFS using a superconducting measurement technology was completed in 2011.

Nitrogen has an atomic number larger than carbon by one. The energy of its characteristic X-ray is 392 electron volts (eV); the difference from that of carbon, 277 eV, is only 115 eV.

Although the energy resolution of the latest semiconductor X-ray detectors is 50 eV or so, which is smaller than the difference, at this resolution, while light elements can be distinguished if they exist in a large mount, it is not possible to distinguish a light element at a very low concentration, such as dopants.

In contrast, the superconducting X-ray detector developed by AIST has the resolution that exceeds the theoretical limitation of semiconductor X-ray detectors. Therefore, it is possible to measure the XAFS spectrum of the nitrogen dopant in SiC using the superconducting detector.

This SC-XAFS is installed in the BL-11A beam line of Photon Factory, KEK and has been available to the public since 2012 in the projects such as the AIST advanced equipment sharing innovation platform and the microstructural analysis platform in the nanotechnology platform project.

AIST says itself and only the Advanced Light Source in the USA have this kind of advanced measurement instrument; and only AIST has developed a superconducting detector, the key of the analytical instrument. ITC developed the ion injection technology and the heat treatment technology applicable to SiC and supplies samples to users.

Figure 1 (a) shows a histogram of the energy resolution of each element of the superconducting array detector. At a maximum resolution of 10 eV, which exceeds the limit of 50 eV of semiconductor detectors, the detector can distinguish a trace amount of nitrogen (N) from the matrix carbon (C) in a large quantity (Fig. 1 (b)), thus enabling the acquisition of XAFS spectra with accuracy usable for comparison with first-principle calculation (Fig. 2 (b)).

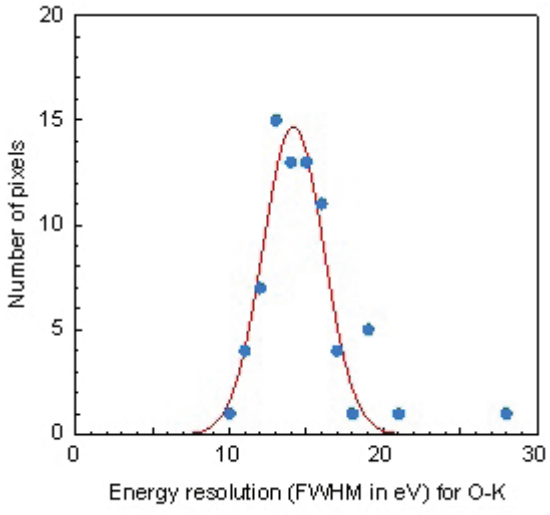


Figure 1 : (a) The energy resolution of the superconducting X-ray detector with respect to the characteristic X-ray of oxygen (b) An example of the detection of the N dopant in a very low concentration in SiC

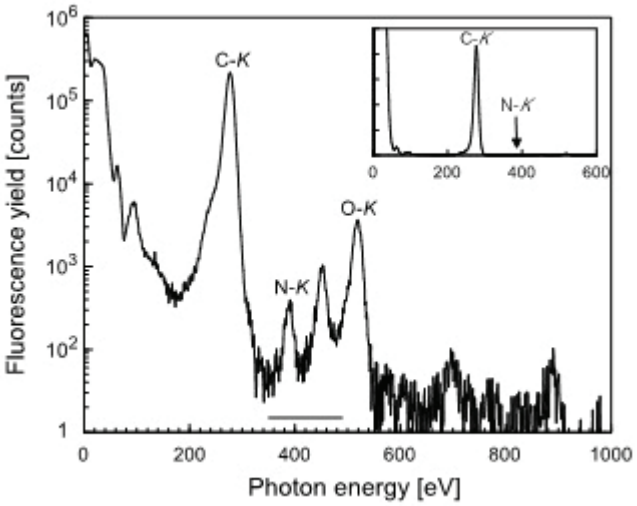


Figure 1 : (b) The strong peak of abundant C in SiC and the weak peak of N are distinguishable. In the insertion in (b), the vertical axis is in a linear scale. It is clear that N exists in a very low concentration

The SiC wafer into which the nitrogen dopant was introduced by ion plantation at a temperature of 500 °C and the wafers heat-treated at 1400 °C or 1800 °C after the ion plantation were subjected to the measurement of XAFS spectra (Fig. 2 (a)). The result of this experiment agreed with the first-principle calculation with FEFF, in which it was assumed that nitrogen atoms were located in the C sites (Fig. 2 (b)).

Thus, it was confirmed that most of N atoms were located in the C sites immediately after the ion plantation. It was empirical knowledge that ion plantation at a temperature as high as 500 °C was necessary for the doping to SiC, the reason for which, however, was unknown. The reason revealed in the present study is that it is necessary to locate N in the C sites before heat treatment at high temperature.

What's more, according to the spectrum in the region lower than 400 eV, it is presumed that a chemical bond is formed between carbon and nitrogen in a disordered crystal state immediately after the ion plantation. As the crystal disorder resolves as a result of the heat treatment at high temperature, this chemical bond breaks, leaving only the chemical bond of nitrogen and silicon, which is preferable for the doping.

As described here, it is revealed that the doping to SiC is complex and requires a completely different method from that for the doping to Si, in which the lattice site substitution can be realised by heat treatment after ion implantation at room temperature.

It is now possible to determine the lattice site of the trace N dopant introduced in SiC; no such measurement was possible hitherto. What's more, the state of the chemical bonds of the N dopant with the base materials, Si and C, is revealed. By combining SC-XAFS and the first-principle calculation, it is proved that the detection and microstructural analysis of a trace amount of the light elements in a crystal is possible, both of which were impossible until now.

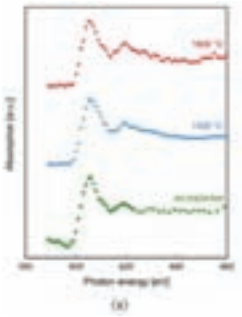


Figure 2 : (a) The XAFS spectrum of the SiC wafer without heat treatment immediately after the N ion plantation at 500 °C, and those of the SiC wafer heat-treated at high-temperatures after the ion implantation

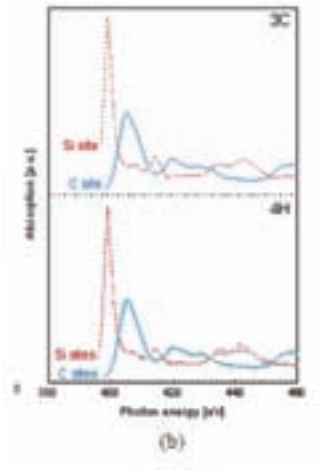


Figure 2 : (b) The XAFS spectra assumed from the first-principle calculations with the Si site replaced by N and with the C site replaced by N

The experiment data agrees with the result of the calculation on the assumption that the C sites were replaced in the comparison of (a) the measured spectra and (b) the calculated spectra for the 3C and 4H polytypes, which were two typical crystal structure SiC.

The developed technology is expected to contribute to the optimisation of the doping process of SiC semiconductors. Besides SiC, SC-XAFS will be applied to the analysis of other wide-gap semiconductors, magnetic materials, etc.; their functions depend on trace light elements.

What's more, improvement will be attempted in the resolution of the superconducting X-ray detector and the capability of the detection of a trace amount of light elements, thus expanding the range of the impurity concentrations covered by SC-XAFS

Cree & Eta to unveil 70% efficient GaN PA for mobile base stations

With the gallium nitride power amplifier, the two firms have

established a new Industry standard with significant energy and carbon footprint reductions

Cree and Eta Devices will demonstrate what they claim is the world's most efficient reported power amplifier for mobile base stations at the 2013 Mobile World Congress.

Current generation mobile base station amplifiers employing silicon LDMOS transistors can provide amplifier efficiencies up to 45 percent. By contrast, Eta Devices' next-generation power amplifiers are able to deliver efficiencies higher than 70 percent under a 4G LTE modulation format, and are thus poised to revolutionise current industry efficiency standards.

"Eta Devices' next-generation power amplifiers leverage the performance and reliability advantages of Cree's GaN HEMT RF transistors to realise game-changing efficiency benefits for the mobile base station industry," says Jim Milligan, business director, Cree RF. "Our transistors have been instrumental in demonstrating Eta Devices' amplifiers, which perform 50 percent more efficiently than the best incumbent silicon power amplifiers currently available in the 4G LTE market."

The world's mobile networks consume approximately 120TWh of electricity per year, and 50-80 percent of these networks' power is consumed by their power amplifiers and associated components. Implementing Eta Devices' new power amplifier solution on a global level could save mobile operators 60TWh of energy per year, which is equivalent to the amount of power produced by more than seven average-sized American nuclear power plants. It could also save up to 50 percent of the $36.5 billion spent to power mobile base stations each year.

"Mobile operators gain dramatic advantages by adopting our new technology,"comments Mattias Astrom, CEO of Eta Devices. "In addition to cost savings, our power amplifiers provide operators with a significantly reduced carbon footprint, which contributes to a more sustainable planet. In fact, if implemented on a global basis, our solution would reduce carbon emissions by approximately 36 million tons per year, which is equivalent to eliminating the annual greenhouse gas emissions produced by 7 million cars."

Fabless semiconductor company, Eta Devices Inc. is headquartered in Cambridge, Massachusetts with an R&D office in Stockholm, Sweden.

Its disruptive technology solves the key power challenges in the mobile communications industry. In base stations, this leads to significantly reduced power consumption and smaller cabinets. For handsets, battery life is considerably increased and multiband communications can be enabled at a fraction of the cost and footprint; this makes it possible to use the same handset model all over the world.

Cree shares downgraded

The firm's shares fell 0.39 percent to trade at $45.54 on Tuesday. Over the past year, the stock has been trading between $22.25 and $46.88

Cree shares were downgraded to "perform" from "outperform" by Oppenheimer based on valuation.

The brokerage, which removed price target of $42 on the stock, believes now is a good time to take money off the table.

"Cree currently trades at a 35x forward P/E multiple, a two-year high. Although we believe in the technology advantage of Cree and the long-term growth prospects of the LED lighting market, the near term may not be "all clear" to support such lofty valuation," Oppenheimer says.

The brokerage believes the stock could continue to rally over the next 3-6 months as immediate headwinds seem overblown, China orders pick up following the New Year, and spring ushers in more favourable weather for municipal and new commercial lighting.

"However, visibility remains limited and longer term competitive dynamics linger; to us, risk/reward looks balanced," Oppenheimer adds.

"Cree is still our favourite name in the LED supply chain, but valuation prompts us to take a more conservative stance and wait for a better entry point," the brokerage writes.

Cree's shift to a fixture business, and its component business fighting the commodity bug, each present unique challenges over the long haul. The brokerage sees Cree as ultimately being successful, but also don't see the risk these challenges present priced into the stock.

Henkel optimises metal and heatsink connection in power devices

Henkel has developed a new type of paste with enhanced thermal conductivity for power modules such as those based on gallium nitride and silicon carbide. It allows a higher power density for the same ageing resistance

Power electronics are experiencing a continuous rise in their power densities. As a result, thermal management for today's power semiconductors must be integrated as early as their design phase.

Only then can reliable cooling be safeguarded over the long term. A particularly important role is assigned to thermal conduction at the link between the component and the heat sink. In these cases, materials are often used that cannot meet the growing requirements.

In its search for a remedy, Infineon Technologies AG has incorporated a TIM material solution from Henkel Electronic

Materials to now make available a heat conducting compound optimised specifically for the architecture of power semiconductors in modules.

Compound semiconductors used for power applications are GaN or SiC based.

This so called thermal interface material (TIM) greatly reduces the contact resistance between the metal areas on the power semiconductor and the heat sink. On the EconoPACKTM+ of the new D Series, the contact resistance between the module and heat sink drops by 20 percent.

With a high filler content, the material reliably applies its improved properties of thermal contact resistance from the first moment the module is switched on. There is no need for a separate burn in cycle usual on many comparable materials with phase change properties.

The optimised heat transfer extends both the service life and the reliability of the new Infineon D series EconoPACKTM+ module (on the right)

The development of the new heat conducting material focused on ease of processing in the form of honeycombs stencil-printed on modules (as shown above). This prevents air from becoming trapped in the link to the heat sink.

What's more, the heat conducting material does not contain any substances harmful to health, meeting the requirements under the Directive 2002/95/EC (RoHS). Also, the TIM is free of silicone and does not conduct electricity.

"With this Henkel TIM, we have the best silicone-free solution for the growing requirements in the thermal management of power semiconductors at our disposal," claims Martin Schulz, who is responsible for the qualification at the Application Engineering of Infineon Technologies AG.

"The paste simplifies the link between the module and the heat sink, optimises heat transfer, and so extends both the service life and the reliability of the modules." The TIM was developed for use on Infineon modules and is now available for the IGBT EconoPACKTM+ module series.

The new thermal material was developed by Henkel Electronic Materials of the USA, a subsidiary of Henkel, to meet the stringent requirements of Infineon Technologies AG. Both companies have enjoyed many years of good cooperation.

"The development of LOCTITE TCP 7000 is a major step forward for high power, high temperature thermal management," explains Henkel's Jason Brandi, Market Development Manager. "A printable, phase change TIM with such robust thermal cycling performance is indeed a breakthrough, overcoming the limitations of alternative materials and pioneering a brand new solution for power module thermal management."

Both companies are now planning to deepen their cooperation in the development of new materials and to extend this to new projects.

NANEO extends production capacity with Veeco IBD tool

The SPECTOR system will be used to produce high quality optical products such as lasers and those used in Raman spectroscopy, telecommunications, and aerospace

NANEO Precision IBS Coatings GmbH, an optical coatings company located in Rheinbreitbach, Germany, has recently ordered a Veeco SPECTOR Ion Beam Deposition (IBD) System.

The SPECTOR system will be used to produce high quality optics in a broad range of applications including ultrafast optics, high power lasers, Raman spectroscopy, telecommunications, and aerospace.

SPECTOR IBD Optical Coating System

Daniel Kopf, Chief Executive Officer at NANEO, comments, "Veeco's SPECTOR IBD system allows us the process flexibility needed to meet growing demand for our high precision optics providing excellent precision and uniformity, lowest loss and high laser damage threshold. Veeco's reliable platform makes them an ideal partner as we ramp production."

James Northup, Veeco's Vice President and General Manager, comments, "We are pleased NANEO chose our system for their manufacturing expansion. The SPECTOR IBD Optical Coating System enables users to manufacture the highest precision and quality films meeting the performance requirements for virtually every optical thin film coating application. We look forward to providing excellent support and service to the NANEO team as they increase production."

NANEO specialises in the production of custom made precision optical coatings for high end applications in the laser and

photonics industry. The company produces high precision coatings for applications in the fields of high power lasers, high power beam combination, ultrafast lasers, optical measurement systems, telecommunications, aerospace and scientific research.

Integra introduces 100MHz - 1GHz GaN HEMT

The gallium nitride module is suited to Broadband applications

Integra Technologies has launched the IGN0110UM100, a dual-lead packaged GaN high electron mobility transistor (HEMT).

This device is designed for Broadband applications operating over the 100MHz – 1GHz instantaneous frequency band.

Under CW conditions it supplies a minimum of 100 watts of output power with 12dB gain. Specified operation is with Class AB bias. It is also operable under a wide range of pulse widths and duty factors. It operates with spectral purity into all phases of 3:1 output load VSWR.

All devices are 100 percent screened for large signal RF parameters in a fixed tuned broadband matching circuit / test fixture. Integra says the use of external tuners is not permitted during screening.

Cree takes on Mike McDevitt as Chief Financial Officer

McDevitt brings more than two decades of finance and operations leadership and has served as Vice President and Interim CFO of the company since May 22nd, 2012

Cree has appointed Mike McDevitt as Executive Vice President and Chief Financial Officer (CFO), which became effective last week.

“Mike is an invaluable member of the Cree team and I am very pleased to announce his appointment as CFO,” says Chuck Swoboda, Cree chairman and CEO. “After conducting an exhaustive national search, we realised Mike is the best candidate for the job. Mike’s proven leadership will help Cree drive innovation and accelerated adoption of LED lighting.”

Prior to his appointment as Interim CFO, McDevitt held several key leadership roles at Cree including Director of Sales Operations from 2011-2012, Director of Financial Planning from 2005-2011 and Corporate Controller from 2002-2005.

Yole: Inverter market to rocket to $71 billion in 2020

SiC, used in PV inverters, will have a market size of $43 million and GaN JFETs will be introduced in 2013

Yole Développement has announced its “Inverter market trends for 2013 - 2020 and major technology changes” report.

The publication provides a focus on the six most attractive applications (PV, wind turbines, EV/HEV, rail traction, motor drives and UPS) and a new analysis on power stack trend from the firm’s previous report.

There is significant growth in the inverter market, which reached $45 billion in 2012 for motion and conversion.

Energy related topics have become more and more important in 2012 - vehicle electrification, renewable energies, electricity transportation, and as a direct result, the power electronics market has increased.

This growth is driven by a number of factors. These include high volume and cost pressure applications such as EV / HEV and high added-value markets like renewable energies and rail traction.

“We estimate the inverter market to be $45 billion in 2012 and to reach $71 billion by 2020. A total of more than 28 million units were shipped in 2012 and we estimate that will grow to 80 million units in 2020,” explains Brice Le Gouic, Activity Leader, Power Electronics at Yole Développement.

Thus, the main components of inverter, passive and semiconductor modules (that we will find in power stacks) represent enticing industries. The power module market was $1.9 billion in 2012 and passive components achieved a market size of more than $4 billion, including capacitors, resistors, connectors, busbars and - newly added in this updated report - magnetic components (inductors and transformers).

As expected, wide band gap semiconductor devices have also started to penetrate those high-end market segments:

SiC is present in PV inverters – a total market size of $43 million primarily driven by diodes inmicro-inverters, but also by JFETs – and GaN which should be introduced in 2013.

Semiconductor technological developments continue to evolve and sharpen inverter performance

Yole’s 2012 investigation confirmed that semiconductor improvements enabled more efficient conversion, lighter

systems and more reliable end-products.

IGBTs have improved (higher current density, thinner and faster), as have SiC and GaN based devices.

GaN could be delayed in its market introduction, but SiC is already here and several companies showed SiC power module capabilities all last year.

Adoption of power stack is driving the modular approach across applications.

The Power Stack is the custom design and manufacturing of an inverter's sub-unit which includes only the core components: power semiconductor module, cooling system, capacitors, resistors, current sensors, busbars and connectors.

Power Stack is the innovative sub-system of an inverter. Inverter and device makers are becoming power stack manufacturers for several reasons:

• Vertical integration

• Access to several applications, since power stacks are less application-dependent than inverters

• Internal cost reductions

• Access to high-end markets

• Sustain R&D in-house

Large firms such as Ingeteam, Semikron or ABB are now involved, but power stack also interests smaller players such as AgileSwitch – former IGBT driver manufacturer – who are part of this about $500 million market.

Major changes are happening across the supply chain.

Power electronics often requires having several types of knowledge and experience gained know-how in mechanics, electronics, semiconductors, electrics, fluidics and hydraulics, and connectors. Therefore, development can be complicated and final products expensive.

Japanese and Chinese players, especially system makers, tend toward internal vertical integration and master the manufacturing processes of each sub-system and component.

In the case of Japanese companies, this tendency is mostly driven by cost reduction and absorption of intermediary margins, whereas Chinese companies want to access the technology and show some proof of quality.

On the other hand, EU and US players are diversified and acquisition of new or complementary competencies (such as Mersen, Rogers or Power Integration) or high-end R&D and prototyping services (APEI, Primes, imec, GE Global Research) is becoming more common.

Bridgelux appoints Bradley J. Bullington as CEO

Also, Bill Watkins, who nurtured and developed GaN on Silicon will become chairman of the board of directors

Bridgelux has appointed Bradley J. Bullington, the company's former Vice President, Strategy and Corporate Development and General Manager, Technology Solutions, as Chief Executive Officer.

William Watkins has moved up to Chairman of the Board of Directors, having served as CEO of the company from January, 2010 until taking this new role.

Bullington joined Bridgelux from Seagate in 2010, where he worked with Watkins, and has been responsible for the company's overall business strategy and all corporate and market development activities. These include strategic partnerships and joint venture development, technology licensing, capital formation and the legal function. He also ran Bridgelux's Technology Solutions business.

"Brad has driven Bridgelux's strategic direction and corporate development initiatives since joining the Company when I came aboard," says Watkins. "I look forward to working with him to ensure a smooth transition, as well as going forward as Bridgelux enters its next phase of growth."

"Bill has restructured and recapitalised the company, nurtured and developed our leadership position in GaN on Silicon, and significantly strengthened Bridgelux's position in the rapidly growing global lighting market," adds Alan Salzman, CEO and Managing Partner of VantagePoint Capital Partners.

"The Board is thrilled that Bridgelux will continue to benefit from Bill's tremendous knowledge, expertise, and guidance as the Company moves ahead. We also look forward to working with

Brad as he continues to build on Bridgelux's leadership in the solid state lighting industry."

Prior to joining Bridgelux, Bullington held executive strategy, corporate and business development roles at Seagate Technology from 2006 to 2009.

Bullington held similar positions at Maxtor Corporation, where he was also a founding member of Maxtor's Branded Products Group (BPG), an industry pioneer in the external storage solutions market.

Prior to entering the data storage industry, he was a management consultant for A.T. Kearney, where he served a range of clients focused on issues of strategy and operations in the software and technology hardware, aerospace, retail and financial services industries.

He began his professional services career at Deloitte & Touche.

Bullington received his B.A. in Business Administration, with a Certificate of International Studies in Business, from the University of Washington.

Mitsubishi Electric advances SiC ingot processing

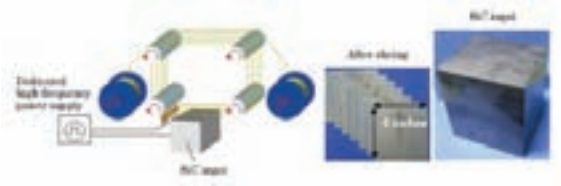
The firms new technology improves productivity of silicon carbide slice processing for semiconductor wafers

SiC is expected to be used increasingly in power semiconductors due to its superior energy-saving and CO2 emissions-reduction properties compared to silicon.

Until now, sliced wafers have been produced through multi-wire saw with diamond particles because SiC is the third hardest compound on earth.

But this method requires lengthy machining time and large kerf widths.

The new parallel multi-wire electrical discharge machining method utilises Mitsubishi Electric's proven electrical discharge technology for difficult-to-cut material, and employs a dedicated power supply specially developed for SiC.



The key technologies include

Simultaneous cutting of SiC ingots into 40 pieces

- Forty wire electrodes with a diameter of 0.1 mm aligned at 0.6mm intervals are rotated to cut 40 slices at once, improving productivity.

- The non-contact, thermal process-wire electrical discharge method slices faster and at closer intervals compared to contact cutting (220 microns or less cut at a speed of 80 microns per minute)

- More wafer slices extracted per SiC ingot for improved efficiency.

Power supply dedicated to SiC slice processing

- Simultaneous wire cuts with even energy enabled by 40 electrically independent power feed contacts to wire electrodes.

- Uninterrupted processing with even very thin (0.1mm) wire electrodes thanks to a newly developed high-frequency power supply tailored to the characteristics of SiC material.

Pending patents for the technology number 22 in Japan and 10 overseas.

GaN devices market to soar at a CAGR of 18 percent

One of the key factors contributing to market growth in semiconductors is the high thermal conductivity of gallium nitride over other non-silicon substrates

The gallium nitride semiconductor devices market has been witnessing the increasing preference for GaN with different substrates.

However, the complexity in matching the cost and performance could pose a challenge to the growth of this market.

TechNavio's report, the "Global Gallium Nitride Semiconductor Devices Market 2012-2016", has been prepared based on an in-depth market analysis with inputs from industry experts.

According to TechNavio, the key vendors dominating this market space are NXP, RFMD and Triquint.

New players include Plessey Semiconductor based in the UK.

The other vendors mentioned in the report are Nichia, Osram Opto, Royal Philips Electronics N.V. and Toyoda Gosei Co. Ltd.

Equipment and Materials

SemiSouth SiC manufacturing and test equipment to be sold off

Following the closure of the silicon carbide device manufacturer several months ago, semiconductor fabrication, electronic test , dicing and final assembly equipment are to be disposed of

Heritage Global Partners (HGP) and The Branford Group have announced their upcoming major global webcast auction sale of late model SiC semiconductor manufacturing assets and testing equipment of SemiSouth Laboratories.

SemiSouth was founded in 2001 by former Mississippi State University (MSU) faculty member Jeffrey Casady and current MSU electrical and computer engineering professor Michael Mazzola. Before its closure, the company manufactured SiC devices for high-power, high-efficiency, harsh-environment power management and conversion applications.

HGP is an asset advisory and auction services and a wholly owned subsidiary of Counsel RB Capital. The Branford Group, deals with surplus industrial machinery, equipment auctions and valuations.

The assets being sold include: semiconductor fabrication equipment, electronic test equipment, dicing equipment and final assembly equipment.

“Our upcoming sale, in partnership with The Branford Group, features SemiSouth’s wide array of SiC manufacturing and related testing equipment, representing an ideal opportunity for interested parties to take advantage of these late model state-of-the-art industry assets,” says Craig Thompson, Director of Sales at Heritage Global Partners.

“The SiC materials and electrical components being sold via our global webcast are ideal for high-power, high-efficiency, harsh-environment power management and conversion applications. Typical applications range from power conversion to variable-speed drives to high-power, harsh-environment military and aerospace applications,” adds William Gardner, President of The Branford Group.

A full listing of the items up for sale can be found online at: www.hgpauction.com and www.thebranfordgroup.com.

The global webcast auction is scheduled to begin at 10 am CT on April 4th, 2013.

Interested bidders are encouraged to attend the on-site preview April 3rd, between 9 am and 4 pm CT at 201 Research Boulevard on the campus of Mississippi State University in Starkville, Mississippi.

Aixtron AIX G5+ wins CS Manufacturing Award 2013

The compound semiconductor industry commended the firm’s gallium nitride-on-silicon (GaN-on-Si) system. The tool is designed to handle five 200 mm wafers per production run providing high throughput and high yield growth of GaN devices on large area substrates

Aixtron SE has announced that it has been awarded the 2013 Compound Semiconductor Manufacturing Award for its latest development, the AIX G5+ reactor for GaN-on-silicon epi-wafer growth.

The Award recognises key areas of innovation surrounding the chip manufacturing process from research to completed device, focusing on the people, processes and products that drive the industry forward.

Frank Schulte, Aixtron (on the right), receives the Award from Richard Stevenson, CS magazine

Editor Richard Stevenson from Compound Semiconductor (CS) magazine presented the award yesterday, March 4th, 2013 to Aixtron’s Vice President Europe Frank Schulte.

“GaN-on-silicon technology promises to revolutionise power electronics and slash the cost of LEDs, spurring a lighting revolution,” he commented at the award ceremony in conjunction with the CS Europe exhibition in Frankfurt, Germany. “One manufacturing tool that I am tipping to play a major role in driving both these changes is the Aixtron AIX G5+, a reactor that combines high throughput with impressive levels of uniformity.”

Andreas Toennis, Chief Technology Officer at Aixtron SE, comments, “Delivering results on the leading edge of GaN-on-Si technology, we are very pleased that our achievements are recognised by the compound semiconductor industry through this prestigious prize. The AIX G5+ reactor has been specifically designed to produce GaN based devices on silicon without compromising performance or yield compared to processes on sapphire substrates.”

“GaN-on-Si is a very promising technology for future power electronics applications and high brightness LED manufacturing,” Frank Schulte adds.

The AIX G5+ is designed to handle five 200 mm wafers per production run providing high throughput and high yield growth of GaN devices on large area substrates.

New shares from Aixtron stock option program not entitled to dividend

The global provider of deposition equipment to the semiconductor industry says it has a number of stock option programs in place

Aixtron SE stock option programs grant employees the right to purchase Aixtron shares under certain conditions.

Under the terms of the stock option plan 2007, stock options can currently be exercised. New shares resulting from exercised options are not entitled to a dividend for fiscal year 2012 and will therefore be traded on the Frankfurt Stock Exchange under the separate ISIN DE000A1TNVU3 until and including the day of the Annual General Meeting 2013 on May 23rd, 2013.

Aixtron's Executive and Supervisory Boards will propose to the shareholders' meeting that the 2012 loss of EUR -33.2m should be carried forward to new account.

EV Group expands Covalent Bonding Technologies for III-Vs

The firm's new solutions will enable covalent combinations of compound semiconductors, other engineered substrates and heterogeneous materials integration for applications such as high mobility transistors and novel RF devices

nanotechnology and semiconductor markets, is developing equipment and process technology to enable covalent bonds at room temperature.

This breakthrough technology will be available on a new equipment platform, called EVG580 ComBond. It will include process modules that are designed to perform surface preparation processes on both semiconductor materials and metals.

EVG built on its decades of experience with plasma activated wafer bonding to create a novel process through which the treated surfaces form strong bonds at room temperature instantaneously without the need for annealing.

"In response to market needs for more sophisticated integration processes for combining materials with different coefficients of thermal expansion, we have developed a revolutionary process technology that enables the formation of bond interfaces between heterogeneous materials at room temperature," states Markus Wimplinger, corporate technology development and IP director for EV Group.

"Our unparalleled expertise in wafer bonding process technology will allow us to provide different variants of the new process according to the requirements of different substrate materials and applications."

EV Group's new process solutions will enable covalent combinations of compound semiconductors, other engineered substrates and heterogeneous materials integration for applications such as silicon photonics, high mobility transistors, high-performance/low-power logic devices and novel RF devices.

Equipment systems based on a 200mm modular platform, tailored for the specific needs of the new processes, will be available in 2013.

Jordan Valley`s X-ray tool scoops CS Industry Metrology Tool Award 2013

The company's QC3 diffractometer is suited for analysing III-V semiconductor and nitride based LEDs. The production worthy system can accommodate up to 20 wafers in a single measurement process

Jordan Valley Semiconductor has announced that its QC3 diffractometer is the winner of the CS Industry 2013 Metrology, Test and Measurement award.

"The QC3 High-Resolution X-Ray Diffractometer is a true leapfrog technology over the existing X-ray technology within the compound semiconductor," says Paul Ryan, Corporate VP and UK site manager.

Winner of the CS Industry 2013 Metrology, Test and Measurement Award : Jordan Valley for its QC3 X-ray diffractometer

The QC3 boasts more than an order-of-magnitude improvement in performance compared to previous systems, with scans taking seconds rather than minutes or even hours.

The productivity of the QC3 is further enhanced by the multi-sample stage that can accommodate up to 20 wafers in a single measurement process, with fully automated alignment, measurement, analysis and reporting, meaning an operator no longer needs to manually interpret and record data.

The QC3 uses Jordan Valley's RADS analysis software to provide fast and accurate structural information from the X-Ray data. The RADS software is recognised as one of the industry leaders in X-Ray analysis software.

These features of the QC3 system, coupled with the high data quality and throughput, leads to faster identification of epi excursions and their root causes, increasing yield and profit per wafer. Over 50 systems have already been shipped and installed in facilities across the world, mainly in China, Taiwan and USA.

The CS Industry Awards 2013 recognise success and development along the entire value chain of the Compound Semiconductor industry from research to completed device, focusing on the people, processes and products that drive the industry forward.

The CS Industry Awards will remind us what is good about the industry - the people who drive it with their technical expertise and customer orientated perspectives. Nominations are open to all companies, individuals and organisations within the CS industry and voting will occur through Compound Semiconductor online and print services.

"Jordan Valley is extremely proud to be named as winner of CS industry award," says Isaac Mazor, Jordan Valley founder and CEO. "Our growth is a testament to our entire organisation's commitment to technological superiority and to the wide adoption of our x-ray metrology into the advanced semiconductor manufacturing processes as well as other emerging markets such as the LED, GaN and other compound semiconductors."

Jordan Valley Semiconductors (JVS) develops manufactures and sells fully automated metrology tools for advanced technology nodes based on non-contacting and non-destructive tools.

The company offers the semiconductor industry the most comprehensive portfolio of advanced metrology tools, based on technologies such as XRR, XRF, XRD, HRXRD & XRDI (Imaging for defects).

JV provides two other product to the Compound industry: Delta-X for LED and QC Velox that is the next generation HRXRD system for Epi manufactory.

Jordan Valley's investors include Clal Industries and Investments Ltd., Intel Capital and Elron Electronics Industries Ltd..

With headquarters in Migdal Haemek Israel, the company has subsidiaries in Durham UK, Austin Texas USA, Dresden, Germany, Hsin-Chu Taiwan, Suwon Korea and worldwide representatives network.

Praxair prices $500 million of 1.2 percent notes due 2018

The company eventually intends to use the proceeds for general corporate purposes, including repayment of debt and share repurchases

Manufacturer and distributor of atmospheric and process gases used in MOCVD growth, Praxair has priced $500 million of 1.20% notes due March 4th, 2018.

The notes are being offered under the firm's universal shelf registration statement filed with the U.S. Securities and Exchange Commission. The offering is being underwritten by Citigroup Global Markets Inc.

The offering is expected to close on March 4th, 2013. The company anticipates using the proceeds of the offering for general corporate purposes, including repayment of debt and share repurchases under the company's share repurchase program. Prior to their application, the net proceeds may be used to repay short-term debt and/or invested in short-term investments.

The offering is being made by means of a prospectus and related prospectus supplement only.

Brooks Instrument to unveil novel MFC for MOCVD growth

The firm will exhibit its digital solutions for flow, vacuum and pressure measurement and monitoring at SEMICON China

Brooks Instrument will launch the GF135 pressure transient insensitive (PTI) mass flow controller at SEMICON China.

In its first year at SEMICON China, Brooks will showcase the GF135 and other products, along with partner SCH Electronics at booth #5505.

Flow, vacuum and pressure control and monitoring are vital in semiconductor growth, including compound semiconductors grown by MOCVD.

The GF135 improves yield and uptime with real-time integral rate-of-decay flow measurement and advanced diagnostic capabilities to verify accuracy, check valve leak-by and monitor sensor drift without stopping production.

It provides excellent actual process gas accuracy and ultra-fast flow settling time for reduced process cycle time. Onboard diagnostic data logging, zero stability trending and correction, and early detection of valve corrosion or clogging allow semiconductor manufacturers to achieve tighter tolerances

and maintain uniformity in etch profiles and critical dimensions. Brooks says the combination of these features allows the GF135 to deliver exceptional accuracy and cost savings to the semiconductor industry.

In addition, Brooks will demo its GF81 mass flow controller, the new high-flow version of the GF80. The GF81 is the mass flow controller of choice for process engineers in solar, coatings and industrial thin-film applications.

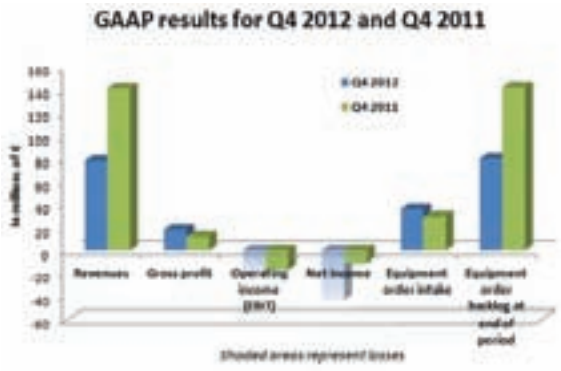
The GF81 offers flow rates up to 300 slpm, as well as a high-purity flow path. Unlike other high-flow mass flow controllers, it has a smaller footprint and offers the broadest range of communication protocols. Brook says the GF81 also provides market-leading process gas accuracy, delivering higher accuracy than competitive high-flow, non multi-gas/multi-range devices.

Aixtron seeing weak order visibility despite rising utilisation rates

The MOCVD tool maker says it experienced its highest 2012 order Intake and revenues recorded in Q4/2012. Management will now focus on cost control and cash flow and continuing R&D investments will be used to fund future market opportunities

Aixtron SE, a provider of deposition equipment to the semiconductor industry, has announced revenues of EUR (€)227.8 million and an EBIT loss of €-132.3m for the fiscal year 2012.

The firm also reported its Q4/2012 results which are depicted in the graph below.



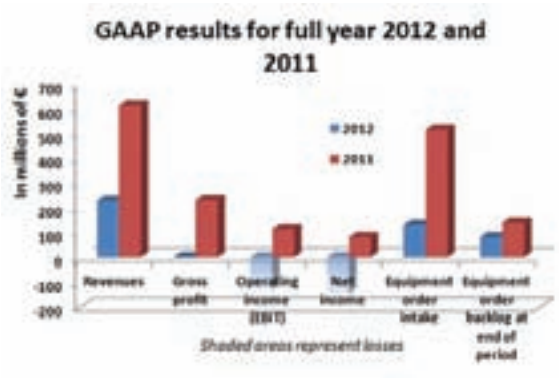
A slow recovery of revenues, but a virtually flat order intake throughout the year reflects a reluctant investment attitude by customers and a continuation of macroeconomic uncertainty.

Despite an improving market consensus on the potential outlook for the back end of 2013, management is unable at this stage to offer a precise revenue and EBIT margin guidance for the year, due to the prevailing low visibility.

Financial Highlights

Throughout fiscal year 2012, Aixtron customers remained hesitant in adding significant LED manufacturing capacity, despite increasingly high utilisation rates at some mainline Asian manufacturers.

Aixtron recorded revenues of €227.8 million for the full year 2012, which although nearly €8 million higher than the Q3 forecast for the full year, still represents a decrease of €383.2 million, or 63 percent, compared to €611.0 million in 2011. H2/2012 revenues were however about 58 percent higher than H1/2012.



Total order intake in 2012 was €131.4m, 74 percent down compared to 2011 (€513.4 million) although H2/2012 orders were c. 14 percent higher than H1/2012.

The year-end order backlog stood at €79.4 million on December 31st, 2012; 44 percent lower than at the same time in 2011 (December 31st, 2011: €141.0 million). One third of this percentage point reduction came from the €19 million order backlog adjustment made in Q3/2012.

The second half order intake development that became clearer in Q3/2012 did not constitute the expected second half market recovery and was catalyst for a thorough internal review into the immediate outlook. The management conclusion, announced in October 2012, was that the opening year objective of remaining EBIT profitable in 2012 was not achievable.

The accompanying risk assessment that was conducted as part of this business review also concluded that the likelihood of ongoing subdued demand necessitated the reduction in value of certain work in progress assemblies, components and spare parts. As a result, the company executed a significant write-down of inventories in Q3/12.

The subdued business environment, evident throughout the year 2012, had the consequent effect on Aixtron's 2012 earnings. Gross profit declined to €400 thousand (2011: €231.4million) and EBIT turned negative to €-132.3 million (2011: €112.9 million). The company continues to implement cost reduction measures which include both efficiency improvements and cost reductions measures throughout the organisation.

The 2012 net result of €-145.4 million, was considerably down from the €79.5 million recorded in 2011 and resulted in a basic loss per share of €-1.44 (2011: earnings of €0.79).

Appropriation of Net Loss

Aixtron's Executive and Supervisory Boards will propose to the shareholders' meeting that the 2012 loss should be carried forward and consequently no dividend for 2012 will be distributed.

Management Review

Management expects demand for MOCVD production equipment to potentially improve as demand for LEDs increases later in the current year. On the same timeline, management also envisages incremental equipment demand coming from non-LED emerging MOCVD applications and other technology markets, including silicon and organic semiconductor applications.

Nevertheless, the exact timing of that order intake pickup is difficult to predict whilst order visibility remains so low.

Paul Hyland, President & Chief Executive Officer of Aixtron says, "2012 proved to be an exceptionally challenging year for Aixtron, largely due to the severe and extended macroeconomic headwinds that the whole world has been suffering from. Our original expectation that 2012 would develop into a transitory year with the prospect of a significantly better second half has evidently not materialised."

"However, the ongoing, albeit low level of demand we have seen in the second half of 2012 and into 2013, encourages us to reiterate our view that we have reached the bottom of the current cycle and that we might reasonably expect to see further market recovery at some point during 2013 driven by increasing demand for LED manufacturing equipment."

"We also remain confident that we will see increased demand for our manufacturing equipment for non-LED applications such as power electronics, silicon or organic applications going forward. Despite the current short-term challenges, we will continue to invest into the development of manufacturing technologies for these and other emerging markets to secure our technological leadership and stay 'fit for the future', adds Hyland.

Outlook

Despite the generally more positive outlook for the year 2013, there remains a high degree of uncertainty about the timing of a significant order recovery and management is consequently unable to offer a precise revenue and EBIT margin guidance for the year at this time.

The call may be accessed by dialling in at +49 (69) 247501–899 or +1 (212) 444–0297. A conference call audio replay or a transcript of the conference call will be available at http://www.Aixtron.com, section "Investors, Reports/Presentations", following the conference call.

NIT unveils InGaAs wide ranging SWIR camera

The firm's indium gallium arsenide photodiodes are suited for signals from 900nm to 1700nm

New Imaging Technologies (NIT) has introduced the wide dynamic range (WiDy) short wave infrared (SWIR) camera, integrating a wide dynamic range (WDR) InGaAs sensor operating from 900 nanometres (nm) to 1700nm.

The WiDy SWIR uses a 320 × 256-pixel InGaAs photodiode array sensor coupled to the NIT NSC0803 WDR read-out integrated circuit (ROIC) from NIT.

The InGaAs photodiodes provide a high quantum efficiency (QE) signal response from 900nm to 1700nm. When used with the NIT WDR ROIC technologies, the InGaAs photodiodes deliver more than 140 decibels of dynamic range in a single image without any external control.

The WiDy SWIR has a simple USB digital output and is delivered with WiDyWiew software operating under Microsoft Windows. The frame rate is software-controllable from 1 hertz (Hz) to 150Hz and can be synchronised from an external input/output signal.

Potential applications include laser measurements, high temperature thermography, waste sorting, biomedical imaging and more.

New VP Linda Reinhard to take sapphire forward at GT

Reihard's initial focus will be on growing sapphire material and the ASF equipment business which is primarily used by the LED industry

GT Advanced Technologies has appointed Linda Reinhard as vice president, new business development and product management for the company's sapphire, DSS and HiCz products.

She will report to Dan Squiller, GT's chief operating officer. Reinhard will be responsible for leading GT's growth into new market segments and driving the product roadmap to capitalise on these new opportunities including sapphire for cover and touch screen applications.

"Linda brings deep experience and a proven track record in both product management and new business development," says Dan Squiller, GT's chief operating officer. "Linda's initial focus will be on growing our sapphire material and ASF equipment business, particularly new opportunities in the cover and touch screen markets. She has extensive experience in Asia as well as in the mobile device segment which we believe could be a significant area of opportunity for our sapphire business. Linda will also drive our product management and

new business development for HiCz and our traditional PV business."

GT's Advanced Sapphire Growth Furnaces (ASF) is a production proven furnace that produces high quality sapphire material for the LED industry.

GT's ASF furnace

Reinhard received her BSEE from University of Illinois and an MBA from The Kellogg Graduate School of Management. She has over 20 years of experience with leading technology companies including Motorola, Cisco, Nokia, and H-P holding senior level positions in new business development, marketing, sales, and product management. She has lived in Asia and has extensive experience in China and Asia Pacific evangelising and introducing new products to major OEMs. Reinhard will be located in GT's headquarters in Merrimack, New Hampshire.

"Our goal for the show is to continue educating the market about the unique properties of GT's ASF-grown sapphire material for cover and touch screen applications," says Linda Reinhard, GT's vice president of business development and product management.

"ASF-grown sapphire's durability and resistance to scratching makes it ideally suited for a wide range of cover and touch screen applications from ruggedised phones, camera covers, point of sale devices and smartphone and touch screen devices. Other reinforced glass and cover screen technologies try to emulate what ASF-grown sapphire does naturally."

GT Advanced Technologies Inc. is a global provider of polysilicon production technology and sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets. The company says its products and services allow its customers to optimise their manufacturing environments and lower their cost of ownership.

Rubicon six inch sapphire sales make up for cheaper small cores

The provider of sapphire substrates and products to the LED, RFIC, semiconductor, and optical industries saw strong demand for six-inch polished wafers in the quarter, particularly from the LED market

Rubicon Technology, Inc. of Bensenville, IL, USAhas reported financial results for its fourth quarter ended December 31st, 2012.

The company reported fourth quarter revenue of $20 million as compared with $19.9 million in the prior quarter. Revenue from six-inch wafer sales showed another sequential increase to $17.5 million from $16.4 million in the prior quarter, a 7 percent increase.

Due to low industry pricing for two through four inch core products, the company decided to sell a limited quantity of those products in the quarter.

Raja Parvez, President and CEO of Rubicon Technology, comments, "We saw strong demand for our six-inch polished wafers in the quarter, particularly from the LED market. We continue to be the largest provider of six-inch polished wafers in the market due to our strength in both large diameter crystal growth and large diameter polishing, evidenced by the fact that we have now shipped over 400,000 polished six-inch wafers to date into the LED and SoS markets."

While the pricing environment has not improved for two through four inch core products, Rubicon has started taking orders for those products for delivery in the first and second quarters in order to begin reducing inventory levels and maintain customer relationships. With the firm's resumption of sales into this market, pricing has decreased further.

William Weissman, CFO of Rubicon Technology, says, "Current pricing of two through four inch core products is now below our carrying cost in finished goods and WIP inventory for those products. As a result, we recorded a $1.6 million adjustment in the period to reflect the value of those products in inventory at the current market price."

He continues, "We believe that our competitors are now selling smaller diameter cores at cash cost in order to reduce inventory or to keep utilisation rates high. However, excess capacity in the market is gradually being absorbed and we believe the pricing environment should eventually improve. Exactly when and how quickly pricing will improve is difficult to predict."

The company reported a sequential reduction in margins due primarily to the lower smaller diameter product pricing and resulting inventory adjustment. The loss per share in the fourth quarter was $(0.05) as compared with a diluted EPS in the third quarter of a positive $0.01 per share.

First Quarter 2013 Guidance

Commenting on the outlook for the first quarter of 2013, Parvez

says, “With the accelerating growth of the general lighting sector of the LED market and with the increasing complexity of mobile devices creating greater opportunity for SoS technology, I am very excited by the longer term growth potential of the markets we serve.

However, they are evolving markets and we will likely continue to see shorter term volatility. In the first quarter, our six-inch wafer orders will be lower. Similar to what we experienced last year, our largest LED customer for six-inch wafers has excess inventory and will not likely need additional material until the second quarter. “

“Also, our SoS customer recently announced that their orders are down based on weaker than expected sales by a key end customer. However, they also expressed confidence in a strong second half of the year based on the expected introduction of new smartphone models by their end customers later in the year. As a result, six-inch revenue will be lower in the first quarter. But, we believe we will see strong orders for six-inch wafers in the second half from both the SoS and LED markets.”

Rubicon expects first quarter revenue to be approximately $8 million, down sequentially due to lower six-inch wafer sales. With the reduced sales volumes, utilisation rates will be low in both crystal growth and polishing, putting pressure on the company’s margins in the quarter. As a result, the company expects a loss per share between $(0.10) and $(0.14) in the first quarter based on 22.5 million shares outstanding and a 50 percent tax benefit.

S3 to distribute Trion semiconductor tools in Europe

The manufacturer of plasma etch, strip and deposition systems for critical surfaces in the semiconductor and related industries has signed an agreement with S3 Alliance. S3 will work with R&D, MEMS and production fabs

Trion Technology has formed a strategic alliance with European distributor, S3 Alliance.

S3 Alliance will distribute and support Trion’s full line of products to customers throughout Europe.

S3 Alliance provides Trion Technology further penetration into the European market with an installed service and support network. Trion’s products expand S3 Alliance market offerings to the European customer base.

“We are pleased to be working with Trion Technology” says Thomas Riedel, Managing Director of S3 Alliance GmbH. “They have a strong product range for production descum and photoresist removal and have extensive experience with RIE etching, ICP and microwave plasma generation as well as for PECVD. Trion products are perfectly enhancing our portfolio for our common targeted markets.

“We have contacted most of the existing European customers and have had only positive feedback,” adds Thomas Riedel.

S3 Alliance will be working with R&D, MEMS and production fabs. Key accounts include major companies in the semiconductor industry, government research, universities, and research and development laboratories.

“This alliance demonstrates Trion’s continued dedication to providing world-class customer service and support,” continues Randy Crockett, President of Trion Technology. “We believe that providing highly responsive service is an essential factor in making our customers happy.”

Founded in 1989, Trion Technology, Inc. of Clearwater, Florida, USA supplies a variety of plasma etch and deposition equipment for the manufacturing of compound semiconductors and MEMS.

Trion’s products feature the smallest footprint and lowest cost systems in the industry with proven production reliability.

S3 Alliance is a European trading and service company with a broad product portfolio in the semiconductor and related industries.

Avantes advances its Fibre Optic Multiplexers

The firm has revealed a new range of broadband fibres, which combine the advantages of high OH solarisation resistant fibre for the UV with low OH fibre for the NIR

Manufacturer of fibre optic spectroscopy instruments and systems, Avantes, has released a new generation of Fibre Optic Multiplexers (FOMs).

They are faster, more reliable and quieter than ever before. The FOM easily integrates to Avantes’ advanced spectroscopy software AvaSoft.

Avantes FOM

Fibre Optic Multiplexers enable single or multiple light sources and spectrometers to make multi-point serial measurements. This new generation now features USB 2.0, complete integration into AvaSoft and full Avantes DLL support.

All next generation Fibre Optic Multiplexers are supplied with the new broadband fibres exclusive to Avantes. Broadband fibres combine the advantages of high OH solarisation resistant fibre for the UV with low OH fibre for the NIR.

Broadband fibre is a huge leap forward for fibre optic spectroscopy applications which have historically been forced to choose between UV/VIS and NIR fibre or combine two types of fibre into an assembly making it more costly and complex.

Benno Oderkerk, founder and CEO of Avantes says, "Our Fibre Optic Multiplexers see a wide variety of usage in our customer base. The great advantage is the flexibility in which measurements can be done. Furthermore, the extensive programming possibilities mean that even in setups with different integration times, the Avantes FOM will allow a suitable setting."

The FOM is available in three different versions: 1 x 16, 2 x 8 and 4 x 4. As standard, they are supplied with 400µm fibre optic cables. Any other diameter is available on request.

Aixtron appoints new general manager in Korea

The aim of the new GM is to help Korea become one of the world's major countries employing MOCVD manufacturing technology

Aixtron SE has taken on SukYoung Kim as General Manager of its subsidiary Aixtron Korea Co., Ltd.

SukYoung Kim, GM Aixtron Korea Co., Ltd.

Kim has been working in the international semiconductor industry in Korea and the USA for many years and most recently held the position of Regional President and Representative Director of Novellus Systems in Korea.

In his new position as General Manager at Aixtron Korea, he takes over strategic and operational responsibility from Eun Sook (E.S.) Choi who held this position at Aixtron Korea until now. Choi will further support Aixtron as a consultant.

Bernd Schulte, Executive Vice President and Chief Operating Officer of Aixtron SE, says, "Korea is one of the global centres of advanced high-power LED products with many important key players. I am delighted to announce the appointment of SukYoung, which demonstrates the strategic importance of Korea's significance as a key market within Aixtron."

Kim comments, "Aixtron has highly advanced technology not only in compound, but also silicon and organic semiconductors. Our target is to support our Korean customers' strategies for further development and to provide leadership across the business sector, helping Korea become one of the world's major countries employing MOCVD manufacturing technology."

Aixtron CEO quits

LED expert and ex Osram board member Martin Goetzeler will take over from Paul Hyland on March 1st, 2013

MOCVD tool manufacturer Aixtron is having a tough time.

Less than a month ago, Holger Jürgensen (deputy chairman of the supervisory board) and Karl-Hermann Kuklies (ordinary member of the supervisory board) of Aixtron, both resigned.

The firm has also recently had a round of redundancies.

Now, Aixtron SE has announced that Paul Hyland, President and CEO, will leave the company by mutual agreement with effect as of February 28th, 2013, for personal reasons.

Paul Hyland, President and CEO of Aixtron SE

The Supervisory Board has appointed Martin Goetzeler (50), an internationally experienced top manager and industry expert, as Hyland's successor. Goetzeler will join the company on March 1st, 2013.

Within the Executive Board, he will be responsible for the areas strategy, production, purchasing and logistics, investor relations and group communication.

Before his appointment Goetzeler served on the executive board of Siemens' subsidiary Osram and also held various international leadership positions within the Siemens group. He is an acknowledged expert in the LED and lighting industry.

For many years, Martin Goetzeler served as President of the European Technology Platform Photonics21, which, among other things, advises the European Commission in determining major strategic research in the area of photonics.

His extensive experience in the target markets of Aixtron will further strengthen Aixtron's technology leading position in a period of considerable market change. Goetzeler says, "I am

looking forward to the task of leading Aixtron as a leading provider of semiconductor technology production solutions along the way towards industrial mass production."

He adds, "We have the opportunity to address some of the current social megatrends such as energy efficiency and intelligent networking, which are dominated by LEDs, OLEDs and power electronics. There is substantial growth potential for Aixtron in all of these areas."

Hyland comments, "I am very pleased that I had the opportunity to participate in Aixtron's route to becoming a globally acknowledged leading technology company. I am pleased to be able to hand over the CEO role to Mr. Goetzeler at this time. Mr. Goetzeler can build on a solid foundation, and he has both the leadership qualities and experience to take Aixtron successfully onto the next level."

Kim Schindelhauer, the chairman of the Supervisory Board of Aixtron SE, expressed his gratitude to Hyland for his contributions to the company and says, "Mr. Hyland has successfully managed the Company during his tenure through many ups and downs in the semiconductor industry. For this, we would like to express our great appreciation. We are delighted to have found someone like Mr. Goetzeler, a versatile manager with extensive knowledge in the high-tech market and international experience. Mr. Hyland will actively support Mr. Goetzeler in taking up his office and ensure a smooth transition."

Laytec upgrades in-situ GaN LED monitoring system

The firm's latest UV pyrometer incorporates real-time UV emissivity correction for enhanced accuracy of gallium nitride surface temperature during the growth of complex LED structures

In an ideal world, LED manufacturers would know the emission wavelength of the final device during MOCVD growth.

Today, according to the Solid State Lighting road map, the wavelength variation across a wafer should be less than 1 nm. This means a less than 1 K (10C) variation of the GaN surface temperature during InGaN MQW growth.

LayTec's Pyro 400 is widely used for enabling fab-wide GaN surface temperature uniformity in many LED manufacturers production lines.

Meanwhile, more complex LED structures and tighter cost reduction targets need even more advanced *in-situ* metrology. Figure 1, below, shows such an example; ternary InGaN and AlGaN layers cause emissivity changes that lead to 0.7 K error of the UV pyrometry reading.

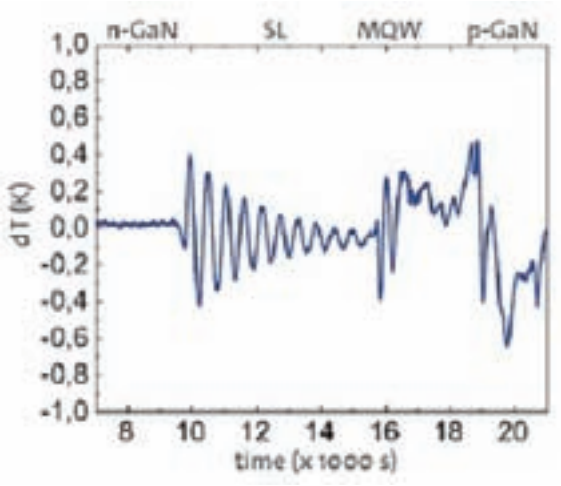


Figure 1: Effect of changing emissivity to UV pyrometer temperature reading: up to 0.7 K errors show up without emissivity correction during growth of a GaN/AlGaN-GaN-SL/ InGaNMQW/ GaN structure

LayTec's answer to this challenge is the Pyro 400 Gen 2. Along with *in-situ* UV pyrometry the new generation tool includes real-time UV emissivity correction for enhanced accuracy of GaN surface temperature during growth of more complex LED structures.

A further challenge to reliable GaN temperature control in HB-LED production is the view-port coating.

Figure 2 shows its effect just before maintenance; the UV transmission of the view-port is significantly reduced and an uncorrected UV pyrometer would give a -10 K temperature artefact. Pyro 400 Gen 2 solves this problem,too. Laytec claims the tool automatically senses and corrects these coatings and enables a long-lasting 24/7 accuracy in HB-LED emission wavelength.

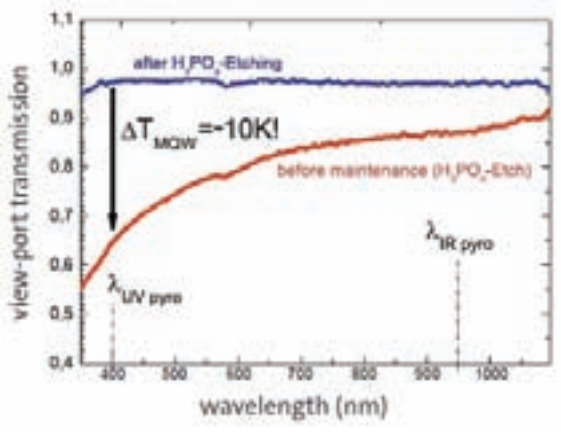


Figure 2: GaN MOCVD view-port before (red) and after maintenance (blue): the transmission at the 400nm detection wavelength of a UV pyrometer is suffering from the window coating (red). The resulting -10K artifact is avoided by Pyro 400 Gen2

Last, but not least, an assisting infrared pyrometer has been integrated into Pyro 400 Gen 2 for simultaneous monitoring of wafer pocket temperature throughout the full LED growth run.

NANEO extends production capacity with Veeco IBD tool

The SPECTOR system will be used to produce high quality optical products such as lasers and those used in Raman spectroscopy, telecommunications, and aerospace

NANEO Precision IBS Coatings GmbH, an optical coatings company located in Rheinbreitbach, Germany, has recently ordered a Veeco SPECTOR Ion Beam Deposition (IBD) System.

The SPECTOR system will be used to produce high quality optics in a broad range of applications including ultrafast optics, high power lasers, Raman spectroscopy, telecommunications, and aerospace.

SPECTOR IBD Optical Coating System

Daniel Kopf, Chief Executive Officer at NANEO, comments, "Veeco's SPECTOR IBD system allows us the process flexibility needed to meet growing demand for our high precision optics providing excellent precision and uniformity, lowest loss and high laser damage threshold. Veeco's reliable platform makes them an ideal partner as we ramp production."

James Northup, Veeco's Vice President and General Manager, comments, "We are pleased NANEO chose our system for their manufacturing expansion. The SPECTOR IBD Optical Coating System enables users to manufacture the highest precision and quality films meeting the performance requirements for virtually every optical thin film coating application. We look forward to providing excellent support and service to the NANEO team as they increase production."

NANEO specialises in the production of custom made precision optical coatings for high end applications in the laser and photonics industry. The company produces high precision coatings for applications in the fields of high power lasers, high power beam combination, ultrafast lasers, optical measurement systems, telecommunications, aerospace and scientific research.

SEMI-GAS Systems upgrades GSM controller for safer MOCVD growth

The new semi-automatic Megaturion Bulk Valve Manifold Box safely and continuously distributes hazardous process gases as needed, in high flow semiconductor and LED manufacturing applications

SEMI-GAS Systems, a supplier of ultra-high purity gas source and distribution systems, recently updated the GigaGuard GSM (gas safety monitor) controller on its Megaturion Bulk Valve Manifold Box (VMB).

GSM (Gas Safety Monitor) Front View

The new controller is easier to use and provides additional safety features to the system.

The upgraded GigaGuard GSM controller, which supersedes the GSM 1 x 4, is PLC based and features a modern 4.3" colour touch screen. A user-friendly software design features intuitive prompts and alarms, which help to reduce operator error and increase safety.

With the upgraded controller, operators now have the ability to configure both inputs and outputs as well as adjust set points and limits, making the system more adaptable than the previous GSM 1 x 4 controller.

What's more, the GigaGuard GSM independently operates ESO valves, monitors both analogue and digital process sensors, displays delivery pressures and continuously monitors the system environment for hazards while maintaining an active alarm log. To further improve operational safety, the controller incorporates local and remote system shutdown capabilities in the event of a system trip.

Available in 4, 6 and 8 stick configurations as well as in customised designs, the semi-automatic Megaturion VMB safely and continuously distributes hazardous process gases from the source to various tools and points of use, as needed, in high flow semiconductor and LED manufacturing applications.

The GSM enclosure is constructed of welded 16 Ga steel. The flip-down door provides easy access to the system components, including the Siemens S7-1200 series PLC.

Additional standard features include a SEMI-approved EMO (emergency off) button, pneumatic valve manifold and multi-colour LED panel status lights.

Applied Energy Systems, Inc. designs, manufactures, and installs high purity gas delivery systems, as well as provides precision welding services, high purity piping installations and field services for the semiconductor research and development markets.

Riber to sell two MBE reactors in Asia

The repeat order will enable the customer to further develop new material and structures

Riber has announced the sale of two MBE 412 systems to a leading company in Asia.

Benefiting from a high performance, the model 412 system is designed for the development of highly sophisticated semiconductors.

The MBE 412 (multi 2'' or 4'') capacity system was selected as this platform is optimised for this type of application.

These two model 412 orders are a repeat business and will enable the customer to further increase its development activities on new materials and structures.

The system 412 is the latest system developed by Riber which takes into account the increase in complexity of new semiconductor structures. It allows customers to design and grow structures with 12 different materials.

With more than 800 MBE machines installed globally, Riber has successful industrial experience, The firm is one of the leaders in the MBE-based compound semiconductor deposition market.

The ISO 9001 certified company recorded €27.4 million in revenues in 2012 and employs 111 people.

KLA-Tencor issues cash dividend

KLA-Tencor Corporation has declared a quarterly cash dividend of $0.40 per share on its common stock payable on March 1st, 2013 to KLA-Tencor stockholders of record as of the close of business on February 19th, 2013.

KLA-Tencor Corporation, a provider of process control and yield management solutions, partners with customers around the world to develop inspection and metrology technologies.

These technologies serve the semiconductor, LED and other related nanoelectronics industries. With a portfolio of industry-standard products and a team of engineers and scientists, the company has created solutions for its customers for more than 35 years.

Bernard Raboutet resigns from Riber supervisory board

MBE tool manufacturer Riber has announced the resignation of Bernard Raboutet from his position on the company's supervisory board which came into effect on February 5th, 2013.

Riber thanks Bernard Raboutet for his contributions to the board.

Novel Devices

A novel spectroscopy to enhance optical devices

A new technique developed by university researchers could lead to better LEDs, solar cells, and other devices that use layered nanomaterials

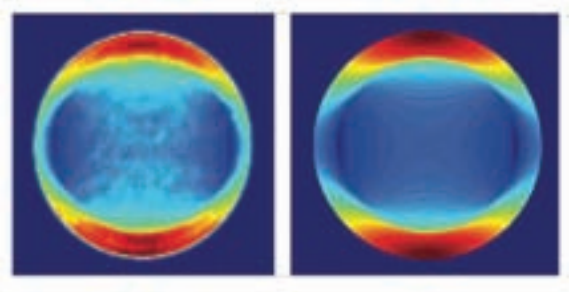
Understanding the source and orientation of light in light-emitting thin films, is now possible with energy-momentum spectroscopy.

This could lead to improvements in optical device performance.

A multi-university research team has used this new spectroscopic method to gain a key insight into how light is emitted from layered nanomaterials and other thin films.

Energy-momentum spectroscopy, enables researchers to look at the light emerging from a thin film and determine whether it is coming from emitters oriented along the plane of the film or from emitters oriented perpendicular to the film.

Knowing the orientations of emitters could help engineers make better use of thin-film materials in optical devices like LEDs or solar cells.



The orientation of light emission - The angular distribution of light emission from monolayer MoS2 , left, closely matches the theoretical calculations for in-plane oriented emitters, right, indicating that light emission from MoS2 originates from in-

plane oriented emitters. (Credit: Zia lab/Brown University)

The research, published online on March 3rd in *Nature Nanotechnology*, was the collaborative effort of scientists from Brown University, Case Western Reserve University, Columbia University, and the University of California - Santa Barbara.

The new technique takes advantage of a fundamental property of thin films: interference.

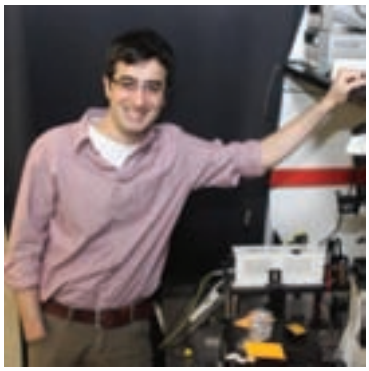
Interference effects can be seen in the rainbow colours visible on the surface of soap bubbles or oil slicks. Scientists can analyse how light constructively and destructively interferes at different angles to draw conclusions about the film itself - how thick it is, for example. This new technique takes that kind of analysis one step further for light-emitting thin films.

"The key difference in our technique is we're looking at the energy as well as the angle and polarisation at which light is emitted," says Rashid Zia, assistant professor of engineering at Brown University and one of the study's lead authors. "We can relate these different angles to distinct orientations of emitters in the film. At some angles and polarisations, we see only the light emission from in-plane emitters, while at other angles and polarisations we see only light originating from out-of-plane emitters."

The researchers demonstrated their technique on two important thin-film materials, molybdenum disulphide (MoS2) and PTCDA. Each represents a class of materials that shows promise for optical applications. MoS2 is a two-dimensional material similar to graphene, and PTCDA is an organic semiconductor. The research showed that light emission from MoS2 occurs only from in-plane emitters. In PTCDA, light comes from two distinct species of emitters, one in-plane and one out-of-plane.

Rashid Zia continues, "If you were making an LED using these layered materials and you knew that the electronic excitations were happening across an interface, then there's a specific way you want to design the structure to get all of that light out and increase its overall efficiency."

The same concept could apply to light-absorbing devices like solar cells. By understanding how the electronic excitations happen in the material, it could be possible to structure it in a way that converts more incoming light to electricity.



Rashid Zia

Zia also points out that once the orientation of the emitters is known, it may be possible to design structured devices that maximise those directional properties.

In most applications, thin-film materials are layered on top of each other. The orientations of emitters in each layer indicate whether electronic excitations are happening within each layer or across layers, and that has implications for how such a device should be configured.

"One of the exciting things about this research is how it brought together people with different expertise," Zia notes. "Our group's expertise at Brown is in developing new forms of spectroscopy and studying the electronic origin of light emission. The Kymissis group at Columbia has a great deal of expertise in organic semiconductors, and the Shan group at Case Western has a great deal of expertise in layered nanomaterials. Jon Schuller, the study's first author, did a great job in bringing all this expertise together. Jon was a visiting scientist here at Brown, a postdoctoral fellow in the Energy Frontier Research Centre at Columbia, and is now a professor at UCSB."

This work is further detailed in the paper, " Orientation of luminescent excitons in layered nanomaterials," by Jon A. Schuller *et al* in *Nature Nanotechnology* (2013), published online on 3rd March 2013. DOI: 10.1038/nnano.2013.20

Funding for the work was provided by the Air Force Office of Scientific Research, the Department of Energy, the National Science Foundation, and the Nanoelectronic Research Initiative of the Semiconductor Research Corporation.

Opel makes breakthrough with POET based n- and p-transistors

The result builds on the previous GaAs (gallium arsenide) based VCSEL milestone. It is a further verification that III-Vs can compete with silicon CMOS in WDM capable optoelectronic devices and functions, FETs and bipolar devices

Opel Technologies has achieved Milestone 4 in its Planar Optoelectronic Technology (POET), achieving radio frequency and microwave operation of both *n*-channel and *p*-channel transistors.

With this achievement, POET extends the capability of its unique monolithic platform to cover integration of a complete range of wavelength-division multiplexed (WDM) capable optoelectronic devices and functions.

This is in addition to complementary electronics based on *n*-channel and *p*-channel transistors as either field effect transistors (FETs) or bipolar devices.

For this milestone, 3inch POET wafers fabricated at BAE Systems (Nashua, NH) yielded submicron *n*-channel and micron-sized *p*-channel transistors operating at frequencies of 42 GHz and 3 GHz respectively. These operating frequencies are expected to be improved even further in the short term to

up to 300-350 GHz range for the *n*-channel device.

Peter Copetti, Executive Director of Opel, notes, "Following the success of our Vertical Cavity Surface Emitting Laser milestone achieved recently, this result further verifies POET's electronic and optical monolithic compatibility, a key advantage of POET as a silicon CMOS replacement. Our on-chip optical generation and detection capability is unique in the semiconductor industry."

Progress on Taylor's work at the Opel lab had been delayed by damage sustained to key equipment during a multi-day power outage caused by Tropical Storm Sandy in late October 2012. However, the rebuild is expected to be completed next week, and the company expects the affected equipment will be recalibrated and operational again by the end of March 2013.

Copetti adds, "Given the calibre of the POET team, we are confident that the lost time will be made up so that it will not have a material impact on the milestone target dates."

At the successful conclusion of the recent private placement fundraising, approximately $1.3 million in new capital equipment was ordered to upgrade the R&D facility capabilities. The company has completed all necessary site infrastructure upgrades and is awaiting the arrival of the new equipment.

Opel expects the new equipment will be installed, calibrated, and commissioned by the end of June, 2013.

By enabling increased speed, density, reliability, power efficiency, and much lower bill-of-materials and assembly costs, POET provides a new technology direction and opportunity for the semiconductor industry.

POET will allow continued advances of semiconductor device performance and capabilities for many years, overcoming the current power and speed bottlenecks of silicon-based circuits,. Opel believes it will change the future development roadmaps of a broad range of semiconductor applications including mobile devices, computer servers, storage arrays, imaging equipment, networking equipment, transportation systems, and test and measurement instruments.

Connecting indium antimonide quantum dots

A novel spin technique has allowed scientists to move closer to creating what they say is the first viable high-speed quantum computer

Recent research offers a new spin on using nanoscale semiconductor structures to build faster computers and electronics. Literally.

University of Pittsburgh and Delft University of Technology researchers have revealed a new method that better preserves the units necessary to power lightning-fast electronics, known as qubits (pronounced CUE-bits).

The scientists explored InSb (indium antimonide) quantum dots in their study.

Hole spins, rather than electron spins, can keep quantum bits in the same physical state up to ten times longer than before, a new report by the scientists, finds.

"Previously, our group and others have used electron spins, but the problem was that they interacted with spins of nuclei, and therefore it was difficult to preserve the alignment and control of electron spins," says Sergey Frolov, assistant professor in the Department of Physics and Astronomy within Pitt's Kenneth P. Dietrich School of Arts and Sciences, who did the work as a postdoctoral fellow at Delft University of Technology in the Netherlands.

Whereas normal computing bits hold mathematical values of zero or one, quantum bits live in a hazy superposition of both states. It is this quality, said Frolov, which allows them to perform multiple calculations at once, offering exponential speed over classical computers. However, maintaining the qubit's state long enough to perform computation remains a long-standing challenge for physicists.

"To create a viable quantum computer, the demonstration of long-lived quantum bits, or qubits, is necessary," continues Frolov. "With our work, we have gotten one step closer."

The holes within hole spins, Frolov explains, are literally empty spaces left when electrons are taken out. Using extremely thin filaments called InSb nanowires, the researchers created a transistor-like device that could transform the electrons into holes.

They then precisely placed one hole in a nanoscale box called "a quantum dot" and controlled the spin of that hole using electric fields. This approach - featuring nanoscale size and a higher density of devices on an electronic chip - is far more advantageous than magnetic control, which has been typically employed until now, notes Frolov.

"Our research shows that holes, or empty spaces, can make better spin qubits than electrons for future quantum computers."

Graphic displaying spin qubits within a nanowire

"Spins are the smallest magnets in our universe. Our vision for a quantum computer is to connect thousands of spins, and now we know how to control a single spin," Frolov adds. "In

the future, we'd like to scale up this concept to include multiple qubits."

This work is further described in the paper, "Electrical control over single hole spins in nanowire quantum dots," by V. S. Pribiag *et al* in *Nature Nanotechnology, (2013)*. DOI:10.1038/nnano.2013.5

The research was supported by the Dutch Organisation for Fundamental Research on Matter, the Netherlands Organisation for Scientific Research, and the European Research Council.

Frolov and his Netherlands colleagues were recent winners of the 2012 Newcomb Cleveland Prize, an annual honour awarded to the author/s of the best research article/report appearing in Science, which is published weekly by the American Association for the Advancement of Science (AAAS).

Lattice location determines trace nitrogen dopants in SiC

A new technology is expected to contribute to the optimisation of the doping process of silicon carbide. The SC-XAFS techniques could also be applied to the analysis of other wide-gap semiconductors such as GaN (gallium nitride)

Researchers have developed an instrument for X-ray absorption fine structure (XAFS) spectroscopy equipped with a superconducting detector.

The study was conducted by Masataka Okubo and others from the Research Institute of Instrumentation Frontier of the National Institute of Advanced Industrial Science and Technology, in collaboration with the Institute of Materials Structure Science of the High Energy Accelerator Research Organisation and Ion Technology Centre Co., Ltd.

With the instrument, the researchers say they have realised, for the first time, local structure analysis of nitrogen dopants (impurity atoms at a very low concentration), which were introduced by ion plantation in SiC, a wide-gap semiconductor, and are necessary for SiC to be a*n*-type semiconductor.

Wide-gap semiconductor power devices, which enable reduction of power loss, are expected to contribute to the suppression of CO2 emissions. To produce devices using SiC, one of the typical wide-gap semiconductor materials, introduction of dopants by ion plantation is necessary for the control of electrical properties.

The dopant atoms need to be located in the particular lattice site in a crystal. However, there has not been a microstructural analysis method.

SC-XAFS was used to measure the XAFS spectra of the nitrogen dopants at a very low concentration in the SiC crystal, and the substitution site of the nitrgoen dopants was determined by comparison with a first-principle calculation. In addition to SiC, SC-XAFS can be applied to wide-gap semiconductors such as GaN and diamond, magnets for low-loss motors, spintronics devices, solar cells, etc.

The superconducting X-ray detector developed by AIST, used to identify N dopants at a very low concentration in SiC (left) and SC-XAFS installed at a beam line of Photon Factory, KEK (right)

SiC has a band gap larger than that of general semiconductors and possesses excellent properties including chemical stability, hardness, and heat resistance. Therefore, it is expected to be a next-generation energy-saving semiconductor which can function in a high-temperature environment.

In recent years, large single-crystal SiC substrates have become available and devices such as diodes and transistors appeared on the market; however, doping, which is necessary to produce devices with the semiconductor, is still imperfect, preventing SiC from fully utilising its intrinsic energy-saving properties.

Doping is a process in which a small amount of impurity is introduced (for substitution) into a crystal lattice site to form a semiconductor with electrons playing a major role in electrical conduction (*n*-type semiconductor) or with holes playing a major role in electrical conduction (*p*-type semiconductor).

SiC is a compound, and thus has a complex crystal structure, which means that doping SiC is far more difficult than doping silicon .

Since dopants should be light elements such as boron, nitrogen, aluminium, or phosphorus, there was no measurement method to study at which site in the SiC crystal they are located, namely the silicon site or the carbon site. Although transmission electron microscopy can visualise atoms, it is difficult to distinguish a trace light element from light elements constituting the matrix material.

To determine dopant lattice sites, XAFS spectroscopy is effective. X-ray fluorescence analysis allows to measure XAFS spectra of a specific element in matrices, and reveals the atomic arrangement and the chemical state around the element.

So far, however, it has been impossible to distinguish the characteristic X-ray of a light element at a very low concentration from those of the matrix elements, silicon and carbon. The lack of the analysis method has hindered the development of wide-gap semiconductors.

AIST has been developing advanced measurement technologies for industrial research and scientific studies, making them available for public use, and standardising them. As a part of these efforts, SC-XAFS using a superconducting measurement technology was completed in 2011.

Nitrogen has an atomic number larger than carbon by one. The energy of its characteristic X-ray is 392 electron volts (eV); the

difference from that of carbon, 277 eV, is only 115 eV.

Although the energy resolution of the latest semiconductor X-ray detectors is 50 eV or so, which is smaller than the difference, at this resolution, while light elements can be distinguished if they exist in a large mount, it is not possible to distinguish a light element at a very low concentration, such as dopants.

In contrast, the superconducting X-ray detector developed by AIST has the resolution that exceeds the theoretical limitation of semiconductor X-ray detectors. Therefore, it is possible to measure the XAFS spectrum of the nitrogen dopant in SiC using the superconducting detector.

This SC-XAFS is installed in the BL-11A beam line of Photon Factory, KEK and has been available to the public since 2012 in the projects such as the AIST advanced equipment sharing innovation platform and the microstructural analysis platform in the nanotechnology platform project.

AIST says itself and only the Advanced Light Source in the USA have this kind of advanced measurement instrument; and only AIST has developed a superconducting detector, the key of the analytical instrument. ITC developed the ion injection technology and the heat treatment technology applicable to SiC and supplies samples to users.

Figure 1 (a) shows a histogram of the energy resolution of each element of the superconducting array detector. At a maximum resolution of 10 eV, which exceeds the limit of 50 eV of semiconductor detectors, the detector can distinguish a trace amount of nitrogen (N) from the matrix carbon (C) in a large quantity (Fig. 1 (b)), thus enabling the acquisition of XAFS spectra with accuracy usable for comparison with first-principle calculation (Fig. 2 (b)).

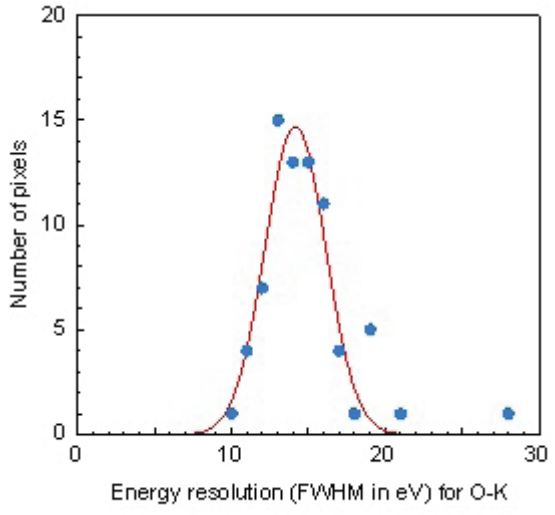


Figure 1 : (a) The energy resolution of the superconducting X-ray detector with respect to the characteristic X-ray of oxygen (b) An example of the detection of the N dopant in a very low concentration in SiC

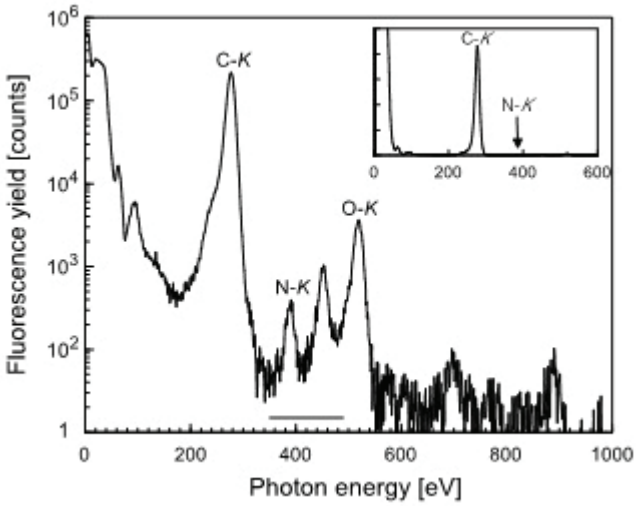


Figure 1 : (b) The strong peak of abundant C in SiC and the weak peak of N are distinguishable. In the insertion in (b), the vertical axis is in a linear scale. It is clear that N exists in a very low concentration

The SiC wafer into which the nitrogen dopant was introduced by ion plantation at a temperature of 500 °C and the wafers heat-treated at 1400 °C or 1800 °C after the ion plantation were subjected to the measurement of XAFS spectra (Fig. 2 (a)). The result of this experiment agreed with the first-principle calculation with FEFF, in which it was assumed that nitrogen atoms were located in the C sites (Fig. 2 (b)).

Thus, it was confirmed that most of N atoms were located in the C sites immediately after the ion plantation. It was empirical knowledge that ion plantation at a temperature as high as 500 °C was necessary for the doping to SiC, the reason for which, however, was unknown. The reason revealed in the present study is that it is necessary to locate N in the C sites before heat treatment at high temperature.

What's more, according to the spectrum in the region lower than 400 eV, it is presumed that a chemical bond is formed between carbon and nitrogen in a disordered crystal state immediately after the ion plantation. As the crystal disorder resolves as a result of the heat treatment at high temperature, this chemical bond breaks, leaving only the chemical bond of nitrogen and silicon, which is preferable for the doping.

As described here, it is revealed that the doping to SiC is complex and requires a completely different method from that for the doping to Si, in which the lattice site substitution can be realised by heat treatment after ion implantation at room temperature.

It is now possible to determine the lattice site of the trace N dopant introduced in SiC; no such measurement was possible hitherto. What's more, the state of the chemical bonds of the N dopant with the base materials, Si and C, is revealed. By combining SC-XAFS and the first-principle calculation, it is proved that the detection and microstructural analysis of a trace amount of the light elements in a crystal is possible, both of which were impossible until now.

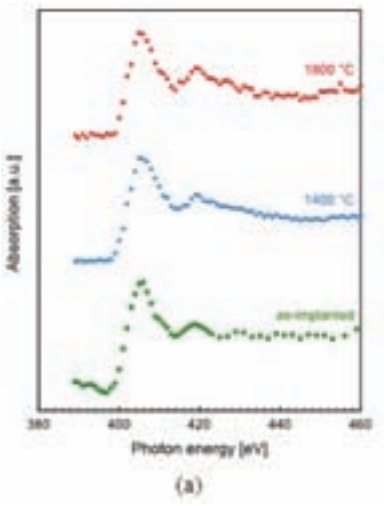


Figure 2 : (a) The XAFS spectrum of the SiC wafer without heat treatment immediately after the N ion plantation at 500 °C, and those of the SiC wafer heat-treated at high-temperatures after the ion implantation

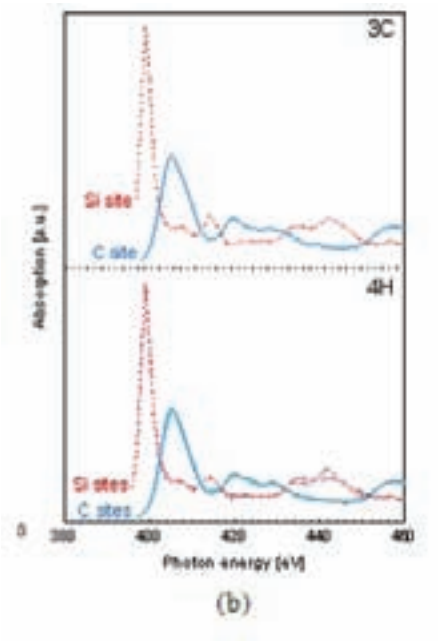


Figure 2 : (b) The XAFS spectra assumed from the first-principle calculations with the Si site replaced by N and with the C site replaced by N

The experiment data agrees with the result of the calculation on the assumption that the C sites were replaced in the comparison of (a) the measured spectra and (b) the calculated spectra for the 3C and 4H polytypes, which were two typical crystal structure SiC.

The developed technology is expected to contribute to the optimisation of the doping process of SiC semiconductors. Besides SiC, SC-XAFS will be applied to the analysis of other wide-gap semiconductors, magnetic materials, etc.; their functions depend on trace light elements.

What's more, improvement will be attempted in the resolution of the superconducting X-ray detector and the capability of the detection of a trace amount of light elements, thus expanding the range of the impurity concentrations covered by SC-XAFS

GaAs quantum dots assemble themselves

Quantum dots can self-assemble at the apex of a GaAs/AlGaAs (gallium arsenide/aluminium gallium arsenide) core/shell nanowire interface. This breakthrough could bolster quantum photonics and solar cell efficiency

Scientists from the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) and other labs have demonstrated a process where quantum dots can self-assemble at optimal locations in nanowires.

This breakthrough could improve solar cells, quantum computing, and lighting devices.

Quantum dots are tiny crystals of semiconductor a few billionths of a metre in diameter. At that size they exhibit beneficial behaviours of quantum physics such as forming electron-hole pairs and harvesting excess energy.

The researchers demonstrated how quantum dots can self-assemble at the apex of the GaAs/AlGaAs core/shell nanowire interface.

Crucially, the quantum dots, besides being highly stable, can be positioned precisely relative to the nanowire's centre. That precision, combined with the materials' ability to provide quantum confinement for both the electrons and the holes, makes the approach a potential game-changer.

Electrons and holes typically locate in the lowest energy position within the confines of high-energy materials in the nanostructures. But in the new demonstration, the electron and hole, overlapping in a near-ideal way, are confined in the quantum dot itself at high energy rather than located at the lowest energy states. In this case, that's the GaAs core. It's like hitting the bulls-eye rather than the periphery.

The quantum dots, as a result, are very bright, spectrally narrow and highly anti-bunched, displaying excellent optical properties even when they are located just a few nanometres from the surface - a feature that even surprised the scientists.

"Some Swiss scientists announced that they had achieved this, but scientists at the conference had a hard time believing it," says NREL senior scientist Jun-Wei Luo, one of the co-authors of the study.

Luo got to work constructing a quantum-dot-in-nanowire system using NREL's supercomputer and was able to demonstrate that despite the fact that the overall band edges are formed by the gallium arsenide core, the thin aluminium-rich barriers provide quantum confinement both for the electrons and the holes inside the aluminium-poor quantum dot. That explains the origin of the highly unusual optical transitions.

Several practical applications are possible. The fact that stable

quantum dots can be placed very close to the surface of the nanometres raises a huge potential for their use in detecting local electric and magnetic fields. The quantum dots also could be used to charge converters for better light-harvesting, as in the case of photovoltaic cells.

This work is described in detail in the paper, "Self-assembled Quantum Dots in a Nanowire System for Quantum Photonics," by M. Heiss *et al* in *Nature Materials,* (2013). DOI:10.1038/nmat3557

The team of scientists working on the project came from universities and laboratories in Sweden, Switzerland, Spain, and the United States.

Transforming cell biology with tiny GaAs QD bioprobes

A new quantum dot device composed of gallium arsenide and light-emitting crystal, marks a new age in the study and influence of living cells. The probe could be used for real-time sensing of specific proteins within cells and be adapted to sense biomolecules such as DNA or RNA

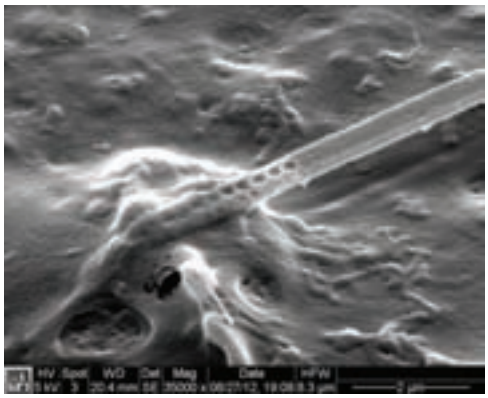
Biological research may soon be transformed by a new class of light-emitting probes small enough to be injected into individual cells without harm to the host.

Welcome to biophotonics, a discipline at the confluence of engineering, biology and medicine in which lasers and LEDs) – are opening up new avenues in the study and influence of living cells.

Engineers at Stanford say this was the first study to demonstrate that sophisticated engineered light resonators can be inserted inside cells without damaging the cell. Even with a resonator embedded inside, a cell is able to function, migrate and reproduce as normal.

The researchers call their device a "nanobeam," because it resembles a steel I-beam with a series of round holes etched through the centre. These beams, however, are not massive, but measure only a few microns in length and just a few hundred nanometres in width and thickness.

It looks a bit like a piece from an erector set of old. The holes through the beams act like a nanoscale hall of mirrors, focusing and amplifying light at the centre of the beam in what are known as photonic cavities. These are the building blocks for nanoscale lasers and LEDs.



A photonic nanobeam inserted in a cell. Clearly visible are the etched holes through the beam as well as the sandwich-like layer structure of the beam itself. The beam structure alternates between layers of GaAs and photonic crystal containing the photon-producing quantum dots

Senior author of a paper describing the work, Jelena Vuckovic, a professor of electrical engineering, says, "Devices like the photonic cavities we have built are quite possibly the most diverse and customisable ingredients in photonics". "Applications span from fundamental physics to nanolasers and biosensors that could have profound impact on biological research."

At the cellular level, a nanobeam acts like a needle able to penetrate cell walls without injury. Once inserted, the beam emits light, yielding a remarkable array of research applications and implications.

While other groups have shown that it is possible to insert simple nanotubes and electrical nanowires into cells, nobody had yet realised such complicated optical components inside biological cells.

"We think this is quite a dramatic shift from existing applications and will enable expanded opportunities for understanding and influencing cellular biology," says the paper's first author Gary Shambat, a doctoral candidate in electrical engineering.

In this case, the studied cells came from a prostate tumour, indicating possible application for the probe in cancer research. The primary and most immediate use would be in the real-time sensing of specific proteins within the cells, but the probe could be adapted to sense any important biomolecules such as DNA or RNA.

To detect these key molecules, researchers coat the probe with certain organic molecules or antibodies that are known to attract the target proteins, just like iron to a magnet. If the desired proteins are present within the cell, they begin to accumulate on the probe and cause a slight-but-detectable shift in the wavelength of the light being emitted from the device. This shift is a positive indication that the protein is present and in what quantity.

Scanning electron microscope (SEM) image shows a nanobeam probe, including a large part of the handle tip, inserted in a typical cell.

"Let's say you have a study that is interested in whether a certain drug produces or inhibits a specific protein. Our biosensor would tell definitively if the drug was working and how well based on the colour of the light from the probe. It would be quite a powerful tool," explains Sanjiv Sam Gambhir, MD, co-author of the paper and chair of the Department of Radiology at the Stanford School of Medicine as well as director of Stanford's Canary Centre for Early Cancer Detection.

As such, embeddable nanoscale optical sensors would represent a key development in the quest for patient-specific cancer therapies - often referred to as personalised medicine - in which drugs are targeted to the patient based on efficacy.

Structurally, the new device is a sandwich of extremely thin layers of GaAs alternated with similarly thin layers of light-emitting crystal, a sort of photonic fuel known as quantum dots. The structure is carved out of chips or wafers, much like sculptures are chiselled out of rock. Once sculpted, the devices remain tethered to the thick substrate.

Shambat and his fellow engineers have been working on similar optical devices for use in ultrafast, ultra-efficient computer applications where having devices immobilised on chips and wafers does not matter so much since they will ultimately be integrated with microelectronics.

For biological applications, however, the thick, heavy substrate presents a serious hurdle for interfacing with single-cells. The underlying and all-important nanocavities are locked in position on the rigid material and unable to penetrate cell walls.

Shambat's breakthrough came when he was able to peel away the photonic nanobeams, leaving the bulky wafer behind. He then glued the ultrathin photonic device to a fibre optic cable with which he steers the needle-like probe toward and into the cell.

Similarly, anticipating that GaAs could be toxic to cells, Shambat also devised a clever way to encapsulate his devices in a thin, electrically insulating coating of alumina and zirconia. The coating serves two purposes: it both protects the cell from the potentially toxic GaAs and protects the probe from degrading in the cell environment.

Once inserted in the cell, the probe emits light, which can be observed from outside. For engineers, it means that almost any current application or use of these powerful photonic devices can be translated into the previously off-limits environment of the cell interior.

In one finding that the authors describe as "stunning", they loaded their nanobeams into cells and watched as the cells grew, migrated around the research environment and reproduced. Each time a cell divided, one of the daughter cells inherited the nanobeam from the parent and the beam continued to function as expected.

This inheritability frees researchers to study living cells over long periods of time, a research advantage not possible with existing detection techniques, which require cells be either dead or fixed in place.

"Our nanoscale probes can reside in cells for long periods of time, potentially providing sensor feedback or giving control signals to the cells down the road," explains Shambat. "We tracked one cell for eight days. That's a long time for a single-cell study."

Further details of this work have been published in the paper, " *Single-Cell Photonic Nanocavity Probes,"* by Shambat *et al* in *Nano Letters*. DOI: 10.1021/nl304602d

Funding for this study was provided by The Beckman Centre for Molecular and Genetic Medicine at Stanford, the Canary Foundation and the Centre for Cancer and Nanotechnology Excellence.

New production method improves quantum-dot performance

Altering the creation of CdSe-CdS QDs could enable everything from more efficient computer displays to enhanced biomedical testing

Quantum dots, tiny particles that emit light in a dazzling array of glowing colours have the potential for many applications, but have faced a series of hurdles to improving performance.

Now an MIT team says that it has succeeded in overcoming all these obstacles at once, while earlier efforts have only been able to tackle them one or a few at a time.

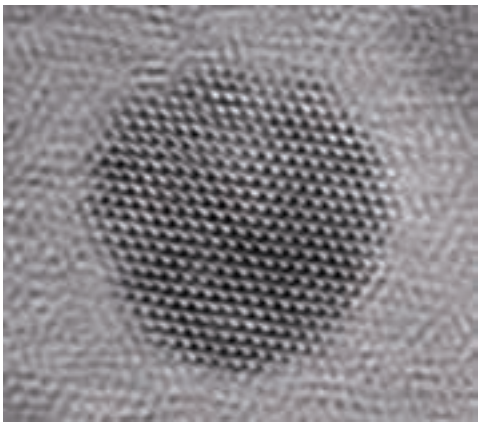
Quantum dots, in this case, a specific type called colloidal quantum dots, are tiny particles of semiconductor material that are so small that their properties differ from those of the bulk material.

They are governed in part by the laws of quantum mechanics that describe how atoms and subatomic particles behave. When illuminated with ultraviolet light, the dots fluoresce brightly in a range of colours, determined by the sizes of the particles.

First discovered in the 1980s, these materials have been the focus of intense research because of their potential to provide significant advantages in a wide variety of optical applications, but their actual usage has been limited by several factors.

Now, research in the journal Nature Materials by MIT researchers Ou Chen and Moungi Bawendi and several others raises the prospect that these limiting factors can all be overcome.

The new process developed by the MIT team produces quantum dots with four important qualities: uniform sizes and shapes; bright emissions, producing close to 100 percent emission efficiency; a very narrow peak of emissions, meaning that the colours emitted by the particles can be precisely controlled; and an elimination of a tendency to blink on and off, which limited the usefulness of earlier quantum-dot applications.



The new quantum dots "combine all these attributes that people think are important, at the same time," says Moungi Bawendi, the Lester Wolfe Professor of Chemistry. (Image: Ou Chen, MIT)

For example, one potential application of great interest to researchers is as a substitute for conventional fluorescent dyes used in medical tests and research. Quantum dots could have several advantages over dyes, including the ability to label many kinds of cells and tissues in different colours because of their ability to produce such narrow, precise colour variations.

But the blinking effect has hindered their use: In fast-moving biological processes, you can sometimes lose track of a single molecule when its attached quantum dot blinks off.

Previous attempts to address one quantum-dot problem tended to make others worse, Chen says. For example, in order to suppress the blinking effect, particles were made with thick shells, but this eliminated some of the advantages of their small size.

The small size of these new dots is important for potential biological applications, Bawendi explains. "Our dots are roughly the size of a protein molecule," he says. If you want to tag something in a biological system, he says, the tag has got to be small enough so that it doesn't overwhelm the sample or interfere significantly with its behaviour.

Quantum dots are also seen as potentially useful in creating energy-efficient computer and television screens. While such displays have been produced with existing quantum-dot technology, their performance could be enhanced through the use of dots with precisely controlled colours and higher efficiency.

So recent research has focused on "the properties we really need to enhance dots' application as light emitters," Bawendi says, which are the properties that the new results have successfully demonstrated. The new quantum dots, for the first time, he says, "combine all these attributes that people think are important, at the same time."

The new particles were made with a core of semiconductor material (cadmium selenide) and thin shells of a different semiconductor (cadmium sulphide). They demonstrated very high emission efficiency (97 percent) as well as small, uniform size and narrow emission peaks. Blinking was strongly suppressed, meaning the dots stay "on" 94 percent of the time.

A key factor in getting these particles to achieve all the desired characteristics was growing them in solution slowly, so their properties could be more precisely controlled, Chen explains. "A very important thing is synthesis speed," he says, "to give enough time to allow every atom to go to the right place."

The slow growth should make it easy to scale up to large production volumes, he says, because it makes it easier to use large containers without losing control over the ultimate sizes of the particles. Chen expects that the first useful applications of this technology could begin to appear within two years.

Further details of this work have been published in the paper, "Compact high-quality CdSe - CdS core - shell nanocrystals with narrow emission linewidths and suppressed blinking," by Ou Chen *et al* in*Nature Materials* (2013). DOI:10.1038/nmat3539.

This work was supported by the National Institutes of Health, the Army Research Office through MIT's Institute for Soldier Nanotechnologies, and by the National Science Foundation through the Collaborative Research in Chemistry Program.

Jenoptik experiences surge in demand for GaP devices

The gallium phosphide based microoptic products are primarily used in the medical industry

Microlenses, microlens arrays, and diffractive optics are used for homogenisation of laser beams for laser eye surgery and aesthetic skin treatment.

They create multi-spot arrays for ophthalmic diagnostics, for collimating and shaping laser beams for surgical applications, and for imaging applications such as optical coherence tomography and scanning confocal microscopy.

Recent advances in near infrared (NIR) and mid-wavelength infrared (MWIR) quantum cascade and fibre lasers in conjunction with new diagnostic and treatment approaches are

placing new demands on microoptics for these applications.

These needs include a broad NIR - MWIR transmission, high numerical aperture (NA), and small form factor for minimally invasive applications.
Jenoptik´s Grayscale lithographically fabricated GaP microlenses and microlens arrays meet these demands with:

1) A broad wavelength range from 600 nm beyond 5 µm

2) A high refractive index of 3.1 allowing a single element lens or lens array with NA's up to 0.85.

3) Complex surface shapes providing for beam collimation and circularization of high divergence diode lasers with a single element.

Scanning confocal microscopy and minimally invasive optical coherence tomography are two examples where a single GaP microlens or microlens array can be used to extend the wavelength range over traditional GRIN and silicon lenses.

Jenoptik's says it fabricates complex aspheric elements with high numerical aperture also provide for better imaging performance when compared with GRIN lens based systems.

What's more, standard manufacturing processes are available for a range of different optical materials such as SiO2, GaAs, CaF2, Al2O3, ZnS, ZnSe, Ge, and chalcogenide glass.

Record-breaking antireflection coating on solar cells

A new development could significantly improve the performance of solar cells, LEDs and photodetectors

A team of researchers from Rensselaer Polytechnic Institute (RPI), Magnolia Solar, Inc. and Pohang University of Science and Technology have demonstrated a novel antireflection (AR) coating.

It beats the widely employed double-layer AR (DLAR) coating on state-of-the-art triple-junction solar cells.

The scientists demonstrated that the solar cells investigated gain over 4 percent in efficiency when replacing the industry-standard DLAR with an optimised four-layer AR coating.

Considering that the solar spectrum is an intrinsically broadband spectrum, such broadband characteristics of the AR coating are undoubtedly beneficial for high power conversion efficiency.

What's more, omnidirectional AR characteristics have become important for the rapidly expanding terrestrial application of solar cells. This is because solar irradiance in terrestrial applications usually has a large range of incident angles for non-tracking solar cells.

Both broadband and omnidirectional AR characteristics are attainable by four-layer AR coatings, as demonstrated by the RPI-led team.

RPI says that the excellent broadband and omnidirectional AR characteristics of the four-layer AR coating are achieved through solving the problem of refractive index matching at multiple layer interfaces.

By using tailored and low-refractive index nanoporous silica layers, the team has greatly reduced the refractive index contrast at the semiconductor / AR coating / air interfaces.

Through a multilayer design methodology powered by a genetic algorithm optimisation, favourable antireflective properties over a specified wavelength range and angle-of-incidence range were found.

Two porous layers of the four-layer AR coating were fabricated by oblique-angle deposition of silica thereby resulting in films with refractive indices of 1.32 and 1.11. This is less than the refractive index of silica. The other two layers are dense and were fabricated by co-deposition of silica / titania using sputtering.

According to the photocurrent measurements performed by the team, the angle-of-incidence (0°- 80°) averaged photocurrent enhancement (over an uncoated triple-junction solar cell) of the four-layer AR coating amounts to 34.4 percent. The enhancement of a DLAR coating is only 25.3 percent.

In the future, the team members Jaehee Cho and E. Fred Schubert, will integrate this novel AR coating technology on surface-textured devices.

They will also investigate innovative fabrication methods for depositing low-refractive index AR coatings on curved surfaces, such as a hemispherical lens.

Further details of this research are described in the paper, "Enhanced Omnidirectional Photovoltaic Performance of Solar Cells Using Multiple-Discrete-Layer Tailored - and Low-Refractive Index Anti-Reflection Coatings," by X. Yan *et al* in *Advanced Functional Materials*, 23, 583 (2013).

Separating the core and shell of CdSe quantum dots

LEDs, solar cells and sensors could benefit from a new technology to study the interface between the core and shell of quantum dots composed of CdTe based materials

The J. William Fulbright College of Arts & Sciences at the

University of Arkansas, has received a $650,000 award from the National Science Foundation.

Colin Heyes, an assistant professor in the department of chemistry and biochemistry in the institute was instrumental in receiving the award.

The Faculty Early Career Development Program award was given to further his investigation of the interfaces between the core and shell of colloidal quantum dots.

Colloidal quantum dots are microscopic semiconductor crystals that are grown in solution.

Adding a shell to the core quantum dot provides a way to control the functionality of these crystals, which can be used to emit light for biomedical imaging, LEDs and spectroscopy or photocurrents for solar cells and chemical sensors.

The research will help scientists better understand the relationship between the structure of the quantum dot and its functionality.

“All of these modern applications rely on the same fundamental electronic processes within quantum dots,” Heyes says. “Our work will provide a better understanding of how to control these crystals to eventually build brighter, faster, longer-lasting and more efficient products.”

Heyes studies the interfacial chemistry between the core, shell and ligands of colloidal quantum dots. Ligands sit on the shell surface and “hold” the colloidal quantum dots in solution; they also provide a chemical connection to the “outside world” so that quantum dots can attach to biological cells, solar cells or act as chemical sensors.

There is a lack of fundamental understanding about the structural properties of the core-shell and shell-ligand interfaces.

Scientists can observe the boundary between the core and shell materials using powerful electron microscopes, but they do not yet understand how the nature of the structural mismatches between the two materials affects their optical and electrical properties.

These mismatches create “holes” or “trap states” that result in losing control of excitons, which are electrons that have been energetically excited. The inability to control excitons result in energy lost as heat rather than converted into useful energy, such as light or electrical currents.

The NSF grant will expand Heyes’ investigation of how the optical and electrical properties of quantum dots are related to the core-shell and shell-ligand interfaces at the single quantum dot level.

Understanding single quantum dots is necessary to advance miniaturised optoelectronics and single molecule fluorescence applications. His research team has produced preliminary data demonstrating that as these interfaces are systematically varied, the optical properties of single quantum dots can be tuned.

“We hypothesise that understanding the relationship between the structures of the core-shell or shell-ligand interfaces and the trap states will allow us to more precisely control these excitons that underlie the optical and electrical properties,” Heyes says.

Heyes’ team will focus specifically on understanding how the trap states are formed and how they contribute to the optical and electronic properties with the eventual goal of avoiding their formation altogether.

The grant will support Heyes’ research in this area for the next five years and will encourage and promote the participation of graduate, undergraduate and minority students. As part of the grant, a two-week, hands-on workshop will be held each summer on the U of A campus.

Students from the university and from institutions in Arkansas and Oklahoma will perform research experiments in Heyes’ lab to promote and foster their interest in chemistry and nanomaterial science for eventual careers in the fields of science, technology, engineering and maths.