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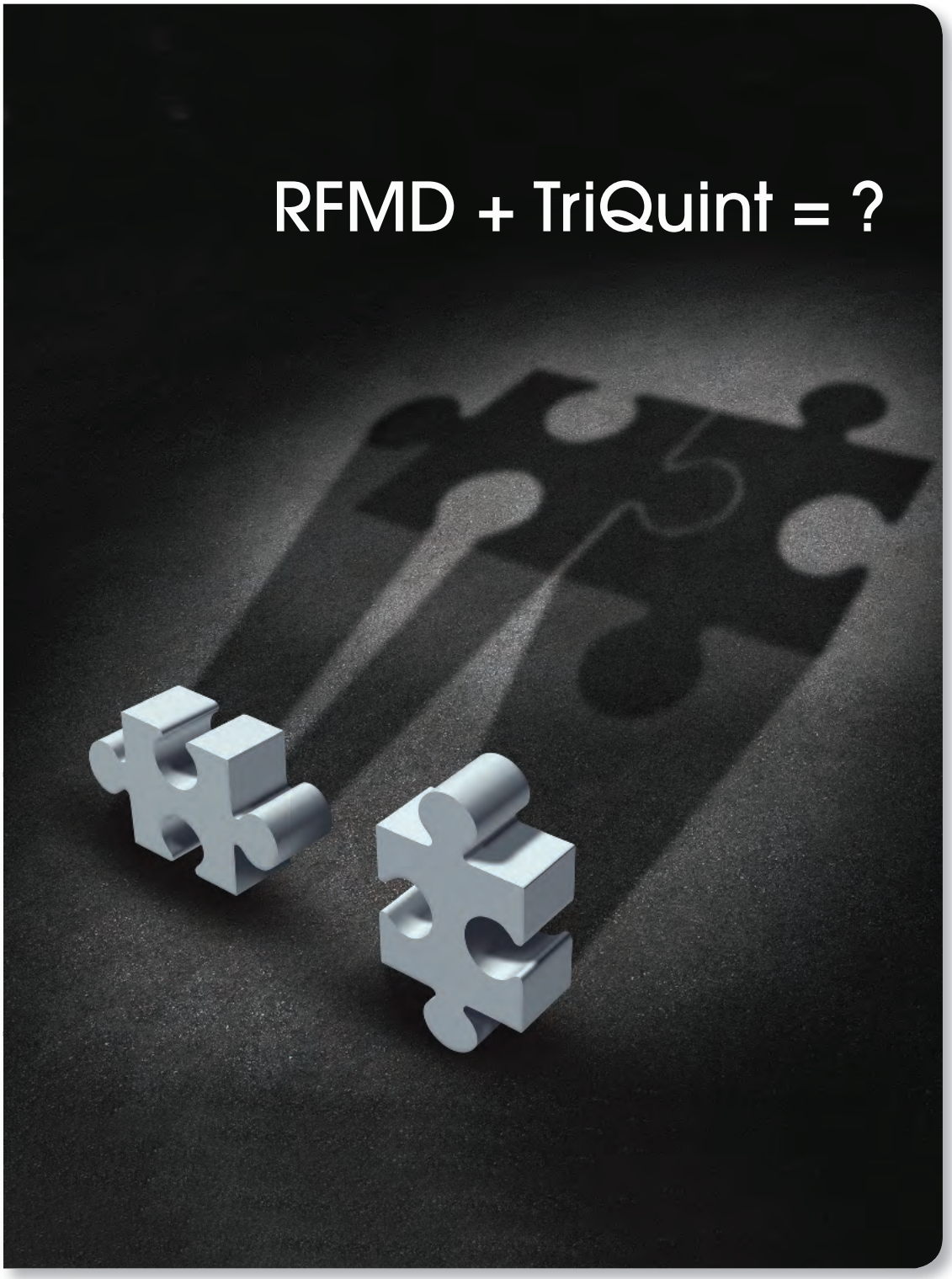

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ALWAYS ONE STEP AHEAD

editorial view

by Dr Richard Stevenson, Editor

Hidden in the filings

I WAS SHOCKED when I heard of the plans for RFMD and TriQuint to merge. And as I mulled over the consequences, several questions popped into my head: Would this really be a merger of equals? What will this mean for the GaAs industry? And who proposed this – was it initiated by TriQuint, or by RFMD?

While we may never know the details of the courtship, I have found out more about it than I ever would have imagined from a source of information that is often very dull: SEC filings. While working my way through the S4 document filed by TriQuint on 14 April, I discovered that this relationship is far from the whirlwind romance that I thought it might have been. Instead, it was one of the biggest, best kept secrets within our community.

It may surprise you to hear that as far back as 2009, the CEOs of both firms were getting together over breakfasts lunches and dinners to discuss the possibility of merging to form a new venture. However, it took until 2013 before these conversations led to serious thinking by the boards about the pros and cons of such a move.

Further revelations from the S4 filing were that it wasn't just RFMD that wanted to unite with TriQuint. There was also an unnamed company putting in several bids to buy the chipmaker, offering first $8.50, and then $10 and finally $10.10 per share.

So it is clear that TriQuint has attributes that other firms find attractive. Its strengths include the filter business that provides a key component in the multi-band power amplifier modules, and a defence business that has a long, rich history and healthy margins.

What isn't so strong is TriQuint's GaAs PA business that is dragging down overall margins, but this division could be put right if it comes under the wing of RFMD.

Certainly, many investors are optimistic about the future of the RFMD-TriQuint venture, with the share price of both firms rising on the back of this news. And I'm sure that the colossus that results has the potential for great things, so long as it can get the people in the right positions, which is not easy when two established firms come together.

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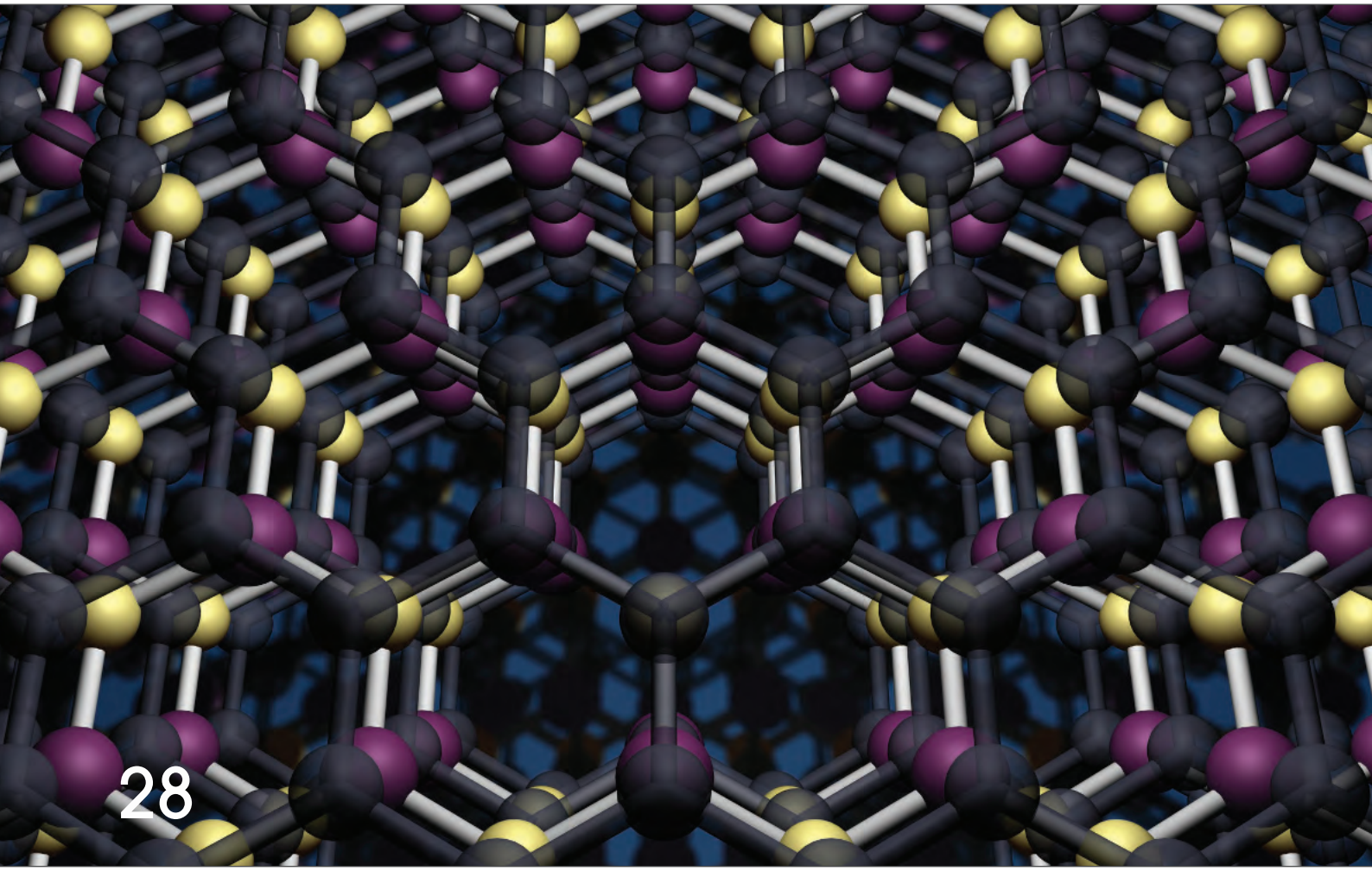

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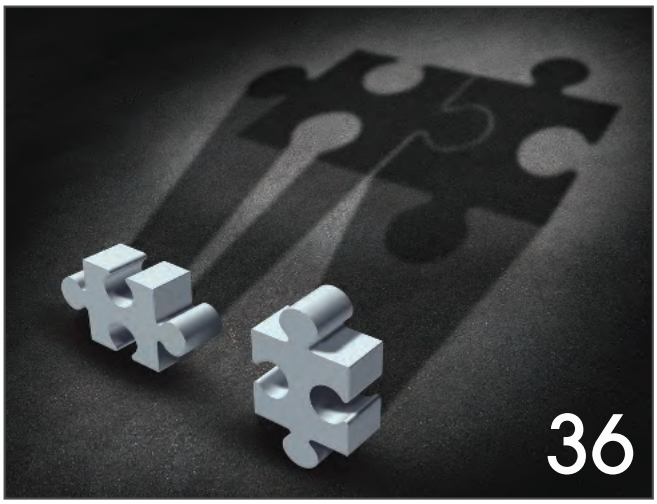
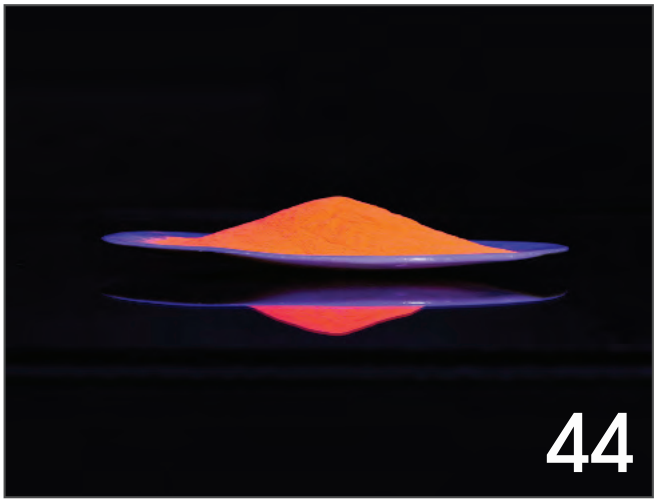
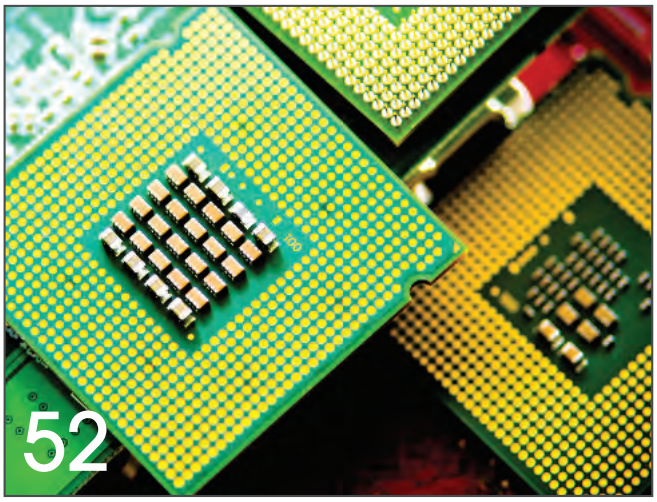






Osram opens new LED assembly plant in China

IN A MOVE to strengthen its position in the market for light-emitting diodes Osram has officially opened its LED assembly plant in Wuxi, China. The factory has a floor area of about 100,000 square meters and will employ as many as 2,100 people by 2017. Osram is investing a low three-digit-million euro amount to set up the plant. "With this step, we're not only expanding our fully loaded backend LED capacities but also boosting our presence in the world's largest single lighting market," said Wolfgang Dehen, Chief Executive Officer of OSRAM Licht AG. "Asia, and particularly China, are key growth drivers for the global lighting and therefore the LED industry."

China accounts for more than 20 percent of the world's lighting market and has recorded a fast growth over the past years, particularly in terms of the uptake of LED lighting technologies. The size of the country's total general illumination market was about €15 billion last year and is expected to rise to about €23 billion by 2019. The market share of semiconductor-based products such as LEDs is forecast to surge to over 60 percent by then compared with only 29 percent in 2013. With the new LED assembly in Wuxi, Osram will be

in a position to address that growth. The contracts for the plant's location were signed in May 2012, with ground-breaking taking place in August that year. "Osram's new LED assembly plant will play a key role in forging Wuxi's LED industry value chain, and we believe operation of the plant will help Wuxi to become one of the foremost optoelectronic semiconductor bases in China, and even Asia," said Wang Quan, Deputy Secretary of Wuxi Party Committee and Mayor of Wuxi.

The factory is planned and run by the Osram Opto Semiconductors business unit. It is the company's second backend site where LED chips are turned into light sources by assembling them into housings. The other site is located in Penang, Malaysia.

LEDs overtake fluorescents for the first time

A Precision-Paragon survey shows lighting professionals expect LED fixtures should increase from 26 percent in 2013 to 49 percent in 2014. Lighting professionals expect to install more LED than fluorescent fixtures over the coming year, according to a recently released 4th Annual Lighting Survey. When asked what is the dominant lighting technology they expect to install in 2014, 49 percent of respondents selected LED, and 46 percent indicated fluorescent. In the 2013 survey, 26 percent of respondents selected LED, and 68 percent indicated fluorescent, as the dominant lighting technology.

Conducted annually since 2010, this year's survey was distributed in December to over 5,000 energy-efficient lighting industry professionals. The survey's topics covered the industry's performance in the past year, as well as expectations for 2014. Survey respondents indicated that in 2013, LEDs accounted for 37 percent of the fixtures they installed- up from 27 percent in 2012, and 13 percent in 2011.

The lighting manufacturer has developed products to keep pace with the increased demand for LED lighting, like the TKD fluorescent-to-LED retrofit kit.

Overall, the survey respondents reported a positive outlook for the energy-efficient lighting industry. Sixty-four percent indicated that they had experienced either modest or substantial growth in 2013, and 82 percent expect the overall energy-efficient lighting industry to experience growth in 2014.

Market for LED lighting in buildings to reach $10.3 billion by end of 2014

MEMOORI estimates that revenue from the global LED Lighting market for buildings hit $8.1 billion in 2013 and will rise to around $10.3 billion by the end of 2014. The market will have grown still further to total almost $23 billion by 2018.

This represents a compound annual growth rate in the overall market of 22.8% over the 6-year period. Beyond the time frame of this report, revenue growth will slow as cost competition intensifies; with the size of the LED lighting market expected to level off by around 2020.

A combination of continued consumer confusion over the benefits of LED lighting, a slow decline in sale prices and lower than expected global GDP growth meant that 2013 revenue growth for LED lighting was disappointing.

However oversupply concerns are likely to ease towards the end of 2014 as capacity is absorbed by a steady increase in global demand.

The major players such as Philips, OSRAM, CREE, Acuity and GE have set in place their strategies to retain a large slice of the market as the LED Lighting business grows. Ever increasing amounts of their revenues are coming from LEDs rather than traditional technologies.

Whilst the future looks bright in the medium term, lighting manufacturers are expressing increasing concern about what's going to happen after 2020 when the replacement market is essentially saturated; with predicted levels of 70-80% adoption of long-lasting LEDs that will dramatically lengthen replacement cycles.

NALCO interested in sourcing technology supplier for gallium extraction plant

National Aluminium Company Ltd (NALCO) is interested in sourcing a suitable and low cost technology supplier for setting up a gallium extraction unit/ plant in the company's Alumina Refinery located at Damanjodi, Odisha through a Joint Venture or standalone having gallium metal purity of ≥ 99.99 % (4N+). The capacity of the plant will be of around ten tonnes per annum, low cost and economically viable with state of the art environment friendly technology environment standard.

For this purpose NALCO invites Expression of Interest (EOI) from interested and competent manufacturers, and technology suppliers interested in providing technology for extraction of gallium from Nalco Bayer liquor (intermediate process liquor generated from Digestion of bauxite by the "Bayer" process) and having expertise in production and marketing of metallic gallium or gallium compounds.

On receiving proposals from the parties again, a fresh tender will be floated to the shortlisted parties for selection of the suitable technology provider on gallium extraction from Bauxitic resources. NALCO was incorporated in 1981 following a major investment decision by the Government of India to exploit a part of the Bauxite deposit discovered in the East Coast of India.

The company says it has charted an excellent track record in both physical and financial performance, and has been listed in the LME (London Metal exchange).Recently, the company was conferred the "Nav Ratna"(literally Nine Jewels} by the Government of India, in recognition of its consistent performance over the years, hereby incorporating higher investment and operational autonomy.

NALCO is operating a multi-location Bauxite Mines-Alumina-Aluminium complex along with a Captive Power Plant, in the State of Odisha, India. A major expansion programme (1st phase) was completed in 2001. The Phase-2 expansion was finished in July, 2012 and upgrading activity of the Refinery after Phase 2 expansion been completed. Mines up-gradation is currently ongoing. The company is listed on National Stock Exchange of India and Mumbai stock exchange.

The process of extraction of Alumina from its mineral bauxite in caustic liquor solution is commonly known as the "Bayer" process. Bauxite received from Mines is either stacked in stock pile or fed directly to secondary crusher for size reduction. Secondary crushed bauxite from Silo is fed to Ball Mill along with caustic liquor for grinding. Ground bauxite slurry after Pre-desilication is digested at atmospheric pressure (temperature 105 - 106 degree C) for extraction of alumina.

Undigested bauxite is separated as Red mud. Aluminate liquor is cooled to precipitate ATH (alumina trihydrate) which is calcined to produce alumina. The gallium dissolves in the liquid phase and get enriched with time as NALCO is not extracting gallium metal or any compound till now. But some amount of gallium is escaping from the plant liquor during discharge of red mud as well as with product alumina.

Microsemi launches new family of SiC MOSFETs for high-voltage and industrial applications

MICROSEMI CORPORATION have introduced its new silicon carbide MOSFET product family with 1200 V solutions. The new SiC MOSFETs are designed for high-power industrial applications where efficiency is critical. These applications include solutions for solar inverters, electric vehicles, welding and medical devices.

The company is positioned to capitalize on SiC semiconductor market growth. Market researcher Yole Développement estimates that the SiC power semiconductor market will grow 39 percent year-over-year from 2015 to 2020, and Market Research estimates the SiC semiconductor market will grow 38 percent year-over-year to $5.3 billion by 2022.

The new SiC MOSFETs provide patented technology from Microsemi and are designed to help customers develop solutions that operate at higher frequency and improve system efficiency.

Microsemi's patented SiC MOSFET technology features include: Best-in-class RDS(on) vs. temperature; ultra-low gate resistance for minimizing switching energy loss; superior maximum switching frequency; and outstanding ruggedness with superior short circuit withstand.

"Microsemi's 1200V SiC MOSFETs are establishing a new benchmark for performance," said Marc Vandenberg, general manager for Microsemi's Power Products Group. "Microsemi continues to expand its SiC product portfolio by capitalizing on our in-house SiC fabrication capabilities and delivering innovative high-power solutions to our customers."

Microsemi's 1200V SiC MOSFETs are rated at 80 milliohms and 50 milliohms and provide customers more development flexibility by offering both industry standard TO-247 and SOT-227 packages.

SiC MOSFETs are also integrated into the company's expanded MOSFET power modules, which are used in battery charging, aerospace, solar, welding and other high-power industrial applications. The new power modules provide higher frequency operation and improve system efficiency.

Project to advance VCSEL high volume supply chain

IQE plc, a global supplier of advanced semiconductor wafer products and services, has joined a new consortium to establish a pan-European supply chain capability for the high volume production of vertical cavity surface emitting lasers (VCSELs) for infrared illumination, data communications, gesture recognition and industrial heating applications.

The aim of the programme is to establish a European based production capability to bring VCSEL manufacturing to a level comparable to LED and CMOS manufacturing.

By bringing together existing high volume production facilities at IQE, along with key end users, the consortium will deliver an end-to-end production supply chain offering significant reduction in the cost-per-function for VCSEL devices by reducing GaAs processing costs whilst increasing device performance.

VCSELs are key enabling technologies for a wide range of applications where demand is proliferating rapidly as this advanced laser becomes the device of choice for many high volume applications including:

- Gesture recognition, for gaming and non-contact navigation (e.g. TV, smartphone, tablet)
- Depth imaging for 3D vision, using 'time of flight (ToF)' technology, driving next wave of handset innovation for must have new phones
- Production line heating automation: significant operating efficiencies can be achieved using VCSEL technology with applications requiring tens of millions of devices
- Low energy optical storage and fast switching in high capacity data centres, servers and ultra-high speed computing
- High speed datacoms, including Active Optical Cables (AOC)
- Ultra-High Density magnetic Storage using Heat Assisted Magnetic Recording (HAMR)
- Illumination for IR cameras for security, safety, night vision
- Other industrial heating applications including paint curing and commercial print shops
- Cosmetics and healthcare including hair removal, antiwrinkle, blemish reduction

IQE has demonstrated advances in VCSEL technology including an established 100mm VCSEL process which has been enhanced by the recent launch of its new 150mm VCSEL wafer products for high volume applications, announced in March 2014.

The Euro 23million VCSEL Pilot Line for IR Illumination, Datacom and Power Applications (VIDaP) programme, whose partners include IQE, Philips, STMicroelectronics, Sick and Sidel, will receive funding under the European Commission's ENIAC program with IQE receiving significant support from the Welsh Government.

New 650V normally-off GaN transistor family

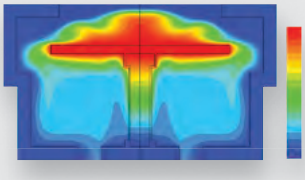
GAN SYSTEMS, a developer of gallium nitride power switching semiconductors, has announced five new normally-off 650V GaN transistors optimised for high speed system design.

The new 650V enhancement mode parts feature a reverse current capability, zero reverse recovery charge and source-sense for optimal high speed design. RoHS compliant, the devices are delivered in GaN Systems' near chipscale, embedded GaNPXpackage which eliminates wire bonds thereby minimising inductance. This package also optimises thermal performance and is extremely compact.

Girvan Patterson, President of GaN Systems comments:"With these new 650V parts as well as our recently-announced 100V family, GaN Systems offers a very wide range of parts which are available for are sampling now. Applications include high speed DC-DC converters, resonant converters, AC motor drives, inverters, battery chargersand switched mode power supplies."

The GS66502P, GS66504P, GS66506P and GS66508P are respectively 8.5A/165mΩ, 17A/82mΩ, 25A/55mΩ and 34A/41mΩ parts, while the GS43106L is a 30A/60mΩ cascode.

Optimize the Thermal Performance of your Process Equipment.



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Shanghai University orders AIXTRON BM R&D reactor

AIXTRON has announced that Shanghai University has ordered a BM R&D reactor to be used by its Sino-Sweden Microsystem Integration Technology Center (SMIT). The R&D system for manufacturing carbon nanotubes and graphene has already shown excellent results at numerous customer sites worldwide.

Prof. Johan Liu, who is leading the graphene/nanotube research at SMIT, comments: "We will be launching extensive new research into the application of nanotubes and graphene using the BM capabilities in thermal- and plasma-based chemical vapor deposition. We chose the AIXTRON system as we achieved excellent results in our longstanding work with the BM reactor at Chalmers University in Sweden. The system has been a workhorse for similar research for the last five years, giving us consistently good results, high uptime, ease of use and process flexibility."

Prof. Liu at SMIT will be developing next generation thermal interface/dissipating materials, heat spreaders, multi-chip interconnects and through silicon vias (TSV) for semiconductor chip packaging using the BM reactor.

The Sino-Sweden Microsystem Integration Technology Center (SMIT),

a research facility established in 2003, combines expertise from Shanghai University and Chalmers University of Technology in Gothenburg (Sweden).

Founded as a cross-border institution, the center conducts research on microsystem and microelectronics integration by focusing on new technology for future microsystems for industrial applications.

Chalmers University of Technology has extensive experience in the area of graphene research.

Veeco launch system for point-of-use gas mixing

VEECO'S Apex Gas Mixing System has been designed to address key issues facing semiconductor manufacturers and foundries - material costs, process repeatability and system up-time.

Veeco say the Apex allows manufacturers to reduce costs by purchasing lower-cost, higher-concentration gases then diluting at the point of use. Depending on the concentrations and quantities needed, this could translate to cost savings.

Built around Veeco's Piezocon Gas Concentration Sensor, Apex system provides real-time process repeatability. The precise control of the gas concentration allows the Apex system to drive greater tool up-time by eliminating the need to re-qualify the tool after every gas cylinder change, reducing – and sometimes eliminating – tool down-time due to routine cylinder changes. The system is suitable for applications requiring low concentration, high precision and cost sensitive gas mixtures and Improves repeatability by 10 times or more when compared to individual gas cylinders Veeco believe.

Brewer Science announce megasonic developer

BREWER SCIENCE, a supplier of advanced materials, processes, and equipment to the microelectronics industry, has announced the first commercial placement of a Cee 300MXD megasonic developer. This developer was commissioned by MicroChem Corp.

The Brewer Science Cee 300MXD megasonic developer applies uniform acoustic energy to spinning substrates to gently dissolve and remove films and residues without damaging fragile device structures.

This precision handling results in stable dimensional control of vertical profiles uniformly across the wafer surface, enabling fabrication of high-aspect-ratio structures for the MEMS, display, compound semiconductor, and advanced packaging markets. Applications include radio-frequency (RF) power, MEMS, sensors, and acoustic wave devices used for wireless communication.

"MicroChem is very pleased to team with Brewer Science on what we believe could be an enabling technology for the future," said Michael Stan, Applications Engineering Manager for MicroChem Corp. "As the MEMS industry and integrated packaging technology continue to demand higher-aspect-ratio structures for TSV and RDL layers, enhanced development techniques will likely become mainstream.

The cost-effective approach being pioneered by Brewer Science gives a supplier such as MicroChem Corp. the advantage of being able to rapidly prototype formulations and processes to meet these demands," he added.

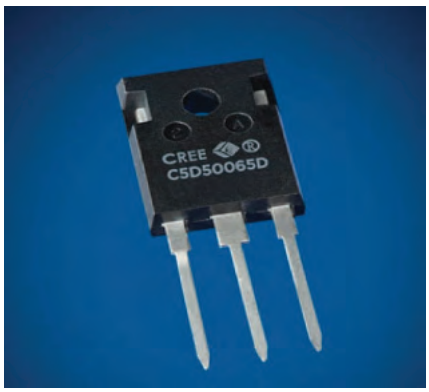
The Cee 300MXD megasonic developer gives customers a bridge from the lab to production by allowing them to avoid significant capital investment and is suitable for low-volume prototyping with a seamless transition to high-volume manufacturing.

Cree launch discrete 20A and 50A 650V SiC

CREE HAS ANNOUNCED the addition of two new discrete 650V SiC rectifiers to its Z-Rec Schottky diode portfolio. Rated at 650V blocking voltage and 50A continuous forward current, Cree's C5D50065D Schottky diode is the first member of Cree's high power CPW5 diode family to be released in packaged form.

Available in a TO-247-3 package, the C5D5065D provides up to 2000A of non-repetitive surge capability at 25 degrees C, combined with the high continuous current-carrying capability of the CPW5 family. The 50A rectifier is suited for automotive on-board chargers, server power supplies, power conditioning, and high-reliability aerospace and military power systems.

Developed to provide increased switching efficiency through a reduced forward voltage, the CVFD20065A Schottky diode provides 20A of forward current capability with a nominal voltage



drop of 1.35V at 25 degrees C and is the first product to be released as part of Cree's new family of Low VF Z-Rec Schottky diode

Cree has also taken additional steps to bolster the surge capability of the CVFD20065A, resulting in a forward surge rating of 1400A at 25 degrees C (10μs pulse) – which the company says is the highest among all commercially available 20A, 650V SiC Schottky diodes.

Chipset supplier choose TriQuint

TRIQUINT SEMICONDUCTOR has announced a chipset povider has selected its two new high-performance 5GHz WLAN front-end modules for the industry's fastest commercially available 4x4 MU-MIMO 802.11ac chipset.

Triquint state that with almost 2Gbps total throughput, the chipset streams flawless, carrier-grade IPTV to multiple devices in full 1080p or 4K Ultra HD resolution.

TriQuint's modules provide the improved linearity, power consumption and thermal performance critical for delivering high-quality HD video in Wi-Fi set-top boxes and media gateways.

TriQuint also launched a family of three high-performance filters to solve challenging Wi-Fi / LTE interference issues. Utilising TriQuint's bulk acoustic wave technology, these advanced filters enable customers to extend Wi-Fi ranges while meeting stringent spectrum regulations worldwide.

"As demand for high-bandwidth Wi-Fi connectivity grows, our customers and chipset partners count on TriQuint to solve the toughest system challenges so they can deliver best-in-class wireless broadband capabilities," said James Klein, Vice President for Infrastructure and Defense Products.

"TriQuint continues to drive WLAN innovation and capture design wins for its high-performance BAW filters in several applications. We're leveraging our broad in-house RF technology portfolio and integration expertise to deliver products for the fast-growing WLAN infrastructure connectivity market."

According to a recent market report, shipments of consumer and enterprise WLAN access points will reach 170 million and 25 million respectively at the end of 2014.

Dow Corning launch silicon carbide wafer grading structure

DOW CORNING has introduced a new industry standard for silicon carbide (SiC) crystal quality by introducing a product grading structure that specifies new tolerances on killer device defects, such as micro pipe dislocations (MPD), threading screw dislocations (TSD) and basal plane dislocations (BPD).

The new grading structure aims to optimize the range, performance and cost of next-generation power electronic device designs fabricated on Dow Corning's portfolio of 100-mm SiC wafers, which the company offers in three new tiers of manufacturing-quality substrates labelled Prime Standard, Prime Select and Prime Ultra.

"As a global technology leader in advanced silicon carbide materials, Dow Corning recognizes that wide-bandgap semiconductor technology must deliver much more than high quality alone – it must deliver exceptional overall value," said Gregg Zank, chief technology officer, Dow Corning.

"Another Dow Corning industry first, our new SiC wafer grading structure meets this need head on. It is the direct result of our close collaboration with the globe's leading power electronics device manufacturers, and aims to help give them what they need to quickly achieve their evolving design goals at an optimal price point."

The company says each successive Prime Grade wafer tier under the new product grading structure will offer tighter tolerances for defect density and other critical performance properties, depending on the demands of their specific device applications.

Other SiC substrate manufacturers promise low micropipe densities, Dow Corning says it is one of the first to specify low tolerances of other killer defects, such as TSD and BPD. Such defects reduce device yields, and inhibit the cost-efficient manufacture of large-area, next-generation power electronic devices with higher current ratings.

The Prime Grade portfolio includes: Prime Standard SiC wafers that guarantee MPD of 0.5 cm^{-2} or less when designing simpler SiC power electronic components, such as Schottky or Junction Barrier Schottky diodes, with low to medium current ratings.

Prime Select SiC wafers deliver more stringent tolerances for MPD (≤ 0.2 cm^{-2}) and BPD (≤ 800 cm^{-2}), making them more suitable for more demanding SiC devices like pin diodes or switches.

Prime Ultra SiC wafers enable design of high-power devices that require the highest crystal quality. SiC substrates in this tier deliver extremely low MPD (≤ 0.1 cm^{-2}), BPD (≤ 500 cm^{-2}), TSD (≤ 300 cm^{-2}) and a tightened wafer resistivity distribution for the design of today's most advanced SiC power electronic devices.

Veeco Q1 2014 results blossom

VEECO INSTRUMENTS INC has announced its financial results for the first quarter ended March 31st, 2014. Veeco's first quarter GAAP results include a one-time gain of $29 million from the reversal of Synos acquisition related contingency accruals since it determined that the post-closing milestones necessary to trigger such contingency payments were not expected to be achieved.

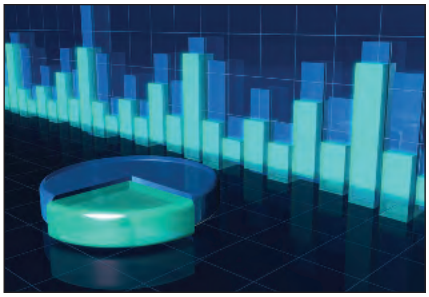
"Veeco's first quarter top and bottom line performance improved meaningfully from the fourth quarter of last year," commented John R. Peeler, Chairman and Chief Executive Officer. "We delivered $91 million in revenue, up 24 percent from the fourth quarter of 2013, driven primarily by an increase in LED & Solar revenue to $71 million ($64 million in MOCVD).

First quarter 2014 Data Storage revenues were $20 million, up from $17 million in the fourth quarter of 2013. EBITA loss was $3 million, significantly improved from last quarter's loss, benefiting from higher volume, an improvement in gross margins to 37 percent, and lower operating spending.

As forecasted, our investments in next generation products and in our growth businesses caused cash to decline modestly during the quarter. Yet our cash and investments balance remains strong at $483 million."

Peeler continued, "Veeco's first quarter 2014 orders improved by 21 percent from the fourth quarter of 2013 to $103 million, the highest level we have reported in nearly two years. This increase was driven by a 59 percent sequential improvement in MOCVD orders to $83 million, which represents the highest amount booked since the third quarter of 2011. Orders were received from top LED customers throughout Asia and elsewhere."

First quarter 2014 Data Storage and MBE orders each declined from the fourth quarter of 2013, to $15 million and $5 million, respectively. Veeco's second quarter 2014 revenue is currently forecasted to be between $87 million



and $97 million. Earnings per share are currently forecasted to be between ($0.46) to ($0.36) on a GAAP basis.

Peeler commented, "After a long downturn in our MOCVD business, LED fab utilisation rates have improved to high levels at most key accounts and LED adoption is happening faster than many had expected. Our customers are also reporting better market demand for LED backlighting products. It is encouraging to see that our leading customers are beginning to place orders for capacity expansions."

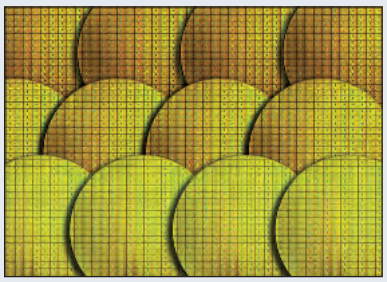
" We currently anticipate that Veeco's second quarter 2014 orders will be similar to or better than first quarter orders. Yet, the timing and magnitude of key customer expansions could cause MOCVD orders to be lumpy and somewhat unpredictable on a quarterly basis, and we lack the visibility to see into the second half of the year.

"We continue to invest in MOCVD product and technology development to further improve our customers' cost of ownership and manufacturing capability."

Peeler concluded, "We are pleased to have made progress improving Veeco's profitability and remain focused on our strategy to turn around our performance:
1) developing and launching game-changing new products that enable cost effective LED lighting, flexible OLED encapsulation and other emerging technologies;
2) improving customer cost of ownership as well as our gross margins;
3) driving process improvement initiatives to make us more efficient; and
4) lowering expenses."

Brewer Science announce Apogee temporary wafer bonder

BREWER SCIENCE, a supplier of thin-wafer handling technology, materials, and equipment to the microelectronics industry, has unveiled the Brewer Science Apogee bonder for temporary wafer bonding applications.



The Apogee bonder supports multiple temporary bonding/ debonding technologies including thermal slide, mechanical peel, and laser release debonding. The Apogee bonder completes the Brewer Science thin wafer handling tool suite for low-volume compound semiconductor production of RF filters, analog power devices, LEDs, and solar devices.

Brewer Science says this collection of tools provides reduced time to market for ultrathin wafer technologies using integrated material and process solutions. The Apogee features include:

- Substrate size range of 50-300 mm
- Dual rigid platens heat wafer stack from both sides, minimizing thermal defects
- Ultraflat self-leveling platens minimize total thickness variation TTV)
- Evacuated bond chamber eliminates voids
- Carrier and device are separated during pre-bond evacuation
- Total thickness variation

Emcore launches two-channel portable terahertz spectrometer

EMCORE CORPORATION has announced its latest breakthrough in terahertz technology with the release of the new PB7220-2000-T/R two-channel portable frequency domain Terahertz (THz) spectrometer.

The PB7220-2000-T/R is capable of simultaneous phase coherent measurements of both the transmission and the reflection properties of a sample. The second channel allows a single system to collect sample information at various angles of reflection or scattering from the sample while continuously monitoring the transmission.

The PB7220-2000-T/R expands Emcore's terahertz spectrometer line which also includes the PB7220-2000-T single channel system. The company's PB7220 series THz spectrometers are designed for THz researchers and application developers who need to study the properties of materials at THz frequencies with high resolution, but don't have the resources or personnel skilled in the complexities of optical measurements. Emcore says they are economical and portable THz systems that can sweep from 100 GHz to over 1.8 THz in a single rapid scan with high-frequency resolution.

The PB7220 series employs precisely tuned, fibre-coupled, semiconductor distributed feedback lasers along with a highly advanced photo-mixing source that puts all the THz power at the frequency of interest, yielding excellent signal-to-noise ratios of up to 70 dB Hz across the scan range.

In addition, the PB7220 series features sophisticated digital control hardware and software to provide a fully turnkey, portable THz spectrometer system.

"The PB7220 two-channel system is the most significant advancement in our THz technology since the introduction of PB7100 THz spectrometer in 2006," says Joseph Demers, Director of Advanced Photonics for Emcore.

"The industry has been seeking an economical two-channel system that can allow the simultaneous measurement of both the transmission and reflection properties of a sample.

"This added versatility in our THz platform makes it an even more valuable and flexible tool for a wider range of research, defence and homeland security related applications," adds Demers.

All PB7220 series models feature fibre-optically-coupled source and detector heads that are mounted on a rail system.

The PB7220-2000-T single-channel system utilises a single rail while the PB7220-2000-R/T two-channel system employs an adaptable optical bench.

For both systems the source and detector heads may be detached from the processor unit and used with extended fibre optic cables to provide maximum measurement flexibility in a wide range of applications.

TriQuint appoints new mobile RF solutions distributor in China

TRIQUINT SEMICONDUCTOR has announced the appointment of Upstar Technology as its new distributor in China for TriQuint high-performance mobile products.

"Upstar's LTE focus and mobile-centric product line mesh well with TriQuint's overall business strategy for China," said Todd DeBonis, TriQuint's Vice President of Global Sales and Strategic Development. "Upstar will provide our customers better access to TriQuint's innovative RF technology, and will help fuel our growth initiatives.

"Thanks to its strong sales and design support teams, Upstar has earned an excellent reputation for working closely with global partners and customers to address their unique requirements."

Upstar Technology is a provider of electronic components and solutions in China. "We're delighted to represent TriQuint in China," said Richard Lo, the acting General Manager of Upstar Technology. "TriQuint is a global leader in providing advanced, high-performance RF products that solve complex LTE system and chipset challenges. We look forward to partnering closely with TriQuint to deliver the benefits of its RF innovations to customers throughout our fast-growing region."

China is the world's largest wireless communications market, with growth driven by rapid consumer adoption of mobile devices and accelerating build-outs of LTE networks.

TriQuint has captured numerous design wins in China for leading smartphones and has also been selected for reference designs by multiple global and regional chipset partners.

Headquartered in Shenzhen with offices in Shanghai and Beijing, Upstar provides OEMs (Original Equipment Manufacturers), ODMs (Original Design Manufacturers) and EMS (Electronics Manufacturing Services) in China with a wide range of electronic components.

With this new partnership, TriQuint's customers in China now have an expanded channel to access TriQuint's RF solutions for mobile products.

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- Complete materials range
- MOCVD, MBE, CVD
- Advanced semiconductor wafer products
- Advanced R&D capabilities
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IQE

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Daylight delivers first laser-based IR microscopy platform

DAYLIGHT SOLUTIONS, a manufacturer of molecular detection and imaging solutions in the mid-infrared, has announced delivery of what it claims is the world's first commercially available laser-based infrared microscopy platform.

The company's advanced microscope was delivered to Rebekah Drezek's Optical Molecular Imaging and Nanobiotechnology Laboratory at Rice University in Houston, Texas.

The system will initially be used to conduct cutting-edge research into laser-based infrared microscopy for the optical diagnosis of breast cancer.

"We are delighted to have received the Spero IR microscopy system," states Drezek. "The combination of spectral tuneability and rapid imaging in these wavelength ranges is unprecedented and we are very excited to begin using the system to develop enhanced optical cancer diagnostics."

The award-winning microscope, marketed under the brand name Spero, opens up a new world of research possibilities with breakthrough chemical imaging and analysis on a real-time basis.

Powered by Daylight's broadly tuneable Quantum Cascade Laser (QCL) technology, Spero offers a combination of excellent visibility, instantaneous results in "live mode," and a small resource footprint to easily fit into any lab or clinical setting. The system's capabilities are further augmented by automated computational algorithms that enable identification and segmentation of complex chemical signatures. Applications for Spero range from label-free tissue and cell diagnostics in Life Sciences to materials analysis in industrial markets.

Drezek's initial phase of research, funded by the National Science Foundation's Small Business Engineering Research Centre Collaborative Opportunity (SECO) program, will seek to demonstrate the

unique advantages of a tuneable, mid-infrared laser-based system over that of a conventional Fourier Transform Infrared (FTIR) microscope.

The program will also include an evaluation of the Spero's full and sparse data collection modes. In full data collection mode, a complete spectral scan can be collected in five minutes. This will be compared to the sparse data collection mode, in which only a small subset of key wavelengths are rapidly collected in seconds.

During the second phase of the research, the MCF10A and SKBR3 breast cell lines will be analysed with the system to assess the predictive value of the infrared spectral data for normal, cancer, and cancer sub-types.

"We have always appreciated our close collaboration with Drezek and Rice University and are proud to deliver our Spero microscope to her lab," says Daylight Solutions President, Paul Larson. "We know that her talented team will leverage the advanced capabilities of the instrument to make a very significant impact on the continuing fight against breast cancer."

Anadigics wins orders from Chinese smartphone OEMs

ANADIGICS' PROEFICIENT and ProVantage power amplifiers (PAs) have been selected by multiple Chinese OEMs to enable wireless connectivity in new smartphone designs.

"We are extremely pleased with our design-win progress at multiple OEMs in China," says Dave Cresci, president of Anadigics. "According to a recent report by DigiTimes Research , the sequential annual growth rate in smartphone shipments from Chinese OEMs is expected to exceed 30 percent in 2014."

"Anadigics is well positioned to capitalise on this expected growth with design wins at several key OEMs, including Huawei, ZTE, Coolpad and Innos. We anticipate that these new design wins for our ProEficient and ProVantage power amplifiers should enable a significant increase in our mobile products revenue at Chinese OEMs."

Anadigics' ProEficient and ProVantage solutions utilise the company's patented InGaP-Plus technology. ProEficient power amplifiers also leverage Anadigics' unique design architectures to offer one of the highest efficiencies across all power levels, enabling greater talk time and longer data application use.

ProVantage power amplifiers are designed to provide manufacturers with excellent value by combining high performance with space-saving integration and lower overall system cost.

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Toyota reveals higher efficiency SiC power semiconductor

TOYOTA MOTOR CORPORATION, in collaboration with Denso Corporation and Toyota Central R&D Labs., Inc. (Toyota CRDL), has developed a SiC power semiconductor for use in automotive power control units (PCUs).

Toyota will begin test driving vehicles fitted with the new PCUs on public roads in Japan within a year. Through use of SiC power semiconductors, Toyota aims to improve hybrid vehicle (HV) fuel efficiency by 10 percent under the Japanese Ministry of Land, Infrastructure, Transport and Tourism's (MLIT) JC08 test cycle. The company also aims to reduce PCU size by 80 percent compared to current PCUs with silicon-only power semiconductors.

SiC power semiconductors have low power loss when switching on and off, allowing for efficient current flow even at higher frequencies. This enables the coil and capacitor, which account for approximately 40 percent of the size of the PCU, to be reduced in size.

PCUs play an important role in hybrids and other vehicles with an electrified powertrain: they supply electrical power from the battery to the motor to control vehicle speed, and also send electricity generated during deceleration to the battery for storage. However, PCUs account for approximately 25 percent of the total electrical power loss in HVs, with an estimated 20 percent of the total loss associated with the power semiconductors alone.

Therefore, a key way to improve fuel efficiency is to improve power semiconductor efficiency, specifically by reducing resistance experienced by the passing current. Since launching the Prius gasoline-electric HV in 1997, Toyota has been working on in-house development of power semiconductors and on improving HV fuel efficiency.

As SiC enables higher efficiency than silicon alone, Toyota CRDL and Denso began basic research in the 1980s, with Toyota participating from 2007 to jointly develop SiC semiconductors for practical use. Toyota has installed the jointly developed SiC power semiconductors in PCUs for prototype HVs, and test driving on test courses has confirmed a fuel efficiency increase exceeding 5 percent under the JC08 test cycle.

In December last year, Toyota established a clean room for dedicated development of SiC semiconductors at its Hirose Plant, which is a facility for research, development and production of devices such as electronic controllers and semiconductors.

5N Plus to supply First Solar to 2019

5N PLUS, has entered into new supply agreements with First Solar, covering its compound semiconductor needs until March 31st, 2019. The company has renewed its existing CdTe supply agreement and the compounds' by-products recycling agreement.

In addition, a new supply agreement broadly covering all of First Solar's other compound semiconductor needs up to March 31st, 2019, has also been concluded. Under the new agreements, First Solar has agreed to exclusively purchase from 5N Plus, all the CdTe required by First Solar on a worldwide basis for the manufacturing of solar photovoltaic modules.

"We are very pleased to have extended our agreements with First Solar until 2019, enabling us to bring our relationship with this important customer to another level. While we conceded competitive pricing, we believe that this will be largely compensated over the course of the next quarters by the increase of sales volume providing us with a solid and predictable revenue stream for the next five years," says Jacques L'Ecuyer, President and Chief Executive Officer of 5N Plus.

"First Solar remains committed to reducing solar module cost and improving efficiency, and we intend to be their preferred solution for doing so through our close technical and commercial relationship. We strongly believe that these new supply agreements will allow 5N Plus to benefit from continued growth associated with First Solar's leading position in the solar market," he adds.

"5N Plus has been and continues to be a critical supplier to First Solar. These agreements support our plans to increase the competiveness of CdTe based solar modules and are in line with our corresponding roadmap aimed at achieving this," notes Tymen de Jong, Senior Vice President of Global Operations of First Solar, Inc.

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Cree:

Fading out?

As Cree builds business for the long-term, shares fall as investors lose faith. What's next for the LED lighting heavyweight? Rebecca Pool investigates.

Shares may be falling but Cree's cash-rich balance sheet makes industry acquisitions a very real option for the LED maker

DESPITE POSTING an increase in sales and rising revenues in its latest financial quarter, Cree's overall lower-than-expected earnings saw shares suddenly plummet by 11 percent, slipping another 9 percent in the days that have followed.

Coming in at $405 million, quarterly revenue just missed analyst's estimates of $407 million. And with chief executive Chuck Swoboda pointing out how his company's already squeezed gross margins will continue to fall throughout the fiscal year, some investors have jumped ship.

"Cree is focused on building a long-term viable business which often comes with short term difficult decisions," says Jed Dorsheimer, managing director of equity research firm, Canaccord Genuity. "But investor expectations have been too high and now we are seeing the pull-back."

Indeed, Cree's long-term views have seen near-term operating expenditure rise, and as Dorsheimer puts it: "Investors aren't getting the gross margin expansion or the operating margin expansion, which is calling into question its earning power, so stock has been sold off."

But the drop in shares represents new opportunities for new investors and Dorsheimer believes the coming year holds great promise for Cree. "Our thesis is that 2014 will represent a transition year [for LED lighting] as we move from an early adopter phase into the growth phase and mass adoption in 2015," he says. "All evidence I have seen supports this."

Critically for Cree, wider LED lighting adoption should ease pricing pressures on its components, boost LED replacement bulb and lighting systems sales, leading to margin expansion. And tumbling shares aside, Cree's focus on technology, cost and branding has delivered positive results.

Innovation-wise, the company's success is doubtless. In just over a year the company has released five versions of its LED light bulb. Then last month, it demonstrated a 303 lumen per Watt, high power LED; the first LED component to exceed 300 lumen per Watt ever.

Amid dogged development, the company has also pushed the price of the light bulb lower and lower. Its 60 W equivalent soft white LED bulb now costs only $6.97 at the Home Depot, down $3 in price in the last month. Meanwhile Philips' SlimStyle version currently costs $8.97.

As Swoboda said in his post-earnings call: "We continue to work with the Home Depot to test the price to consumers... The lower retail price points... have already increased sales and confirm there are significantly more opportunities to drive LED adoption."

Dorsheimer expects replacement bulb prices will continue to decrease until mass adoption takes place. But not so rapidly. "We will probably see an updated version of its bulb... with a

Chuck Swoboda: As industry consolidation sets in, Cree is ready to make acquistions. (Cree)

lower cost structure, but we are not going to see the same level of price cuts," he says. "The combination of subsidies in North America and the prices manufacturers are offering today means we are ready for widespread adoption."

Dorsheimer also reckons the company's partnership with the Home Depot has helped it build the Cree brand. At the beginning of this year, the analyst, for one, didn't believe the name 'Cree' was selling bulbs. Not anymore.

"Cree is definitely becoming well known as a lighting company, which is their goal," he says. "They have having success here and the Home Depot has helped."

But if the market really is on the cusp of mass LED adoption, where next for Cree? Despite its hefty spending on development and brand building, Cree remains a cash-rich company. On its latest balance sheet, cash and investments come in at $1.2 billion, and so now the company is eyeing future acquisitions.

As part of his post-earnings call, Swoboda said: "We believe some opportunities may emerge over the next 24 months... as industry begins to go through a consolidation phase. The strength of our operating model gives us the flexibility to make these investments and continue to maintain a strong balance sheet."

For a vertically integrated cash-rich company such as Cree, surely the opportunities for acquisitions are vast? Dorsheimer believes Cree will remain focused. He reckons thanks to its well-established components and bulb business segments, acquisitions from these markets are unlikely.

But highlighting how Philips Electronics bought commercial and industrial lighting systems manufacturer, Genlyte, back in 2008 he says: "Cree is a newcomer in the commercial and industrial lighting systems market. We would positively view any acquisitions that would expand its presence here."

Commercial GaN:

M/A-COM is ready and waiting

With GaN-on-silicon technology entering mass production, industry power players are poised for action. What are M/A-COM's plans? Rebecca Pool investigates.

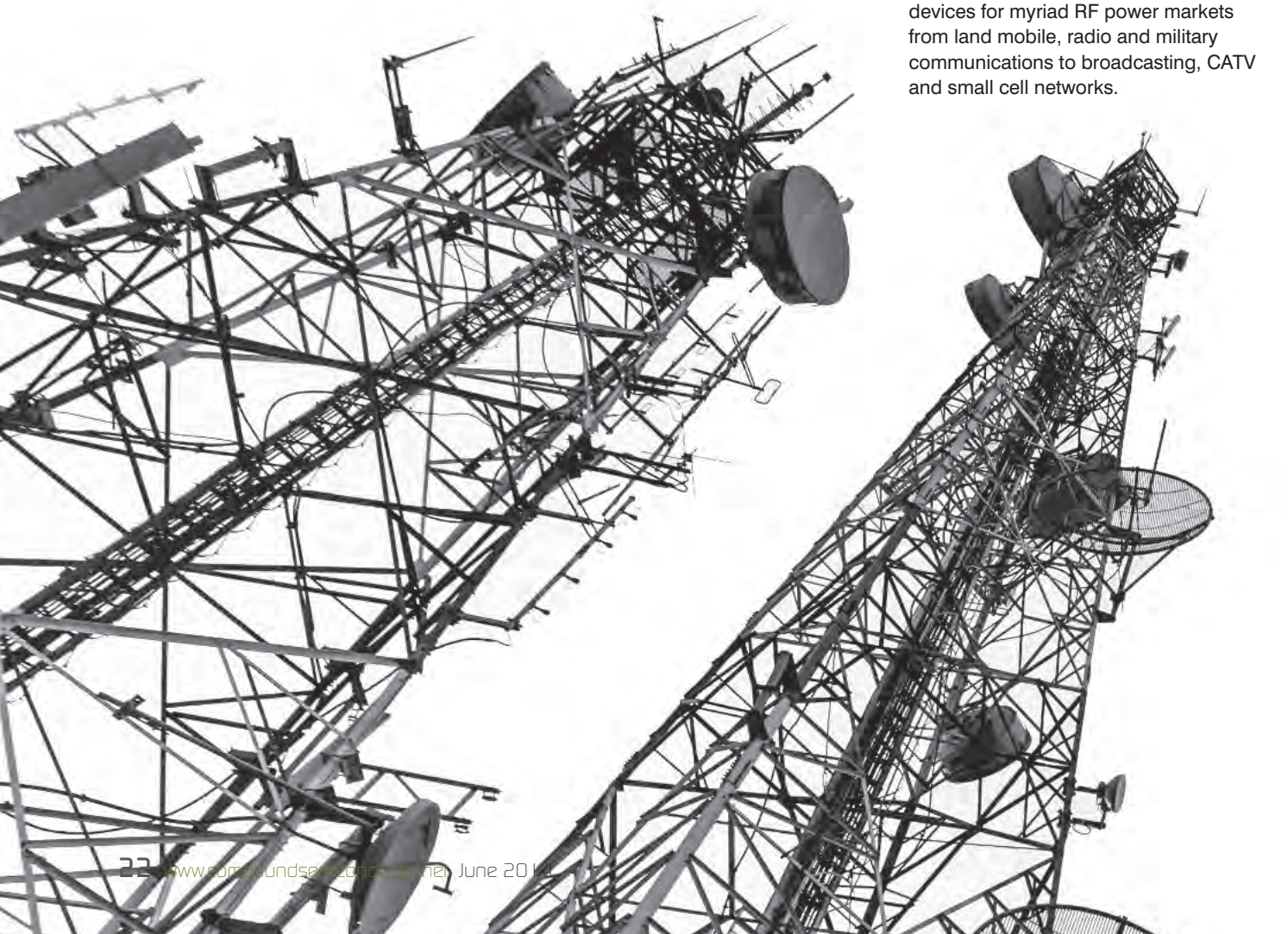
AS GAN-ON-SILICON TECHNOLOGY readies for mass production, US-based M/A-COM is preparing to seize significant market share.

In February this year, US provider of high performance semiconductors, M/A-COM, bought long-time GaN RF semiconductor developer, Nitronex, for $26 million in cash. Then, just weeks later it teamed up with UK-based wafer maker IQE to produce four, six and eight inch GaN-on-silicon epiwafers, and claims to be in 'active discussions with select companies' to license out its IP.

M/A-COM isn't a stranger to industry acquisitions. Late last year, it completed its tender of RF device maker, Mindspeed Technologies, US, boosting its SiGe technology presence. And now, Nitronex, looks set to secure its GaN-on-silicon RF power ambitions.

"Nitronex has firstly allowed us to establish a design centre for RF power in the North Carolina region, and we are drawing on the talent pool here," explains Doug Carlson, director of strategy for aerospace and defence at M/A-COM. "We now have the largest portfolio of GaN products in the industry and we are building on that position."

Indeed, while M/A-COM already boasted a strong line-up of RF power products in pulsed avionics, snapping up Nitronex extends its reach to continuous wave applications. With both in hand, the company can now develop devices for myriad RF power markets from land mobile, radio and military communications to broadcasting, CATV and small cell networks.



And as Carlson adds: "Over the next couple of months you should anticipate seeing GaN-on-silicon [devices] with higher power levels for continuous wave applications and with plastic packaging formats. [These will target] power communication applications and will be designed with technologies such as envelope tracking in mind."

But the Nitronex acquisition and subsequent licensing agreements are not all about providing more devices for more markets. As mainstream adoption of GaN-on-silicon technology gathers momentum, M/A-COM executives are keen to convey that their company can now provide the solid, sustainable supply chain that end-users crave.

Company announcements are peppered with guarantees of 'surety of supply' and intentions to 'create the necessary supply chain to accelerate GaN adoption'. And both Carlson, and his colleague Suja Ramnath, senior vice president and general manager of RF and Microwave are quick to emphasise the same.

"What M/A-COM brings to the table... is our channel to market and applications knowledge," highlights Ramnath. "For, example, penetration into the radar market, customers look for a multi-decade sustainable supply chain. We've been around for well over sixty years and have supported these markets of decades."

And as Carlson adds: "It's best to think of our IP licensing program for GaN-on-silicon technology in terms of establishing an industry supply chain that allows major OEMs to adopt the technology with confidence. This is the purpose of the licensing program."

But licensing out GaN-on-silicon IP may not be so straightforward. Semiconductor analysis business, Yole Développement, and patent business, KnowMade, recently warned of an upcoming 'IP battle' for GaN-on-silicon substrates.

Thanks to lower costs and CMOS compatibility, Yole analyst Hong Lin expects the technology to be widely adopted by power electronics and RF applications. However, she also highlights how key GaN players including Toshiba, Samsung, Soitec and Azzurro have reinforced critical patent filings on the technical challenges of depositing GaN onto silicon. Throw in the recent M/A-COM-Nitronex acquisition and interest from Toshiba and Samsung, and Lin predicts an 'IP battle' in the next three years. M/A-COM claims not to be concerned, with Ramnath asserting: "We have vetted our IP position prior to the Nitronex acquisition... and are satisfied that for our applications, we are well positioned and have established a robust defensible position for ourselves."

So assuming IP issues don't stymie progress, when can we actually expect widespread industry adoption of GaN-on-silicon technology for power applications? From M/A-COM's perspective, sooner than you might think.

Within two to five years Ramnath reckons M/A-COM will be supplying products into numerous applications, with the company achieving market dominance within the decade.

And as Carlson adds: "Volumes will come up in the next two to five years, and exiting that five year period, the cost structure of GaN-on-silicon will be on par with silicon. One can then envision the market disruption that will happen."

M/A-COM plans to develop GaN-on-silicon devices for RF power markets including land mobile, radio and military communications, CATV and small cell networks

MOCVD players: Growth at last

Do the latest quarterly results from Veeco and Aixtron point to market recovery? Rebecca Pool investigates.

AS MOCVD equipment suppliers, Veeco and Aixtron, report rising orders and revenues, the long-awaited recovery could finally be here.

In his recent quarterly earnings call, Veeco chief executive, John Peeler, claimed his highest MOCVD order levels for more than two years. And while Aixtron chief executive, Martin Goetzeler, admitted 'revenues and orders are still at a low level', he categorically stated: "The good news is the adoption of LEDs for general lighting purposes is gaining further momentum."

Without a doubt, the LED market is driving recovery and growth for suppliers of MOCVD equipment. In a recent *Global Metal Organic Chemical Vapour Deposition Equipment* market report, Technavio lead analyst, Navin Rajendra cited an increasing demand for LEDs in the global LED lighting market as being a key MOCVD market driver.

Other key market drivers included the increasing adoption of mobile devices – especially 4G handsets across Asia – and photovoltaic cells, but as Rajendra tells *Compound Semiconductor:* "The LED market is going to have a major, major impact."

Not surprisingly, market growth is being driven by Asia-based LED manufacturers. According to Rajendra, in 2013, some 96 percent of revenue generated by sales of MOCVD equipment came from businesses in the Asia-Pacific, with some 2 percent coming from the Americas, and the same again from Europe, Middle East and Africa.

"This is completely understandable as most of the assembling and manufacturing takes place here, so it only makes sense to base your chemical deposition processes in close proximity to this," he says. "In 2013 we have 96 percent here and this will grow to 98 percent [by 2018], which is significant growth for a well established market."

Take a look at the recent Aixtron and Veeco financial results, and each MOCVD player concurs. For Aixtron, 79 percent of total revenues in the first three months of this year came from Asia, with 17 percent coming from Europe and 4 percent, from the US. At the same time, Veeco's Peeler, in his recent earnings call, claimed his company is seeing increased interest in MOCVD equipment from each major country in Asia.

China lead continues

Of the Asia-Pacific businesses, Rajendra highlights how China-based players still dominate and, again thanks to the nation's large manufacturing base, will do so for the next five to six years. As he points out, the Chinese government has set aside vast amounts of land for future manufacturing processes, and adds: "The government still wants more 'local' companies to set up factories here and are providing a number of subsidies to various manufacturing and assembly units."

For example, in January this year, China-based LED maker, Sanan Optoelectronics, reported receiving a US $3.85 million government subsidy while some industry reports suggest the company received some US $13 million in December 2013.

China business aside, Rajendra also expects MOCVD equipment makers will see more revenues coming from LED manufacturers based in South Korea and Taiwan, and believes companies are steadily working through the major LED surpluses in the market.

"As of 2013, the over-supply of LEDs was still there," he says. "Two quarters later and it's still there... but there will be a significant drop at least by the end of this year."

Indeed, Veeco and Aixtron claim to be seeing similar results. Veeco's Peeler asserts LED lighting adoption is accelerating, noting how his customers' equipment utilisation rates are currently 'the highest they have been for a very long time'. And Aixtron's chief financial officer, Wolfgang Breme, attributes a massive 73 percent of all revenues in the first quarter of this year, solely to the LED market.

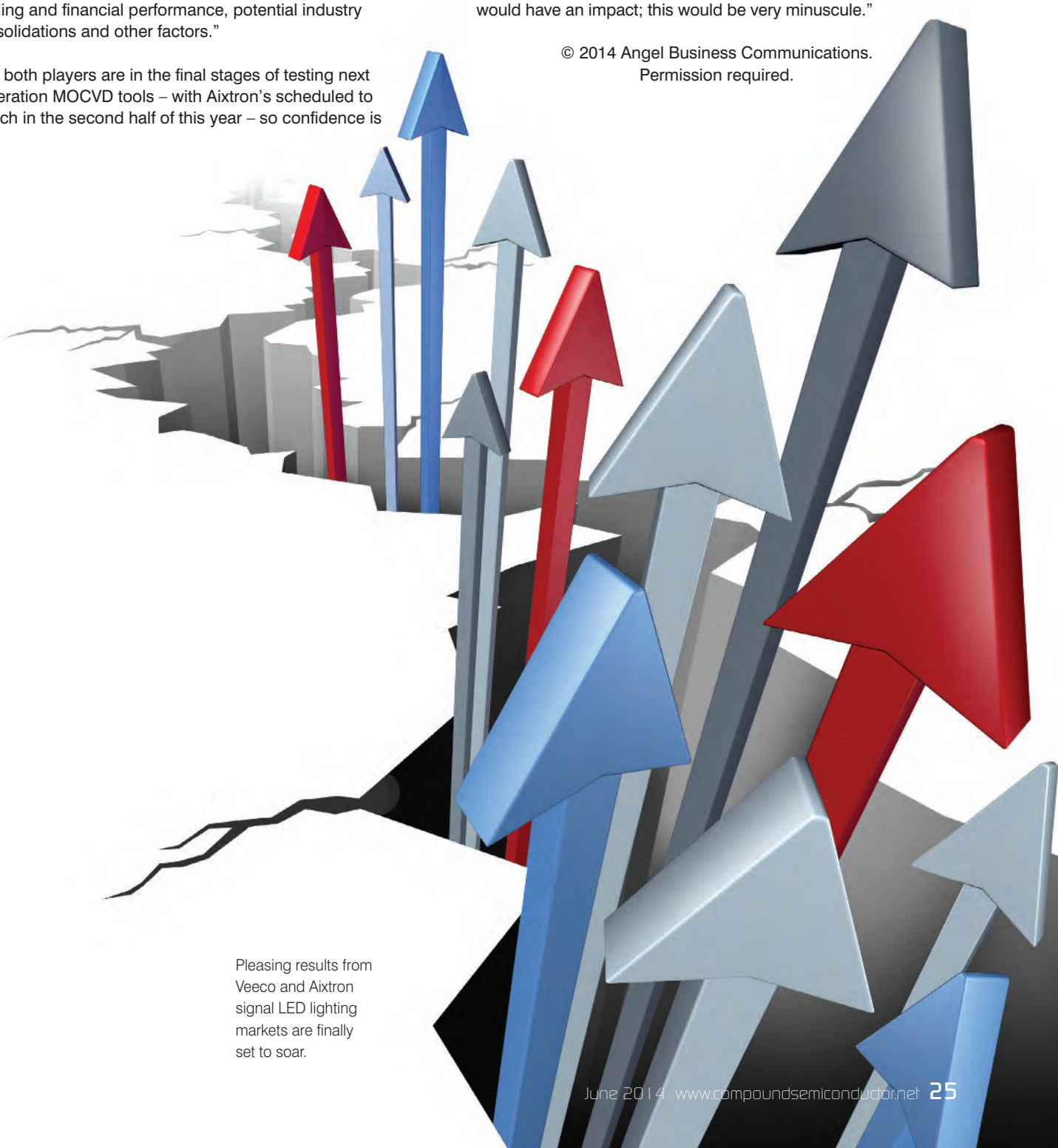
But the equipment makers aren't ready to trumpet rock-solid market pick-up quite yet. Aixtron hasn't yet reported any noticeable increase in investments in LED manufacturing capacity expansions and attributes this quarter's rising revenues to inventory write-downs and restructuring charges included in previous years' figures, as well as lower operating costs. As Aixtron chief executive, Martin Goetzeler, stated in his

company's recent earnings call: "We are seeing a slight pick-up in demand for equipment from LED manufacturers, but that pick-up is not strong enough for us to change our [flat revenue] guidance for 2014."

And while Veeco's Peeler claims the company has seen 'some real substantial pick-up in MOCVD' and expects similar, if not higher, orders in the next quarter, he also adds: "I do want to argue some caution on this recovery as the timing and magnitude of MOCVD deals will be impacted by our customers' funding and financial performance, potential industry consolidations and other factors."

Still, both players are in the final stages of testing next generation MOCVD tools – with Aixtron's scheduled to launch in the second half of this year – so confidence is surely returning. And as Rajendra predicts the MOCVD market will grow from nearly $520 million in 2013 to more than $1 billion in 2018, each is set to reap the rewards.

As the analyst confirms, Veeco remains the MOCVD market leader, but the prospect of any other business capturing market share from the big two is slim. "Taiyo Nippon Sanso is another vendor, is diversifed across many industries but has only 1 percent of the world MOCVD market," he says. "So, the top two have almost 100 percent market share. I doubt any new entry would have an impact; this would be very minuscule."



Pleasing results from Veeco and Aixtron signal LED lighting markets are finally set to soar.

Multi-junction solar cells to push CPV efficiencies beyond 50 percent

GaN-based solar cells for integration to multi-junction photovoltaics could raise concentrated photovoltaic system efficiencies to more than 50 percent, reports Rebecca Pool.

Without a doubt, concentrated photovoltaics using multi-junction solar cells can reach efficiencies that leave other photovoltaic technologies floundering.

Today's typical three junction devices have achieved efficiencies as high as 44.4 percent under concentration while next generation four- and five-junction architectures are approaching 50 percent conversion efficiencies.

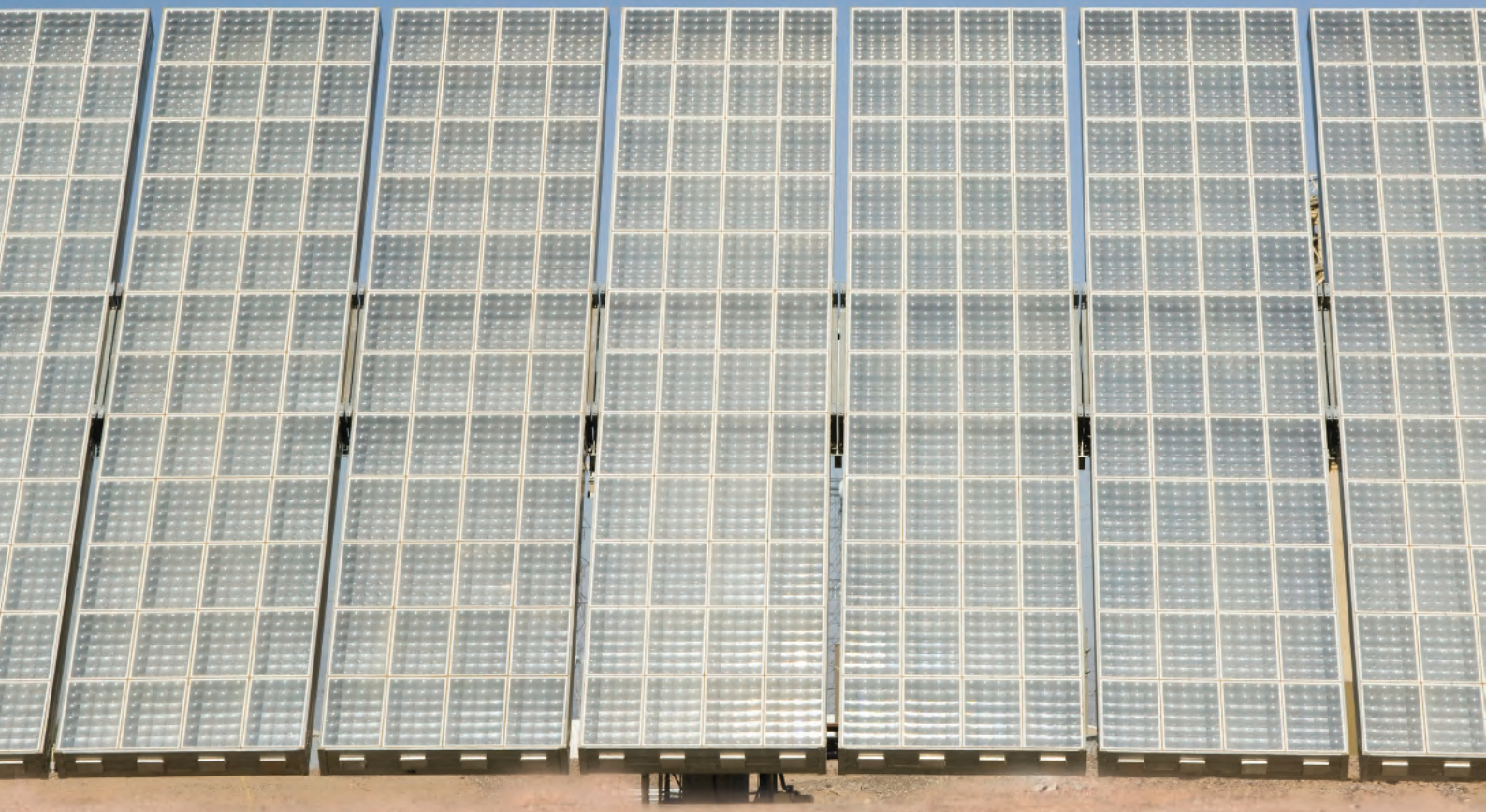
However, these leaps in efficiency come at a cost. MOCVD deposition of the III-V layers that make up a *p-n* junction is complex as manufacturers strive to minimise the lattice mismatches between neighbouring layers that induce strain, degrade materials and stymie device performance.

And crucially, the cost of a CPV system using III-V cells is yet to be truly competitive with industry-standard silicon-based photovoltaic systems. Factor in falling silicon prices and it's easy to see why several key CPV system makers have folded.

One clear way to cut the cost of a CPV system is to boost the efficiency of its solar cells by adding another junction. However, the constraints associated with lattice-matching makes the epitaxial growth of a fourth or fifth junction a real challenge.

As a result, some researchers aim to grow high-energy junctions separately, and then add these to an underlying multi-junction cell. One such group is based at the University of California, Santa Barbara, and has fabricated an InGaN/GaN multi-quantum well solar cell with a wide bandgap of 2.65 eV.

Serving as the fifth junction, the researchers intend to optically bond



this 'sub-cell' to an underlying GaAs multi-junction solar cell. This move will side-step the lattice mismatch issues that prohibit InGaN growth on GaAs structures, and could catapult overall device efficiency to a breath-taking 50 percent or more.

As Nathan Young from the Materials Department at UCSB explains, the InGaN/GaN solar sub-cell produces a relatively small current, and efficient current matching with the underlying junctions simply isn't possible. Consequently the bonding layer – a transparent and non-conducting polymer – is critical to isolate the this cell from the underlying multi-junction cell.

"There's no electrical connection [between the junctions], we're just keeping the device optically coupled," he says. "We basically place the InGaN/GaN sub-cell onto the multi-junction cell and bond it with a transparent polymer. We then take out an extra contact so we can link the structures electrically."

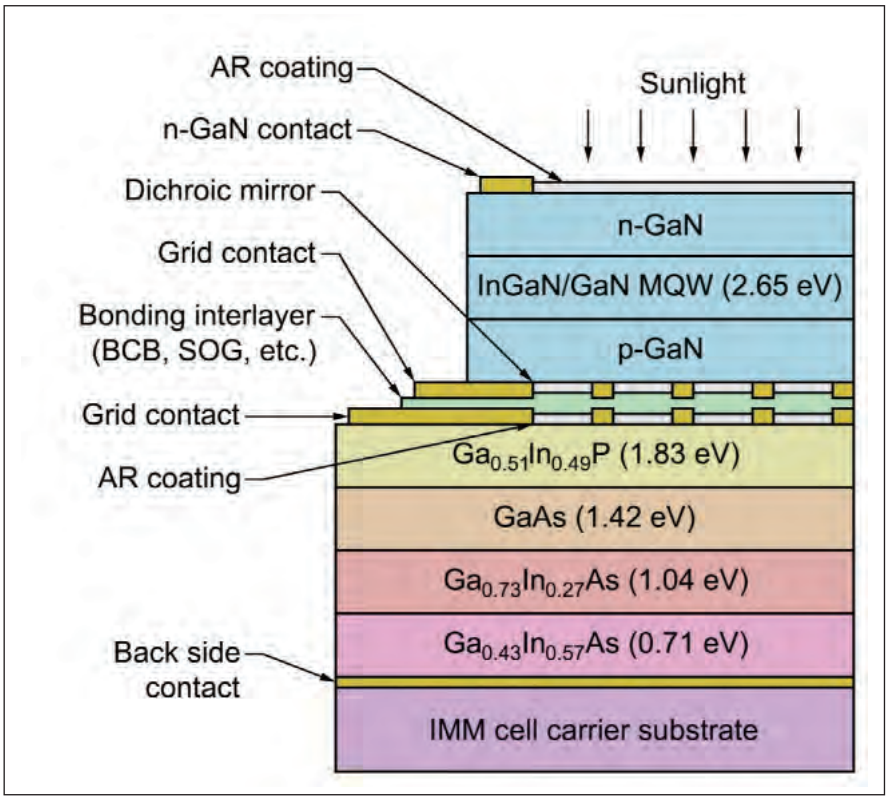
According to Young, while the additional contact introduces an extra step to device manufacture, depositing one more epitaxial, current-matched junction simply isn't an option. As he explains: "This inability to current match an InGaN cell with a 2.65 eV bandgap is unavoidable... InGaN is the only material that can perform efficiently at this wide bandgap."

Broadband coatings

A crucial part of the research has been to add optical coatings – as is standard practice in today's multi-junction cells – to the InGaN/GaN cells. As Young highlights: "Before [coatings] were added to the cell, it just wasn't performing that well as it wasn't absorbing enough light."

In this case, the challenge was to develop coatings that exhibited anti-reflection properties across sufficiently wide wavelength ranges, and, for the first time, apply these to InGaN/GaN cells.

"We're trying to get as much light as possible into our device, without sacrificing any light that would not be absorbed by the InGaN multi-quantum well layer," says Young's colleague, Emmett Perl, from the Department of Electrical and Computer Engineering at UCSB. To this end, the team designed a system of high performance broadband optical coatings – a front-side anti-reflective coating and back-side dichromic mirror – for the InGaN/GaN solar cell. These actually minimise front surface reflections across the broad spectral range while maximising rear surface reflection only in the spectral range absorbed by the InGaN. The dichromic mirror also allows for the InGaN/GaN cell to absorb additional light on a second pass.



Proposed cross-section of the device structure including contacts and optical coatings

So far, the results are good. Application of the coatings increased the peak external quantum efficiency of the InGaN/GaN cell by 56 percent, and conversion efficiency by 37.5 percent, relative to an uncoated structure.

The team is now looking to boost InGaN device efficiency. Young reckons the sub-cell will need to be at least 50 percent more efficient than current demonstrations, if integration to a five junction stack is to make sense.

Work is also underway to develop a final bonding process for integration. In other multi-junction architectures, the bonding layer has to allow electrical conduction and optical transmission, but as Perl highlights: "Our optical coatings will provide excellent optical transmission into the underlying four junction structure."

"Our electrically isolated terminal configuration also means electrical conduction across this bonding interface isn't necessary," he adds.

Perl is now optimising thermal conduction across the layer as well as its fabrication processes, while at the same time improving the quality of the broadband coatings. Currently investigating the use of anti-reflective nanostructures in the coatings, he believes this additional work will reduce reflections to near zero, for GaN, and is confident any increase in manufacturing costs will be offset by the gains in cell efficiency.

"With the right resources in place, I think an integrated device could be demonstrated in two-to-three years, with a 50 percent [efficient] device in the next five to seven years," says Young. "With time and effort, we believe the inherent scalability of this technology provides good commercial opportunities for CPV."

Left: Concentrated photovoltaic systems: Will next generation multi-junction cells take efficiencies over 50%?

Graphene:
Opening The Bandgap

A host of lesser-known compound semiconductors are being used to exploit graphene's electronic properties. Reports Rebecca Pool.

SOME TEN YEARS AGO, UK-based University of Manchester researchers, Kostya Novoselov and Andre Geim, published their seminal Science paper on graphene. Using scotch tape, the physicists peeled layers of graphene from a graphite block, dissolved the tape to leave ultra-thin flakes of graphene that they used to fabricate rudimentary silicon oxide-based transistors.

The rest is history. Just one atom thick, graphene forms a high quality crystal lattice with no vacancies and no dislocations, yielding remarkable properties. Studies by Geim and Novoselov – since awarded the Nobel Prize for Physics – revealed the material's conducting electrons arrange into quasi-particles that behave more like neutrinos, moving close to the speed of light. With their first transistors displaying ballistic transport, linear current-voltage characteristics and huge sustainable currents, the researchers could only conclude: "graphene may be the best possible metal for metallic transistor applications".

However, a clear obstacle to the use of graphene as an alternative to silicon electronics is its lack of bandgap; with electrons flowing at any energy, low power dissipation in the off state is very difficult. Given this, researchers worldwide have been exploring ways to create an artificial bandgap – applying an electric field, modifying graphene's structure or doping with impurities - but device characteristics have fallen short of the wonder material's intrinsic properties.
On a different track, Novoselov and a handful of other researchers have been fabricating heterostructures based on single layers of graphene and novel compound semiconductors. These structures comprise layers of alternating 2D crystals - graphene and the insulating material - stacked up to form a device. As Novoselov says: "Research on heterostructures is gaining momentum, and the possibilities for controlling properties of heterostructures might become very useful for future applications."

Novoselov and his team at the University of Manchester have largely focused on using 2D crystals of hexagonal boron nitride to fabricate graphene heterostructures. Just over two years ago they unveiled a bipolar field-effect transistor based on layers of graphene and atomically thin boron nitride with on-off ratios an order of magnitude greater than planar graphene FETs. At the same time, other researchers have fabricated devices with mobilities almost an order of magnitude better than devices on silicon dioxide.

As Novoselov's colleague, Colin Woods, explains, hBN has a very similar lattice to graphene, making it an attractive candidate for building graphene heterostructures. "It's also a high bandgap semiconductor and has a high crystal purity so we've been getting very good results with these heterostructures," he adds. Excitingly, recent research published in *Nature Physics*, shows that growing graphene on hBN can alter its crystal structure, opening a gap between its electron energy bands.

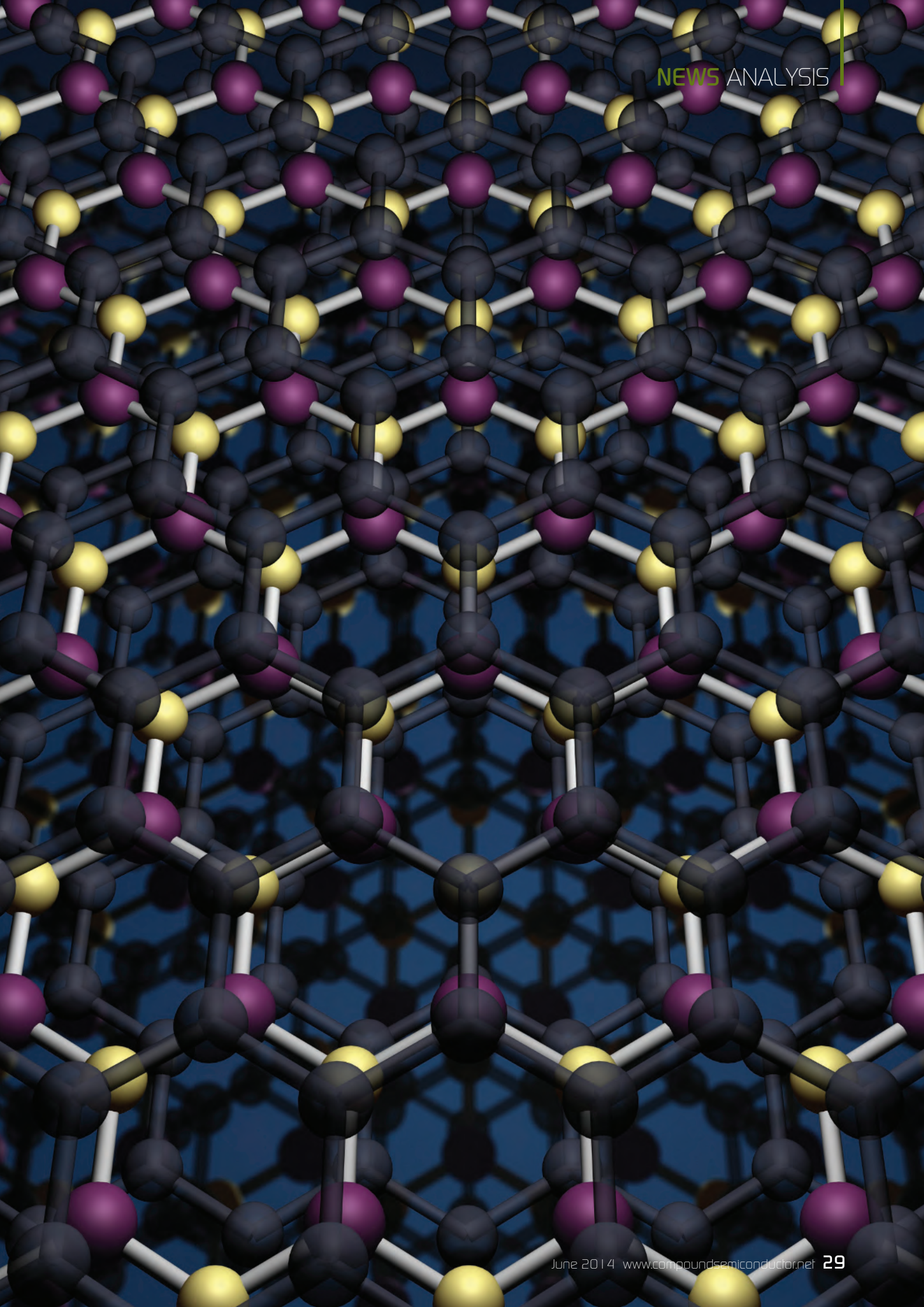
Novoselov, Woods and colleagues found that when the two lattices are oriented in a certain way, the distance between graphene's carbon atoms is stretched so its lattice matches that of hBN, and the bandgap is opened. If this alignment is off, the carbon atoms revert to original positions and the bandgap disappears.

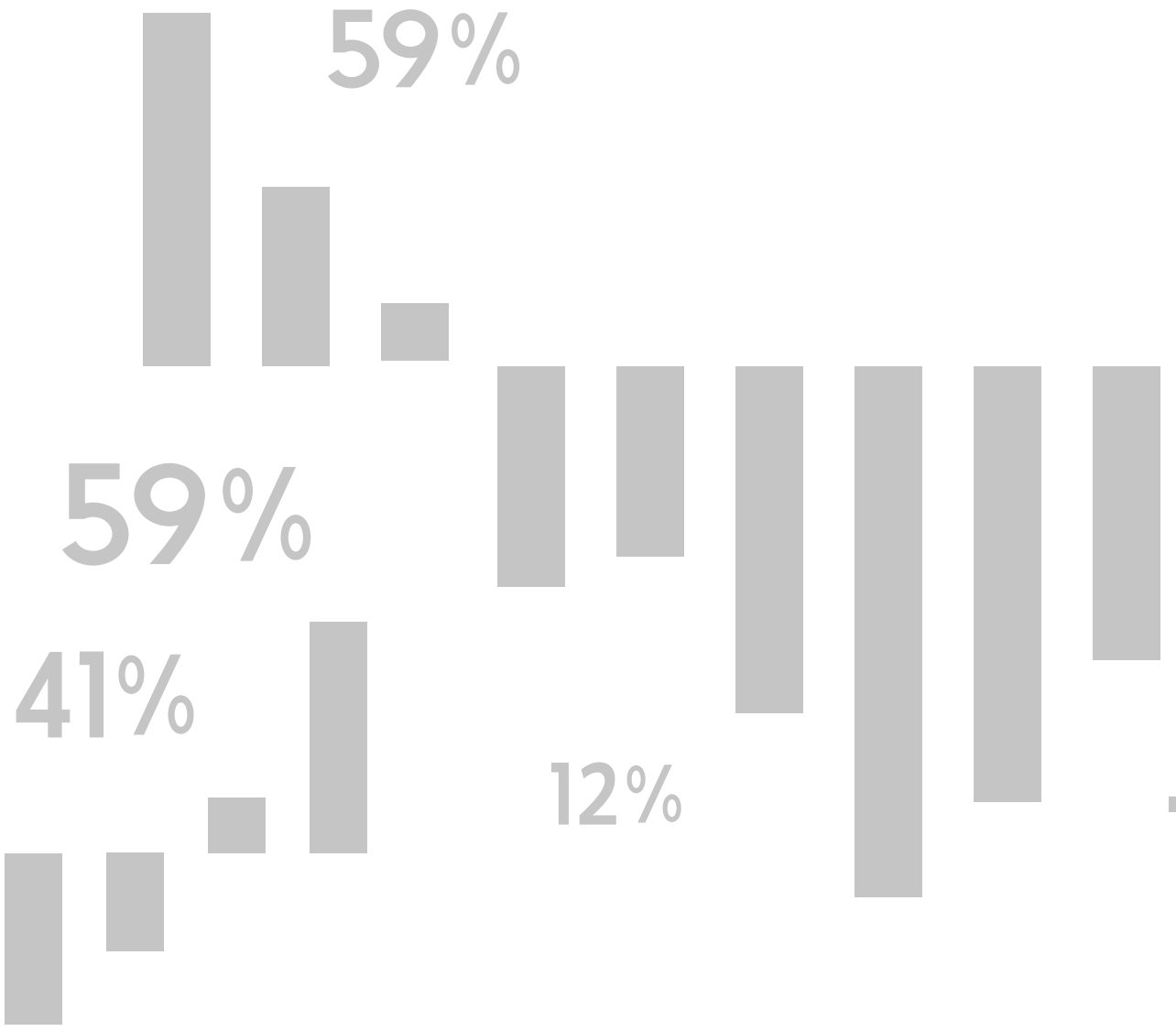
"It was extremely exciting to see the properties of graphene change so dramatically by simply twisting the two crystals only a fraction of a degree," says Woods. "We're not yet sure whether the bandgap is a result of [lattice] strain, but obviously a bandgap in graphene is very desirable."

"It is very small but you never know where this might go in the future," he adds. Crucially, as the researcher points out: "This discovery provides another way to control the properties of graphene heterostructures. Not all the questions are answered and this is certainly a phenomenon worth investigating."

But the research doesn't stop with hBN. Novoselov's group is looking at other 2D crystals – from molybdenum disulphide to niobium diselenide – all of which hold considerable promise for graphene.

"Each material has its own set of properties and its difficult to single out a single crystal and say 'yes its properties are going to be good' as they change as you alter the number of layers in the heterostructure," says Woods. "But this is a very exciting time to be looking at graphene; people honestly don't know what's going to happen until they do it."

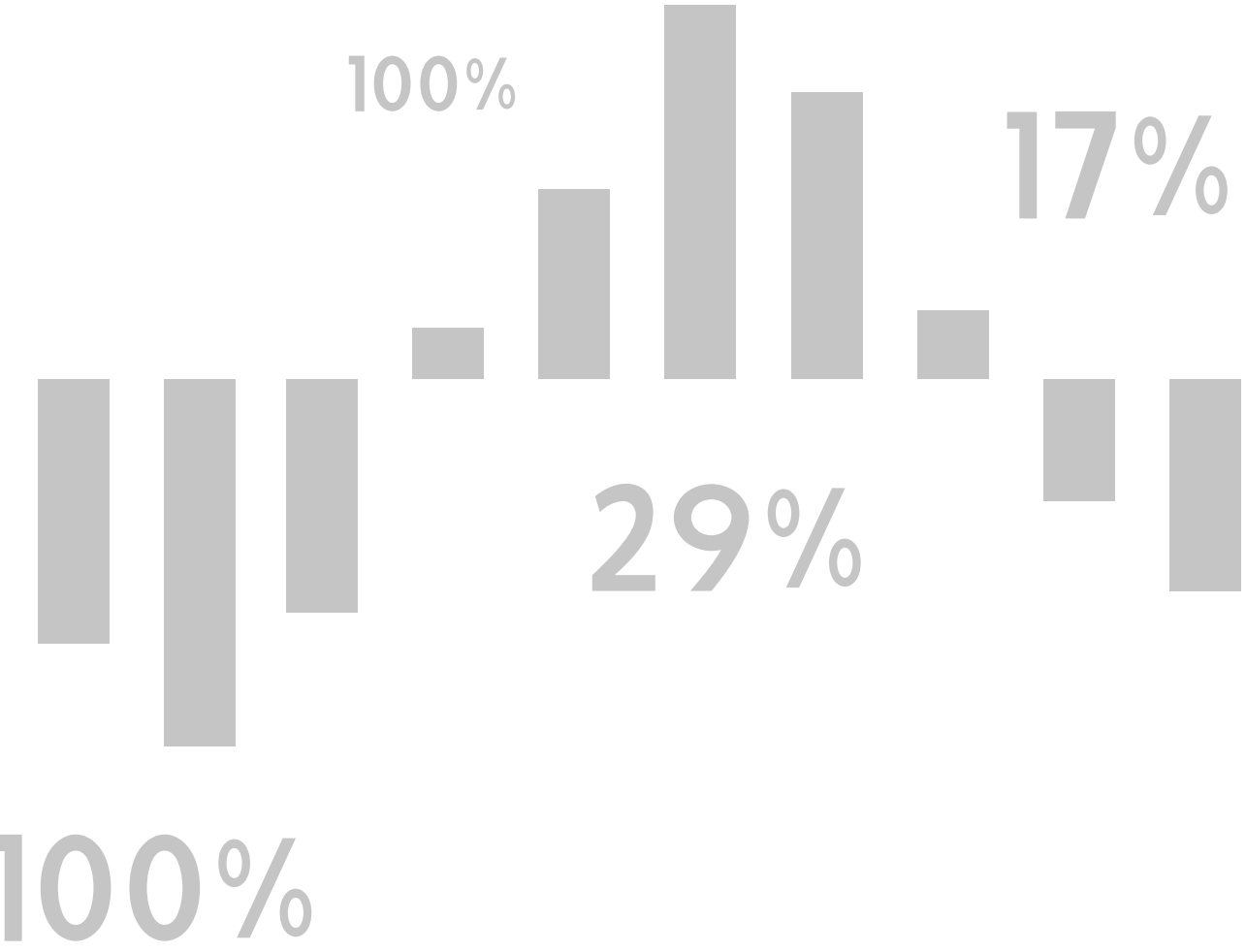




Shares soar for telco firms

In the last 12 months, share prices for Oclaro and Finisar have more than doubled. What's driving this growth?

RICHARD STEVEVENSON INVESTIGATES



THEY SAY THAT when you hit rock bottom the only way is up. And that's been the case for the optical component makers Oclaro. After footing our yearly shareprice leader board in 2012 and again in 2013, it has now managed to climb off the bottom rung – and better still, has leapt all the way to the top (see p. 34).

While fellow optical component maker Finisar can't match this, its share price has more than doubled over the last 12 months, and together these performances suggest that the optical sector is not a bad place to invest right now. That would make sense, given demand for ever-higher bandwidth and the growth in cloud centres, which require larger data centres and an increasing number of longer, high-speed connections.

The share price of Oclaro is now at its highest point since April 2012. Historically, however, it is still far short of its recent peaks. Back in February 2011 shares were worth around $18, which is about five times what they are today, and if you look at the share prices of the two companies that merged to form Oclaro in April 2009 – Bookham and Avanex – you'll find that shares sold for far more than that in the dot.com boom. Oclaro will never hit as high a valuation as its predecessors, but there are signs that it is heading in the right direction, even though it is running at a loss. Although it posted a loss of $25.3 million for the fiscal quarter ending on 28 December, 2013, gross margin and revenue were up 4 percent and $6.3 million compared to the previous quarter, and this enabled sales to hit $102.9 million.

To make further improvements to operating margins and take the company to break-even and on to profitability, the board is implementing a substantial restructuring programme. In a conference call on 11 February that discussed earnings for second fiscal quarter, 2014, Oclaro CEO Greg Dougherty updated investors on the goal of halving the workforce of 3000. Reductions in staff numbers began in July 2013, by this January the company was down to 2000 employees, and the following month Dougherty said that Oclaro was on track to be under 1500 people by July.

Alongside the dramatic cull in staff numbers, the company is reducing its number of sites. Recently it operated out of 20 sites, this February it was down to 14 and it should be at just 10 by July. Included within this is the sale of Oclaro's GaAs laser diode business to II-VI in late 2013. This transaction, which was worth

$ (millions)	Q1, 2013	Q2, 2013	Q3, 2013	Q4, 2013	Q1, 2014	Q2, 2014	Q3, 2014
Datacom	**139.5**	**139.8**	**147.7**	**163.9**	**184.4**	**204.3**	**210.3**
Q/Q change (%)	-4.5	0.3	5.6	11.0	12.5	10.7	3.0
Telecom	**81.0**	**92.2**	**90.7**	**79.5**	**81.7**	**86.5**	**83.7**
Q/Q change (%)	-13.6	13.7	-1.6	-12.3	2.7	5.9	-3.2
Total	**220.5**	**232.0**	**238.4**	**243.4**	**266.1**	**290.7**	**294.0**
Q/Q change (%)	-8.1	5.2	2.7	2.1	9.3	9.3	1.1

The datacom side of Finisar's business now accounts for more than two-thirds of the company's revenue.

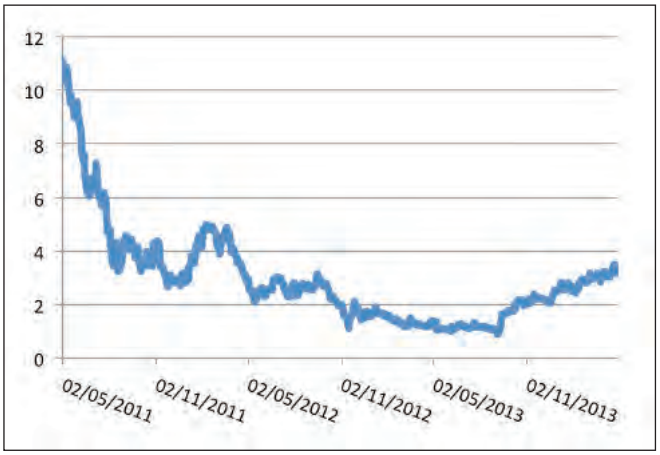
$115 million and announced on 11 September, 2013, provided Oclaro with $88 million in cash and led to a jump in its share price from just over $1.00 to $1.60.

Restructuring and resizing takes time and effort, but Dougherty says that this is not preventing Oclaro from investing strongly in its research and development. According to him, Oclaro is focusing on photonic integration, laser innovation and advanced packaging, because this will enable the introduction of components for telecom and datacom applications that consume less power while operating at higher speeds. "We have targeted development activity in the high growth areas of components and modules for 100G coherent application, indium phosphide integrated circuits, 100G client interfaces, 40G and 100G modules for datacentres as well as tuneable SFP+."

Finisar's sales flourish

Oclaro's rival Finisar, which is in third place on the Compound Semiconductor Share Price Leaderboard, has seen its share price climb from around $13 in the first half of 2013 to north of $20 throughout 2014, with a peak of just over $28. This Sunnyvale-headquartered company, which claims to be the world's largest supplier of optical communication components and subsystems, is in a period of impressive financial performance that includes six successive quarters of revenue growth.

Recent progress is highlighted by looking at the earnings for the third fiscal quarter that ended on 26 January, 2014, and comparing this with the equivalent period for the previous year.



Although Oclaro's share price has more than doubled this year, it is not high by historical standards.

Assessing the company in that manner shows that sales have climbed from $238 million to an all-time record high of $294 million, while gross margin has increased 28.5 percent to 35.9 percent.

Finisar breaks down its quarterly sales figures into those for datacom and telecom applications. The datacom side has seen substantial growth over the last year (see table 1), and topped $210 million in the most recent quarter. This was 3 percent higher than the previous quarter, thanks to increased sales of 40-gigabit Ethernet transceivers.

Now the company is currently positioning itself for further growth, via a combination of acquisitions and the construction of new facilities.

Chief Financial Officer Kurt Adzema told investors on 6 March, 2014, that in the fourth fiscal quarter the company would spend about $33 million on capital equipment, with the majority of this invested in constructing the shell of the second building of the new Wuxi, China production site. "We expect the shell of the building to be completed by fall of 2015 and now plan to immediately start to fit out several floors of the building and then fit out additional floors over time as needed."

Increased capacity has also resulted from the acquisition of u²t this January. "Finisar added u²t's InP-based high-speed receivers and photodetectors, including their industry-leading 100G and 200G coherent receivers that are used by multiple system manufacturers today," said Eitan Gertal in the 6 March call. The acquisition is claimed to consolidate Finisar's previously announced partnership with u²t on InP-based Mach-Zehnder modulators for 100G and 200G coherent applications.

Gertal believes that these receivers, photodiodes and modulator technologies can combine with Finisar's tuneable lasers to provide a full suite of vertically integrated optical components, which can be used to construct very high-performance modules for the 100G and 200G coherent metro and long-haul markets.

To increase sales, Finisar is also continuing to develop several new products with high levels of efficiency. In the datacom sector, the company boasts that it now has modules that consume less power than those of all of its competitors, and on the optical side, it is shipping beta samples of its tuneable SFP+ modules that consume just 1.5 W, thanks to

incorporation of the firm's low-power tuneable lasers and optical subassemblies. These products and the acquisition of u²t will help to swell sales, which should hit $296 million to $311 million in the fourth fiscal quarter. Gross margins for that period should be 35.5 percent.

TriQuint's soaring shares

Nestled between Oclaro and Finisar on the leader board is TriQuint, a company with a share prices that has soared from just below $6 to more than $14 in the last 12 months. It would be both easy and wrong to ascribe all of this gain to the upcoming merger with RFMD. The announcement of that merger is partly to thank – when that news came out, the share price leapt from about $9 to $11, and since then is has climbed further – but it is worth noting that TriQuint's share price increased by 50 percent between May 2013 and early February 2014.

Between those dates the share price shot up by 17 percent on the second quarter earnings and guidance, and nosedived by 20 percent when the third quarter earning were unveiled. Although the second quarter earnings were not that impressive – revenue hit $190.1 million, up 3 percent sequentially – the market was wooed by the promise of far better times ahead. Back then CEO Ralph Quinsey said: "In quarter three 2013, I expect revenue to jump 30 percent sequentially, bringing significantly improved margins and profitability. I believe quarter three is the beginning of a stronger period of performance for TriQuint, built on a differentiated strategy that is defensible and sustainable."

The company predicted sales for the third quarter of $245 million to $255 million, and on 24 October it revealed that it had met that, posting revenue of $250.8 million. But investors were not that happy – failing to meet its earnings per share forecast did not go down well, and although the company was predicting further sales growth, it was slowing down. It took until early February 2014 for the share price to recover from the knock it took following those results, before jumping on the announcement of the merger for reasons discussed in this month's feature "RFMD + TriQuint = ?" (see p.36)

Tough times for Anadigics

While share prices of TriQuint's peers, RFMD and Skyworks, have also increased by more than 50 percent in the last month, it's not been a great time for every player in this sector. Over that

Increasing use of cloud computing is leading to the growth of datacentres, and aiding the sales of optical component manufacturers such as Oclaro and Finisar.

Compound Semiconductor share price leaderboard

Rank	Company	Ticker	Share value, April 30, 2013 ($)	Share value, April 30, 2014 ($)2	% appreciation	Change in Rank
1	Oclaro	OCLR	1.36	3.40	150.0	+19
2	TriQuint	TQNT	5.84	14.18	142.8	+3
3	Finisar	FNSR	12.84	26.15	103.7	+13
4	Skyworks	SWKS	22.07	41.05	86.0	+12
5	RFMD	RFMD	5.61	8.44	50.4	-2
6	Rubicon	RBCN	7.14	10.13	41.9	+12
7	NASDAQ composite	IXIC	3,328.79	4,103.54	23.3	+2
9	Cree	CREE	56.67	68.87	21.5	-8
10	Emcore	EMKR	4.37	4.83	10.5	+2
11	Aixtron (Frankfurt)	AIX	14.93*	15.95*	6.8	+4
12	Infinera	INFN	8.42	8.96	6.4	-6
13	Hittite	HITT	56.11	59.36	5.8	-3
14	IPG Photonics	IPGP	63.57	64.63	1.7	-12
15	AXT	AXTI	2.91	2.91	0.0	4
16	IQE (london)	IQE	0.39*	0.39*	0.0	-3
17	Veeco	VECO	38.07	37.11	-2.5	-13
18	JDSU	JDSU	13.50	12.67	-6.1	-11
19	Riber (Paris)	RIB	4.00*	2.91*	-27.3	-8
20	Anadigics	ANAD	2.10	1.25	-40.5	-6

* Converted to dollars using the exchange rates on 30 April of 1 EURO = 1.3877 USD and 1 GBP = 1.6887 USD

Although the majority of compound semiconductor companies listed on the leaderboard have failed to keep pace with the NASDAQ, many of those that have outperformed this composite have done so by significant margins.

time frame, Anadigics' share price has tumbled by more than 40 percent, and it is now footing the leader board. Its share price did not take a hammering when the RFMD-TriQuint merger was announced in February, but since the start of March it has slid from $1.80 to $1.25.

Insight into the current state of Anadigics' business was provided in the earnings call on 30 April 2014 discussing first fiscal quarter earnings. On that day Terry Gallagher, Vice President and CFO of Anadigics, told investors that revenue for the first quarter totalled $23.3 million. That was a sequential decrease of 35.9 percent or $13 million, and in line with prior guidance.

Gallagher broke this down, detailing first quarter sales for cellular of $12.8 million, a 23.4 percent decline; Wi-Fi revenues of $5.1 million, a 64.9 percent sequential decrease; and infrastructure revenues of $5.4 million, up 4.5 percent sequentially. In this quarter gross margin was just 10.9 percent, capacity utilisation was just 45-50 percent, and the company made a net loss of $9.6 million.

Despite all these negatives, CEO Ron Michels was upbeat: "2014 represents a pivotal year for Anadigics. We believe that our business has moved past the turning point and is on a solid path to achieve EBITDA objectives later this year." According to him, the company has attractive products in many different markets, which should lead to greater sales in the coming months and years.

"During the first quarter, we announced several new mobile devices that are powered by our front-end ICs, including the Huawei P6S and Samsung Galaxy Tab Pro," said Michels, who added that the company is shipping production volumes of its latest infrastructure power amplifiers.

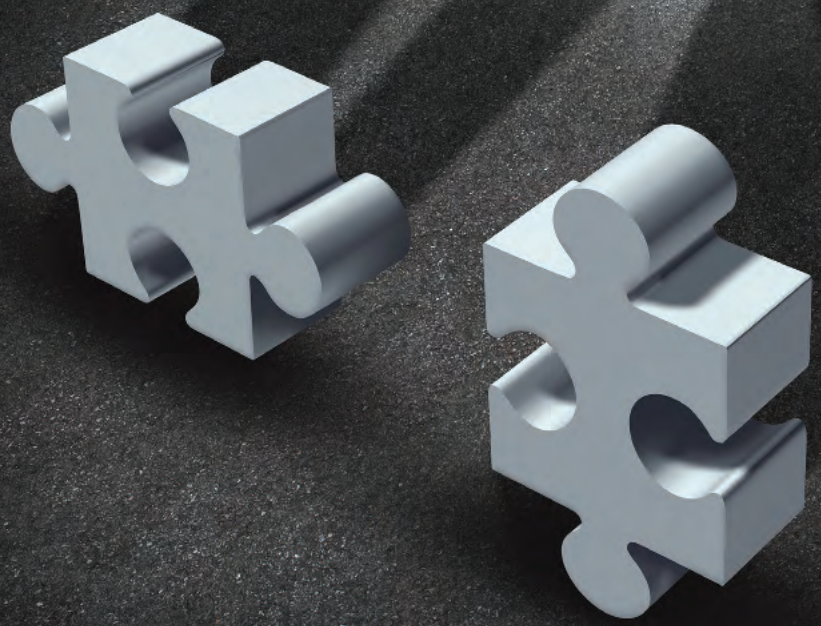
Anadigics may also branch out into new markets, by investing in the research and development of a wafer process technology. "This process technology – offered as a foundry service – provides greater scalability, higher performance and increased value in the production of the VCSEL lasers," said Michels, who pointed out that these optical emitters can enable motion capture and sensing capabilities in many high-volume applications, ranging from smartphones to gaming devices.

If Michels can deliver on his promises and get the company inching nearer to profitability, Anadigics' share price will start to climb. And as Oclaro has shown this year, sometimes that is all it takes to top the leader board. Can Anadigics do this in 2015? Well, we'll just have to wait and see.

TriQuint's shares shot up by 17 percent following the report of second fiscal quarter earnings, which included company CEO Ralph Quinsey telling investors that sales would increase by 30 percent in the following quarter.

RFMD + TriQuint = ?

What will be the result of the merger of these US heavyweights? RICHARD STEVENSON INVESTIGATES



IF YOU MARRY YOUR CHILDHOOD SWEETHEART in your late teens, you'll easily adapt to their ways, but you may struggle to make ends meet. Meanwhile, if you refrain from tying the knot until you have established your career, money worries may disappear, but by then you might have become a creature of habit, so it is best to set up a home with a partner who complements you.

It's a similar state of affairs when companies join together. Start-ups may have little cash to offer the new venture, but they are flexible and dynamic. Established firms, on the other hand, can contribute much more in terms of cash, equipment and sales channels, but they have far more inertia, and changes take time. So, when established firms get together, how well they fit plays a big part in how successful they are.

Right now, a massive merger is being planned between US giants TriQuint and RFMD, two firms that are considered by many to be complementary.

"RFMD is much stronger in handsets, TriQuint is much stronger on the defence side, and although there are obvious overlaps, the strengths of the two companies seem to match up pretty well," says Eric Higham, Director for the GaAs & Compound Semiconductor Technologies Service at Strategy Analytics.

Voicing similar views is James Klein, currently Vice President of Infrastructure and Defence Products at TriQuint. Klein, who in the new outfit will be the President of Infrastructure and Defence, believes that customers are excited about this merger: "We will bring into play a broader portfolio and a broader set of technologies, especially in the infrastructure business."

The still-to-be-named venture should generate about 75 percent of its revenue from the sale of products to handset manufacturers. In this sector, which is migrating towards integrated modules, the new company has all the key building blocks, including GaAs broadband amplifiers, high-volume CMOS PAs, antenna switches and a range of filters. Using this extensive portfolio to launch new products should not prove that taxing, as RFMD is already using TriQuint's filters in some of its products.

In the defence, aerospace and infrastructure division, Klein points out that there is little overlap between the two companies' products. "TriQuint has been more in the defence space and optical, and RFMD has focused on some other spaces, like WiFi and wireless LAN."

Soaring valuations for both companies highlight the investor backing behind the joining together of the two chipmakers. After announcing the merger on 24 February, TriQuint's closing share price for jumped from $9.23 to $11.64 and has since risen to more than $13 – and RFMD's shares have climbed from $5.81 to $7.03 and then on to just above $8 over the same timeframe.

> TriQuint brings filter technology to the party, and I would think that should provide a good leg-up for the combined company. RFMD is pushing pretty heavily on the front-end module approach, and being able to have filters in there – and to have them home-grown – will be an attractive feature.

Within two years of completing the merger, the board of the new company – which will be made up of five directors from both companies, and led by RFMD's CEO Bob Bruggeworth – should have overseen savings of at least $150 million in cost synergies that will enable operation at a gross margin of 45 percent and an operating margin of 25 percent. Part of the cost cutting will result from redundancies, and some analysts are suggesting that TriQuint's GaAs fab in Oregon that produces many of the company's PAs will go.

Sum together the revenues of RFMD and TriQuint and it suggests that the new company should deliver annual sales of $2.067 billion. But that's a very simplistic calculation. Handset manufacturers tend to deal with two suppliers for their products to reduce supply chain risks, and if RFMD and TriQuint have those contracts, a new second source may be enlisted that will put a dent in the revenue of the new outfit. However, Higham thinks that this drawback might be outweighed by additional sales, which are the result of handset makers wanting to work with a very big company that operates at superior economies of scale.

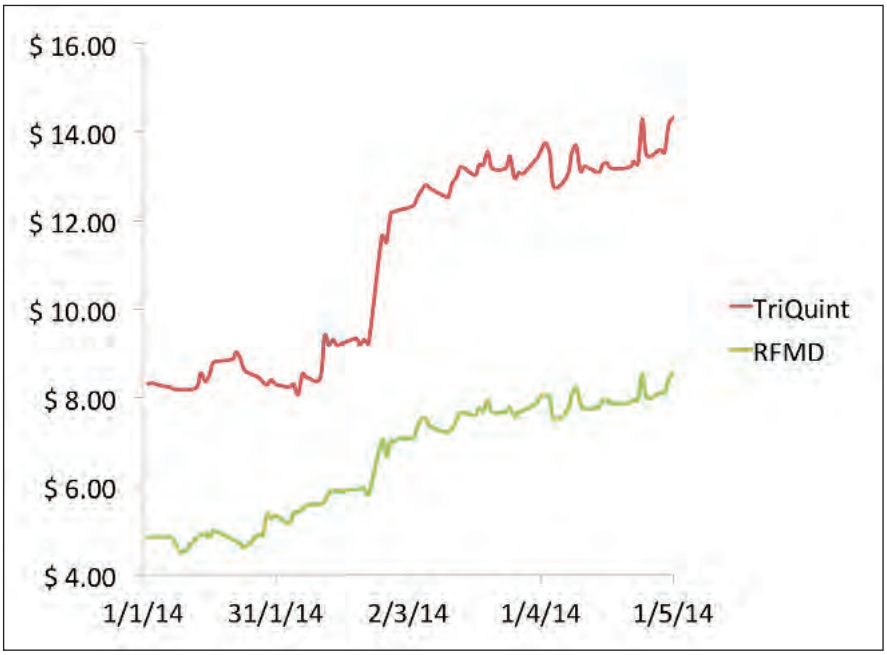
Business model

The handset side of TriQuint's business has recently come in for criticism from one of its key investors, Starboard Value, which owns about 8 percent of the firm's shares. This investor wrote to TriQuint on 29 October, 2013, arguing that more than 100 percent of the company's profits were coming from the networks & defence and bulk acoustic wave filter businesses; but the strong performance of these divisions was overshadowed by the mobile PA business, which suffered from significant utilization issues and missed design cycles. In this letter, which can be viewed on the SEC web site, Starboard also claimed that the PA business operated at gross margins below 10 percent over the last 12 months.

In this correspondence from Starboard, these investors blamed losses on an inefficient manufacturing model, while praising the fab-lite approach taken by Skyworks and Avago. About those two firms, Starboard wrote: Both companies manufacture only a portion of their products internally, while relying on foundries to produce some of their products and for 'swing capacity' when volumes increase significantly.

Higham, who has read the letter from Starboard, broadly agrees with the analysis of the relative profitability of the various divisions within TriQuint. However, he is not convinced by the argument that a fab-lite structure is a pre-requisite for good margins. In his view, the recent success of Skyworks, relative to RFMD, is not simply due to differences in the approach taken to chip manufacture – it also depends on customer relationships.

To explain his view, Higham considers the recent history in the PA market. He points out that that it was not that long ago that RFMD was the number one in the handset market, due to its close relationship with Nokia, the leading handset manufacturer of the time. "Since RFMD had such a tight tie-in with Nokia in their heyday, it forced other companies, primarily Skyworks, to find other technologies, make other



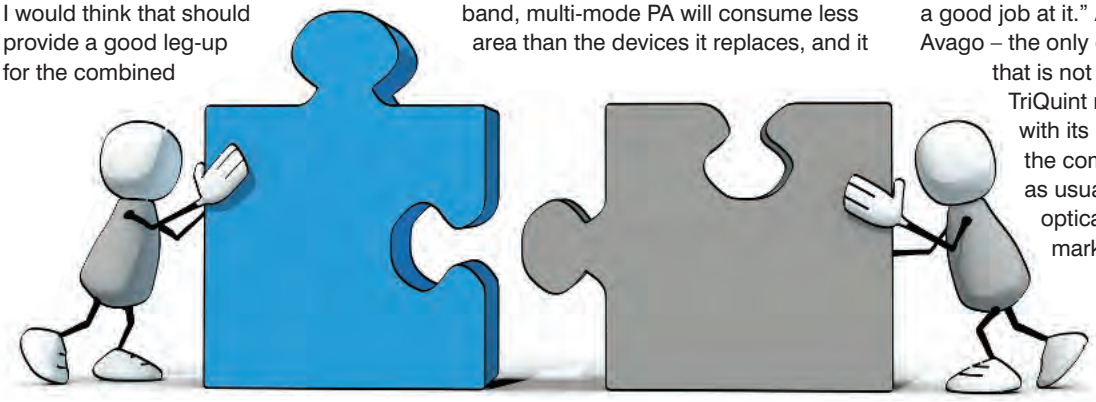
Shares in TriQuint and RFMD have soared since the merger of the two companies was announced on 24 February, 2014

products and find other customers." These efforts ultimately paid dividends when Skyworks found a winning formula in the smartphone market, and the likes of Samsung and LG launched popular products.

Higham blames the troubled times at Nokia for the downward path taken by RFMD, which should soon stop its slide. "It seems that RFMD have bottomed out, and they are now heading back up again with revenue and profitability."

Thanks to the merger, Higham thinks that the new outfit's handset business can do even better. "TriQuint brings filter technology to the party, and I would think that should provide a good leg-up for the combined company. RFMD is pushing pretty heavily on the front-end module approach, and being able to have filters in there – and to have them home-grown – will be an attractive feature."

To operate the handset division at healthy margins, the new company will need to cut costs. "There is some overlap, and they will [have to] figure out what to do with that," warns Higham. He points out that this decision must be made against the backdrop of a move to multi-band, multi-mode PAs, which could have a bigger short-term impact on the GaAs business than the emergence of CMOS PAs. "It is GaAs design cannibalizing itself. That multi-band, multi-mode PA will consume less area than the devices it replaces, and it will also have less bill-of-material costs than the device it replaces." So the management taking charge may not only need to address the excess capacity of the combined outfit, but make further trimmings due to moves to more sophisticated PAs.



Additional challenges for this board will be to manage the transformation in a way that optimises the existing talent, while maintaining a focus on customers. What will help the leaders of both companies is that they have been involved in acquisitions before: RFMD acquired Sirenza in 2007 and Filtronic in 2008, while TriQuint acquired CAP Wireless in 2013 and WJ Communications in 2008.

To ensure that the merger goes well, the leadership will need to strike a fine balance between moving too quickly and failing to get the right people in the right positions, and taking so long that it has a negative impact on the staff. "Potentially, it's a very unproductive time," says Higham. "Engineers don't deal well with uncertainty. If you say to yourself: 'What is the future going to hold?', you might start looking around." And if the most talented decide to leave, they will find it easiest to get a new job, and their exit will create the biggest holes to fill.

Further consolidation?

An additional impact of the merger is that it could trigger further consolidation: Many have already been asking Higham if that is likely to happen.

On the handset side, he feels this is unlikely: "Skyworks are happy with their business model. They were forced into diversification early and they have done a good job at it." And he believes that Avago – the only other firm in the top four that is not involved in the RFMD-TriQuint merger – is content with its position. He expects the company to do "business as usual" while it focuses on optical, automotive and other markets.

"Once you get passed the [top four], you take a big drop down to the number five company,

WIN Semiconductors, and they have a different slant on the business, so I'm not sure there's enough scale on the handset side for consolidation to make sense. You'd have to have everybody consolidate to make any noise on the handset side."

On the aerospace and defence side, it might be a different story. The new company will be the largest player in aerospace, networks, and defence, and also the leader in aerospace and defence. However, it is not far, far larger than some of its rivals. "It's $500 million, and Hittite and M/A COM are in the $300 million range, so some companies might talk about consolidation to pose a threat to that entity."

Even if the merger of RFMD and TriQuint doesn't trigger further consolidation, it will shake up the industry. If the colossus that results draws on the best of both firms, while cutting off the less-good bits, it is definitely going to be a tough competitor in many sectors.

Getting together

Like many relationships, the getting-together of RFMD and TriQuint was far from simple. In fact, in early 2014, it was even possible that TriQuint might have started to engage in a merger with one of two other companies.

The timings of many behind-the-scenes meetings that led to the public announcement of the merger are detailed within an S-4 filing by TriQuint on 14 April.

In this document it is revealed that between spring 2009 and early 2013 representatives of both companies – primarily Bob Bruggeworth, President and Chief Executive Officer of RFMD, and Ralph Quinsey, Chief Executive Officer of TriQuint – met on about eight occasions to discuss their respective views on trends in the RF market, and potential opportunities for a strategic business combination between the two companies. They also exchanged overviews of each company's businesses and discussed possible cost-saving synergies that might be realized from a business combination.

More recently, the following events have occurred:

- On 25 February, 2013, at the Mobile World Congress in Barcelona, Spain, Quinsey broached with Bruggeworth the concept of a transaction that would create two separate companies: one focused on the mobile market and another based on the infrastructure and defence markets. That week Quinsey also met with the CEO of a third party (referred to as Company B in the S-4 filing) and mentioned a similar transaction concept.

- On April 3, 2013, RFMD formally proposed to TriQuint an all-stock acquisition. This would reflect the market price of both firms, and create two market-focused companies.

- On April 12, 2013, TriQuint discussed RFMD's proposal and concluded that it failed to ascribe appropriate value to the company's infrastructure and defence business.

- On June 5, 2013, the CEO of Company B delivered an unsolicited letter to Quinsey and the TriQuint board, offering to buy the company in an all-cash transaction at a per share price of $8.25– that reflected an 18 percent premium to TriQuint's then-current market price.

- On June 11, 2013, the TriQuint board rejected Company B's proposal. On August 22, 2013, over dinner in Portland Quinsey and Bruggeworth discussed a potential "merger of equals", with each company's stockholders owning approximately 50 percent of a combined company.

- On November 19, 2013, Quinsey received a letter from Company B, offering to buy the company for a purchase price of $10.00 per share, comprised a mix of 50 percent cash and 50 percent stock. This price represented a 33 percent premium to TriQuint's then-current market price.

- On November 21, 2013, TriQuint and RFMD started posting due diligence materials into separate virtual data rooms. Five days later they accessed each other's data room and began conducting due diligence investigations.

- On December 13, 2013, TriQuint's board decided not to approve the proposed transaction with RFMD. This was based, in part, on concerns regarding the potential market reaction to the transaction in light of both RFMD's and TriQuint's expected near-term financial results. The board also asked Quinsey to request Company B to improve its existing offer.

- On December 15, 2013, Company B revealed that it would be willing to increase its offer to $10.10 per share

- On January 31, 2014, Company C expressed preliminary interest in an acquisition of TriQuint in its entirety.

- On January 31, 2014, at the request of Starboard, its representatives met with RFMD CFO Dean Priddy and Bruggeworth. Following a tour of the Greensboro wafer fabrication facilities, representatives of Starboard outlined the strategic rationale for a RFMD-TriQuint merger.

- On February 18, 2014, Company B's financial advisor informed representatives of Goldman Sachs that it would not re-affirm its last offer from December 15, 2013 and had determined to withdraw from the process.

- On the evening of February 22, 2014, and following notification from Quinsey that the TriQuint board had met earlier that day and unanimously approved the merger agreement, the RFMD board discussed and approved the proposed transaction.

Accelerating adoption of GaN substrates for LED manufacture

Recycling native GaN substrates via chemical lift-off promises cost-competitive manufacture of high-performance vertical LEDs

BY DAVID ROGERS FROM NANOVATION

COMMERCIALISATION of the GaN LED can be traced back to the development of *p*-type doping of this wide bandgap semiconductor in the early 1990s. Since then, the performance of this device has improved exponentially, enabling it to progress from use in the backlighting of mobile screens to providing a source for solid-state lighting. However, although LED lighting is now commonplace, its cost-performance profile has a long way to go untill the incumbent vacuum-tube-based lighting technologies will cease to dominate.

One of today's key bottlenecks is the requirement to use a 'non-native' substrate. Currently about 95 percent of GaN-based LEDs are grown hetero-epitaxially on *c*-sapphire, because the ideal 'native' GaN substrates, which are limited in availability, are prohibitively expensive. A 2-inch substrate, for example, retails for thousands of dollars, and is primarily used for laser manufacturing.

Sapphire is far from the ideal foundation for the GaN LED. Two of its biggest downsides are that its lattice constants and its thermal expansion coefficient are markedly different from those of GaN. This creates strain in the epilayers, which leads to the generation of point defects and dislocations that limit the potential light output.

The insulating properties of sapphire are another impediment to the manufacture of high-performance LEDs. The high electrical resistivity of sapphire imposes a non-ideal lateral LED device architecture with top-contacts and a confined lateral current flow. This results in current crowding and localized thermal hot spots, which are detrimental to the efficiency, lifetime and maximum brightness of the device.

Compounding these issues is the thermally insulating nature of sapphire, which dramatically restricts heat dissipation. In turn, this further limits efficiency, lifetime and brightness.

Alternative platforms

To combat these issues, producers of chips for high-end LED applications transfer the GaN-based epilayer to a substrate with superior electrical and thermal conductivity. Often this is accomplished with a laser-lift-off and wafer bonding process to remove the LED from the sapphire and transfer it to an alternative substrate. The laser lift-off process involves firing a short wavelength laser beam – typically the 248 nm emission line from a KrF excimer – through the sapphire substrate. Light is absorbed in the first 100 nm of GaN, which decomposes to liberate the LED from the sapphire.

After bonding the LED to an electrically and thermally conductive substrate, this device can exhibit much better heat dissipation and vertical LEDs (VLEDs)

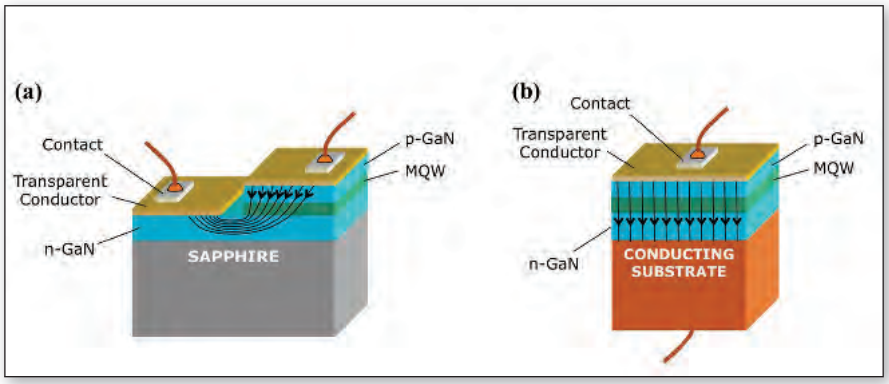


Figure 1. Current crowding is far more severe in a lateral LED (a) than its vertical cousin (b), due to the insulating substrate.

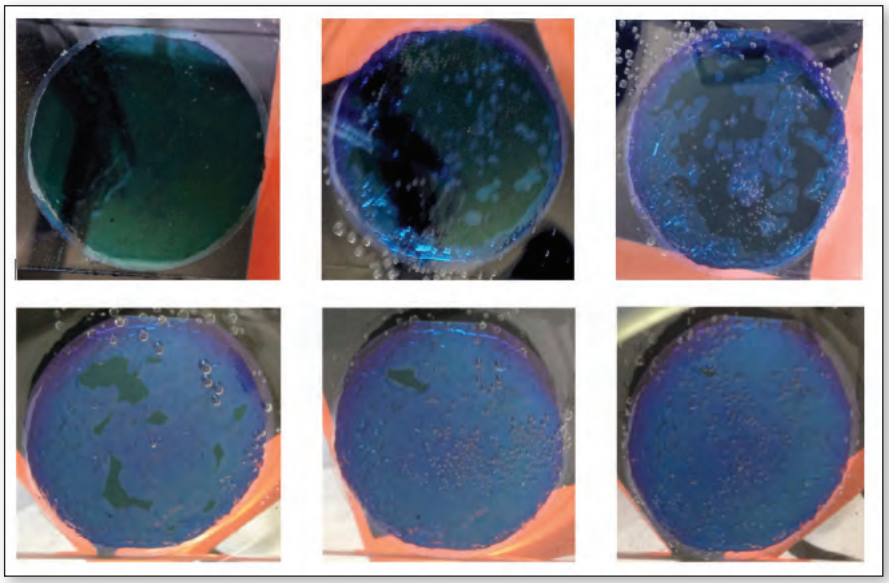


Figure 2. Photographs taken through the backside of a 2-inch GaN/ZnO/sapphire wafer (immersed in ~ 1M HCl) showing a time sequence of the chemical dissolution of ZnO & the progressive detachment of the substrate.

can be formed (see Figure 1), which have current flow through the substrate. Such devices have a much more homogeneous current distribution than a conventional lateral LED, enabling them to be driven up to 25 times higher. VLEDs also avoid complex, costly lithographic steps required to make the top contacts, and have a footprint at least 30 percent smaller than a conventional LED, which means that manufacturers of these devices benefit from a significantly higher chip yield per wafer.

What's more, a flipped device geometry can increase overall light extraction, thanks to laser-induced roughening of the GaN, which reduces the proportion of light trapped by total internal reflection. And on top of this, the substrate can be reclaimed and reused after polishing away the surface residue left by the laser ablation. However, despite all of these advantages associated with laser lift-off, the performance of the transposed LED is still held back by the quality of the original expitaxy on the mismatched sapphire.

It might seem that the ultimate way forward is to grow such VLED structures on GaN substrates (because this would lead to very high crystal quality) and then perform laser lift-off in order to reclaim/reuse the expensive GaN substrate. However, it is not possible to remove this native platform with laser lift-off, because GaN substrates are not transparent to the requisite short-wavelength lasers.

Another substrate option that has attracted a significant amount of attention is ZnO, which not only has the same crystal structure as GaN, but also very similar lattice parameters and comparable thermal expansion coefficients. However, ZnO is much more chemically reactive than GaN.

Due to this, attempts by numerous groups to adopt bulk ZnO substrates have met with problems of back-etching of ZnO by the process gases used in the MOCVD process.

This problem is not insurmountable, however, and it has been overcome, by our ZnO team at Nanovation of Châteaufort, France, working in partnership with the GaN group of Abdallah Ougazzaden at the joint Georgia Tech and CNRS lab in France.

Nanovation is a ZnO dedicated epiwafer foundry, founded in 2001 by four research scientists who identified the commercial potential of ZnO for emerging opto-semiconductor markets: extending from transparent conductors and electronics through to LEDs, lasers and photovoltaics.

To this end, we have pioneered the adoption of pulsed laser deposition as a production tool in the semiconductor industry, based on its unique capacity for forming state-of-the-art ZnO layers with a huge range of properties on almost any substrate.

This remarkable propensity for tuneability results from the exceptionally high energy of the adatoms in the laser ablation plume – they typically have energies of 10 eV to 100 eV, compared to 1 eV to 10 eV for sputtering and 0.1 eV to 1 eV for more common semiconductor deposition methods, such as MBE and CVD.

Thanks to these higher energies, deposition can occur at lower growth temperatures while using a much-extended working range for oxygen

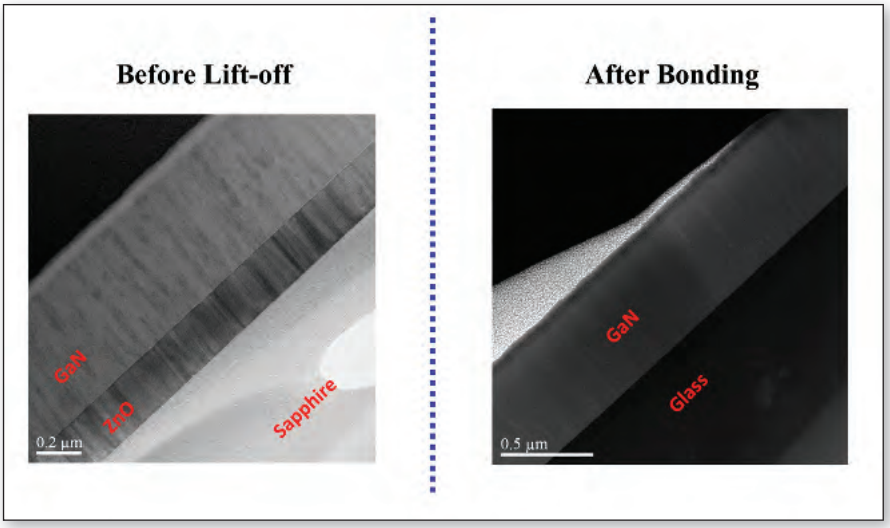


Figure 3. Cross-sectional transmission electron microscope images showing the epitaxial growth of GaN on ZnO/sapphire by MOCVD without back-etching of the ZnO and the excellent GaN/glass interface after chemical lift-off and direct fusion bonding. The lifted GaN layers show no trace of zinc in high-resolution electron microscopy energy dispersive X-ray microanalysis near the interface. [credit: G. Patriarche, LPN, Marcoussis, France].

partial pressure. Thus the oxygen stoichiometry, which is primordial for the properties of oxide-based materials, can be precisely tuned over a much larger range without compromising material quality.

LED structures

The pertinence of ZnO for GaN-based LEDs lies in the optoelectronic grade thin-film pseudo-substrates that we have developed as templates for GaN regrowth.

Over the past few years, the Georgia Tech / CNRS lab has developed a novel MOCVD approach for capping our ZnO epilayers with GaN that is free from back-etching. Once the ZnO layer is encapsulated, a GaN LED structure can be grown under standard MOCVD conditions without damaging the oxide layer.

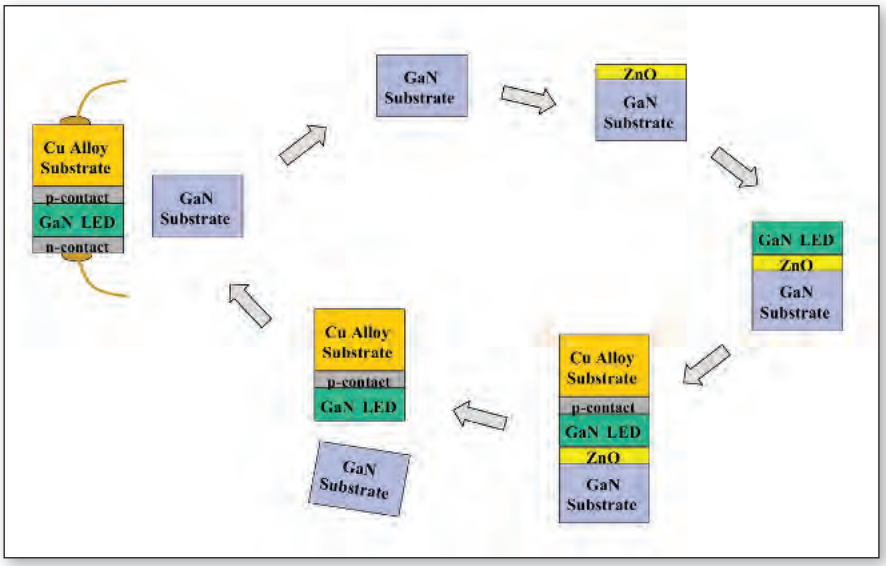


Figure 4. The costs for adoption of a native GaN substrate for vertical GaN LED manufacturing can be slashed by turning to cycles of chemical lift-off and reclaim.

Characterisation of GaN films that are deposited on ZnO reveals a very high material quality. After only 100 nm of growth, these layers are optically active, have a root-mean-square surface roughness of 1 nm, and have much less crystallographic dispersion than GaN films of comparable thickness grown directly on sapphire.

This suggests that a switch from sapphire to ZnO/sapphire for LED production would allow far thinner layers of GaN to be used, which would be advantageous for light out-coupling and external quantum efficiency.

That is not the end of the story, however. We have gone on to demonstrate that ZnO thin-film templates can subsequently be used as sacrificial release layers for the GaN. This process, an alternative to laser lift-off, is based on selective chemical dissolution of the ZnO underlayer. It takes just a few hours and can be performed with a variety of dilute acids or alkalis – because GaN is highly resistant to chemical etching in acids and alkalis other than HF, while ZnO is not (see Figure 2, which is a full 2-inch wafer chemical lift-off progression). The lifted GaN layers show no trace of zinc in high-resolution electron microscopy energy dispersive X-ray microanalysis near the interface.

In parallel work on another materials system carried out at Heriot Watt University in the UK, Kevin Prior's group have developed a process for the full transfer of ZnSe from GaAs to alternative substrates by means of direct wafer bonding after chemical lift-off with a sacrificial MgS underlayer. Mirroring this bonding process, we were able to demonstrate similar transfer of a GaN LED structure from sapphire to an alternative substrate (see Figure 3).

Thanks to funding in 2013 from the European Commission FP7 and the Scottish Universities Physics Alliance, we have been able to unite the partnerships with the groups of Prior and Ougazzaden and go on to demonstrate that a similar process is capable of delivering chemical lift-off of GaN from ZnO-coated bulk GaN substrates.

The advantage of this counter-intuitive approach is the higher quality of the GaN grown on top of the ZnO-coated GaN substrate. Indeed, X-ray diffraction and electron microscopy studies showed that the resulting GaN epilayers had significantly larger grains, less strain and lower defect density than can be obtained by heteroepitaxy on ZnO/sapphire.

Moreover, the GaN film is relaxed, thanks to the underlying GaN substrate straining the ZnO template such that it is lattice-matched to GaN.

X-ray diffraction reveals that a 100 nm-thick overlayer of GaN on the ZnO/GaN template replicates the omega rocking curve linewidth of the GaN substrate (~0.05°), which represents an order of magnitude reduction in crystallographic dispersion compared with GaN layers of similar thickness grown on ZnO/sapphire. In addition to superior epitaxy, the expensive single crystal GaN substrate is not consumed in this process and multiple GaN substrate reclaim and reuse cycles are possible without significant degradation of GaN layer quality (see Figure 4).

Moreover, chemical cleaning suffices and there is, therefore, no wafer loss through repolishing. Consequently, large quantities of GaN substrates are not required for chip production, which means that substrate costs per growth run are compressed to industrially viable levels. This should enable a breakthrough in LED chip manufacturing,in terms of output power per wafer and cost per lumen. There is no reason why this technology cannot even be applied to the rarer, even more expensive, non-polar GaN substrates that are being put forward as a way to combat "droop", the decline in LED efficiency at higher current densities.

This chemical lift-off technique is clearly very promising, and unlocking its true potential could play a major role in the future of solid-state lighting.

The author thanks Carlos Lee of EPIC, the FP7 Nexpresso Programme, the Scottish Universities Physics Alliance and the French Agence National de la Recherche for their support in this work.

Better, brighter phosphors

New formulations increase the quality and intensity of LED lighting

BY HERB SCHLEGEL & NICOLE RUTHERFORD FROM INTEMATIX

THROUGHOUT THE OFFICES, homes and hotels of the world, LED bulbs are rapidly replacing incandescent and fluorescent sources, thanks to their high efficacy and long lifetime. These strengths make them a cost-effective choice in the long run, despite higher up-front costs.

As this transition from a niche to a mainstream product is taking place, demand is growing for LED sources that deliver a higher quality of white light. There are various metrics to measure this, but normally a source is considered to be of high quality if it delivers a wide range of Correlated Colour Temperatures (CCT) and a high Colour Rendering Index (CRI) – and maintains that colour performance over time.

When the LED lighting market was in its infancy, a source with a CCT of 4000K at 70 CRI was deemed acceptable for most applications, but within the last few years retail and hospitality lighting has demanded a CCT of 3000K at 80 CRI. Moreover, with recent advances, these sectors are now asking for CCTs ranging from 2200K to 4000K and CRIs as high as 98.

To meet this demand, manufacturers of phosphor materials must develop products for the efficient generation of white light that provides a very wide spectral range.

At Intematix of Fremont, CA, we are doing just that, with an ever-expanding portfolio of phosphors that include green and yellow aluminates, green and yellow garnets, red nitrides and silicates.

These phosphors span a wide range of wavelengths, have very high efficiencies – they can reach a quantum efficiency of more than 97 percent – and can be applied to a wide range of applications from mobile to TV displays and general and automotive illumination.

Generating white light

The LEDs that are used in lighting today are an evolution of the first white-emitting LEDs, which emerged from Japan in the 1990s and employed a blue-emitting chip to pump a yellow phosphor (see Figure 2a). In this form of white-emitting device, not all of the blue emission is absorbed by this phosphor, and white light results from colour mixing of blue and yellow. This approach, still widely used today, has the merit of a very high efficiency. However, the colour rendering index is low, due to the lack of emission in the red and orange regions of the visible spectrum.

To improve the CRI of solid-state sources, manufacturers are increasingly turning to a two- or even three-phosphor strategy. A broader range of CCTs and higher CRIs are possible by supplementing the yellow phosphor with one that emits in the red, while even higher values can be obtained with the combination of a red and green phosphor (see Figures 2b and 2c).

The pioneers of the white LED based on a blue-emitting chip – Shuji Nakamura of Nichia and the academic group led by Isamu Akasaki and Hiroshi Amano from Nagoya University – were first to discover that the combination of YAG and a blue emitting semiconductor chip delivered white light with high luminance. To protect their discovery, Nichia filed patents on this combination and in 1996 was granted US Patent 5,998,925. This patent, which describes the use of a phosphor that 'absorbs part of the blue light and emits a yellowish light', places restrictions on the use of a blue chip in combination with any garnet composition containing at least one element from: the group of yttrium, lutetium, selenium, lanthanum and samarium; and one element from the group aluminium, gallium and indium and being activated by cerium.

It is worth noting that the Nichia patent does not restrict the manufacture and sale of YAG phosphor, but rather, its application to create a white LED. Consequently, companies that have a license under this patent may purchase YAG from any manufacturer for use in their LED devices. Nevertheless, the license imposes an extra cost that most LED manufacturers would like to avoid by using phosphors other than YAG.

Figure 1: Intematix produces a range of phosphor materials, including those based on YAG, silicates, nitrides and aluminates.

To address this need, in 2006 we began commercial production of phosphors based on silicate materials. Being one of the early producers with unique compositions, our silicates quickly became widely used, thanks to their high brightness, wide range of available colours, and relatively narrow emission bandwidths – characteristics highly valued by manufacturers of displays, the dominant market for white LEDs. Three years later, we expanded our offering with our own brand of garnet phosphor, which we called NYAG.

In the last few years, we have continued to broaden our product line with a focus on meeting the requirements of the emerging lighting market by launching green and yellow aluminate (GAL) and red nitride products. These innovations have increased the number of high-performance phosphor families available to LED manufacturers and we continue to fine-tune and optimise each family for brightness and particle size, shape, finish and consistency. We now offer one of the industry's widest ranges of particle sizes, allowing customers to choose the best size and distribution for a particular application. For example, smaller particles are easier to disperse in silicone and generally give the best angular colour uniformity, while larger particles tend to deliver higher brightness.

Looking to the solid state lighting market, our GAL phosphor offers a broader emission spectrum than silicate phosphors, or even YAG materials, so it is particularly ideal for bulb replacement applications where a broad spectral output similar to incandescent light is required. Meanwhile, our red nitride phosphors have an emission bandwidth that is narrower, similar to those of silicates. When emitting in the red, a narrow emission is desired – if there is spectral output at infrared wavelengths, where the eye is insensitive, the energy is wasted on unseen light.

Both our red and green phosphors have the edge over earlier silicates in terms of performance in mid to high power LEDs. In a high power LED, the phosphor typically reaches a temperature of 100 °C or higher, and in that regime the GAL and red nitride phosphors can deliver an efficiency that is 10-15 percent higher than that of silicates. This greater thermal stability is highlighted by measurements showing that the emission intensity of GAL phosphors declines by just a few percent between 0 °C and 200 °C, compared to a fall of more than 20 percent for traditional YAG (see Figures 3 and 4).

What's more, the combination of our GAL and red phosphors can enable a near-perfect colour rendering of up to 98 CRI.

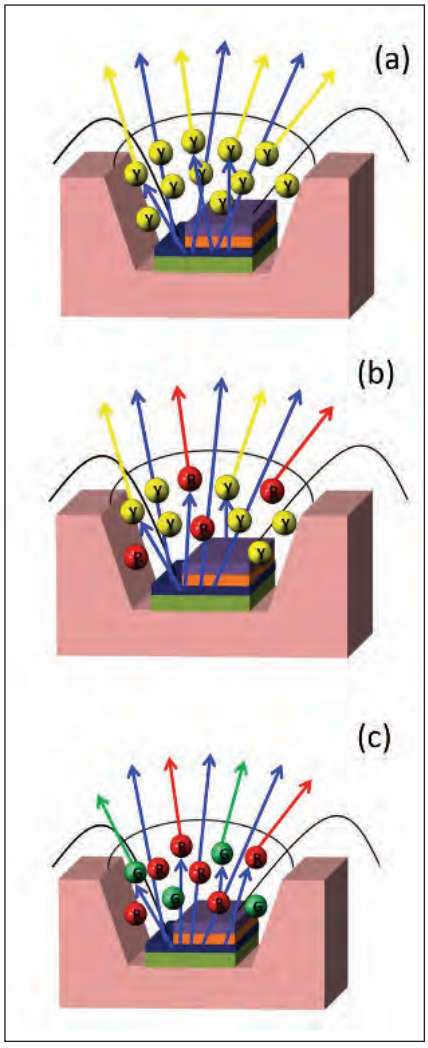
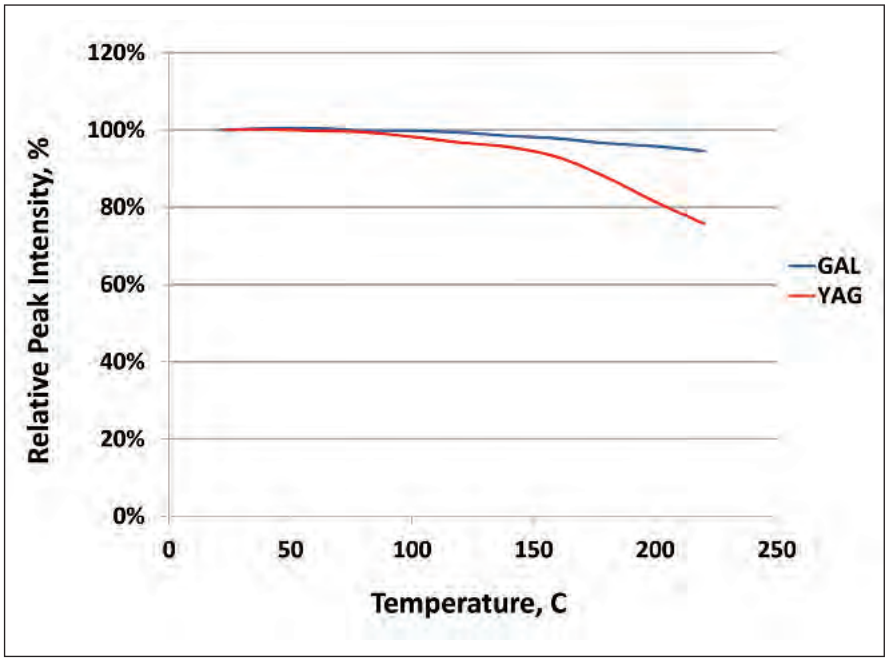


Figure 2: Today, three different methods are used to make a white-emitting LED product. These variations are associated with the phosphors, which are directly applied to the LED chip. The pioneers of the white-emitting LED added a yellow phosphor to a blue LED (a). Higher colour-quality, which comes at the expense of inferior efficiency, is possible by adding a red phosphor (b), or employing the combination of a red and a green phosphor (c).



Figures 3: Green aluminate (GAL) has excellent thermal stability, allowing it to aid the production of efficient LED light bulbs operating at high current densities.

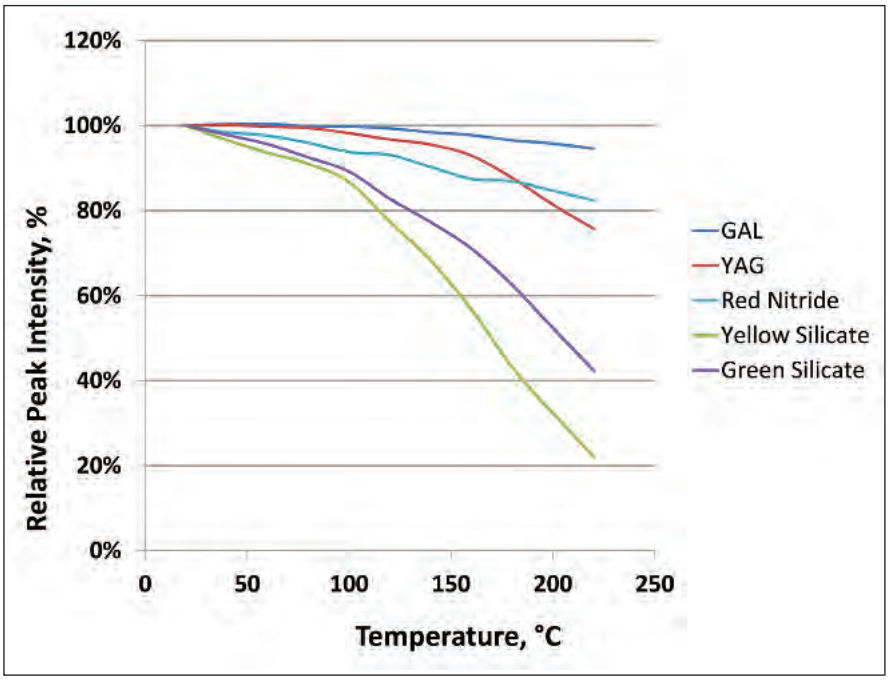


Figure 4: Intematix has improved thermal stability by turning to new materials.

While GAL phosphor's broad green emission enables high CRI, our red phosphors hold the key to producing higher values of R9, which is a measure of how well an illumination source can capture deep, saturated shades of red. These phosphors, which are used in white LEDs serving retail and hospitality markets, are setting a new benchmark for colour stability: one that is imperceptible to the human eye, and measured at just 2SDCM (that is, a 2-step MacAdam ellipse, which is a well-known metric for measuring shifts in colour) in aggressive accelerated lifetime tests. In addition, these phosphors are relatively new, so different wavelengths and methods to improve the efficiency of each composition are continually being discovered (see Figure 5).

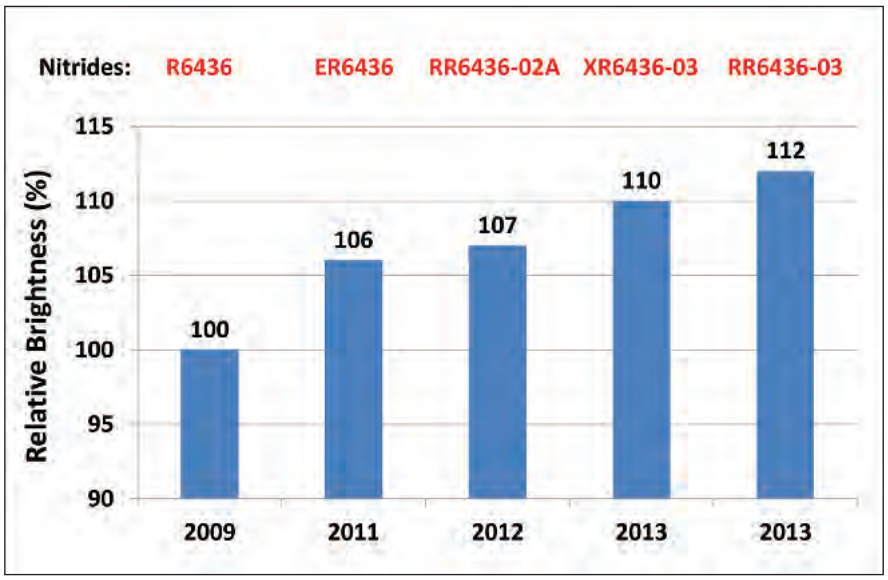


Figure 5: Intematix has steadily increased the brightness of its red nitride materials.

A bright future

Shipments of phosphors will rise as the LED-based lighting market grows. McKinsey & Company have reported that the LED-based lighting market should increase in value at an average of 38 percent per year between 2012 and 2016, and we anticipate that phosphor sales should increase even faster, as LED makers must use more red and green phosphor in the production of higher quality white-light sources with lower CCTs and higher CRI characteristics. Demand for more advanced phosphor materials is also rising as LED makers adopt more complex mixing strategies to compete on optimised brightness, CRI and R9 values.

Another reason we are very positive about the future is that, increasingly, our phosphor portfolio not only has materials with stable chemical structures that will last upwards of 50,000 hours – that is at least the lifetime of the bulb – but it also contains materials with excellent thermal stability.

Bulb makers want to drive their LEDs very hard, because this reduces the total chip count and thus the bill of materials, and this requires phosphors that are more chemically and thermally stable at high temperatures. Our newest phosphors perform particularly well in this regime.

For example, a chip packaged with GAL can maintain 97-98 percent of its initial brightness at 150 °C, and our red nitride survives the most rigorous lifetime tests with virtually no loss of brightness and perfectly stable colour. Bulb makers are also moving away from phosphor-coated LEDs to a remote-phosphor architecture. Because phosphor particles are small, the light they create is naturally diffuse – so in a phosphor-coated LED, as light is created, a portion is emitted back toward the chip surface and is lost. This loss is avoided with remote phosphor, which also has the benefit of operating at a lower temperature, further increasing the overall efficiency.

To support the growth of solid-state lighting based on remote phosphors, we have developed materials specifically for this application, which can be applied to either a two-dimensional sheet or a three-dimensional shape, such as dome or a tube. Thanks to superior geometries, efficacy is typically 15 percent higher. However, a 30 percent hike in efficiency is possible compared to a white LED with a diffuser.

By delivering this improvement, while ensuring excellent colour quality and stability with our robust, highly efficient phosphors, we are helping to drive a revolution in solid-state lighting.

This revolution is not just about trimming our carbon dioxide footprint by using highly efficient LEDs, more and more it is about illuminating homes and offices with a superior white light, making them better, more productive places to be.

Phosphors and China

In mainland China, the vast majority of LED packaging firms are hampered by a lack of LED device IP associated with using the combination of blue chips and YAG or silicate phosphor. As a result, most Chinese companies face restrictions that impair their exports of Chinese products.

Intematix is helping to address the difficulties faced by these Chinese companies, by delivering superior product performance, leveraging our local China manufacturing base, and offering an IP portfolio that covers both red and green phosphor compositions and their application in LEDs. Intematix phosphors are particularly valuable for Chinese LED makers who want to complete with higher light quality and must offer IP protected products to drive product exports to luminaire manufacturers selling to end customers such as Home Depot and Ikea.

Hybrid approach yields the best GaN crystals and wafers

Marrying HVPE and ammonothermal growth techniques will accelerate the production of ultra-high quality GaN

BY MICHAL BOCKOWSKI FROM THE INSITUTE OF HIGH PRESSURE PHYSICS, POLISH ACADEMY OF SCIENCES AND ZLATKO SITAR FROM THE WIDE BANDGAP LABORATORY AT NORTH CAROLINA STATE UNIVERSITY

IF A PERFECT PROCESS were to exist for forming boules of GaN, it would create material that is completely free from dislocations, impurities and bow. In addition, this process would quickly yield crystals with very large dimensions, so that substrates sliced from them would provide a cheap, ideal foundation for the manufacture of LEDs, lasers and power electronics.

However, as we all know, such a process does not exist. Instead, makers of GaN devices have to choose between a far-from-perfect native platform that is very pricey – a 2-inch GaN substrate retails for $2000 or more – and several options for larger, foreign substrates that have the drawback of leading to inferior material quality. Makers of laser diodes don't actually have this second choice, because they must work with very high quality material, so GaN is used. However, for the manufacturers of LEDs and transistors, GaN is nearly always deemed to be too expensive, so sapphire, silicon and SiC are widely adopted. These foreign substrates all have a lattice mismatch to GaN that leads to the generation of copious defects in the epistructures, resulting in the loss of device performance and lifetime.

It should be possible to address the lack of an affordable, ultra-high-quality GaN substrate with a process that has been developed by partnership between the Institute of High Pressure Physics of the Polish Academy of Sciences (IHPP PAS), working in close partnership with both Ammono S.A. and scientists at the Wide Bandgap Laboratory at North Carolina State University (NCSU). This team that we are part of employ a technology that involves uniting two existing techniques: HVPE and ammonothermal growth.

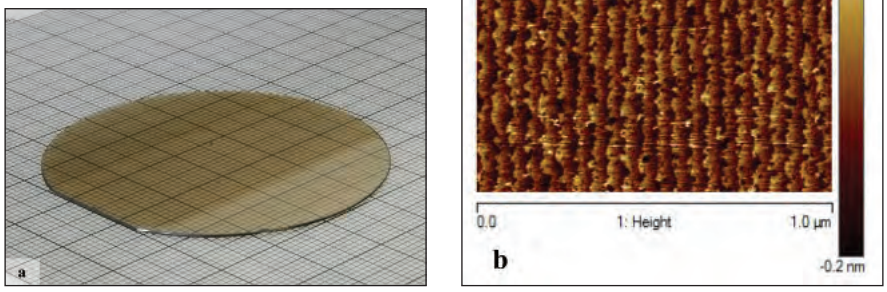


Fig. 1: a) A polished 2-inch GaN wafer produced by Ammono S.A. (courtesy of Ammono S.A.); b) An atomic force microscope image of the epi-ready (0001) surface of the Ammono-GaN wafer after chemo-mechanical polishing; the image shows the desired bi-layer steps; root-mean-square roughness is below 0.1 nm (courtesy of G. Kamler and G. Nowak, IHPP PAS).

Virtues of HVPE

Strengths of the former, HVPE, include a relatively high growth rate, which can exceed 100 μm/h, and a possibility to crystallize high-purity material. Thanks to these attributes, HVPE is a well-established method for making GaN substrates – this growth technique is employed by the likes of Sumitomo Electric Industry, Hitachi Metals, Furukawa Co, Mitsubishi Chemical, and Saint Gobain (formerly Lumilog).

These leading manufacturers of GaN begin by placing a foreign substrate, typically sapphire or GaAs, into a HVPE reactor, before heating the chamber to around 1300K. Introducing ammonia and gallium chloride at ambient pressure leads to the crystallization of GaN on foreign substrates, and when this thick film is removed via etching or self-separation techniques, a GaN substrate results.

Manufacture of these GaN substrates is well established. For example, market leader Sumitomo already demonstrated 6-inch freestanding material back in

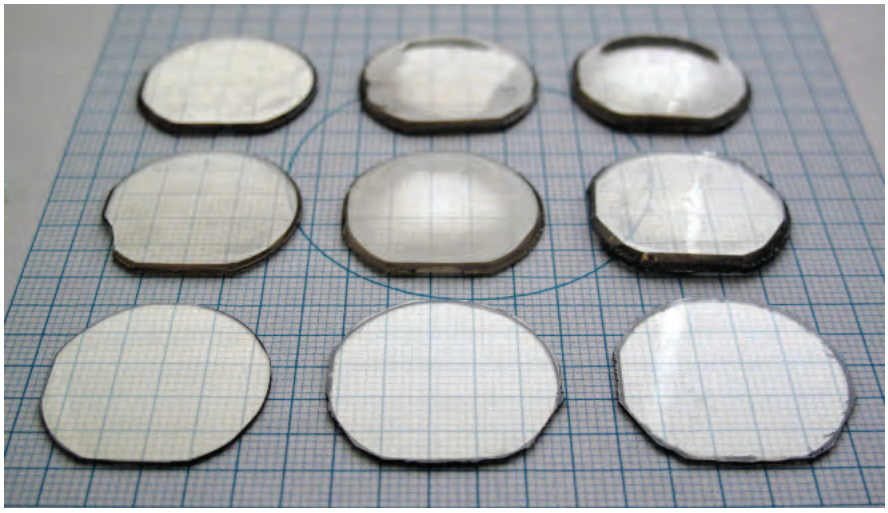


Fig. 2: HVPE-GaN crystals, thicker than 1 mm, crystallized on 1-inch Ammono-GaN wafers in a few hours (courtesy of T. Sochacki, IHPP PAS).

2010. However, the hetero-epitaxial growth causes the substrates to be riddled with a high density of defects, which typically number 10^6 - 10^7 cm^{-2}. What's more, the growth on a foreign substrate causes a large lattice bow – for example, when GaN is grown on sapphire the bowing radius of the (0001) crystallographic planes is always below 10 m. This is not good enough for epitaxy and device processing on 2-inch wafers, which require bowing radii exceeding 30 m.

Lattice bow also plays havoc with the growth of thick HVPE-GaN boules, the fabrication of large, freestanding substrates, and the use of freestanding HVPE-GaN crystals as seeds for crystal multiplication. Note that there is no point in crystallizing more material on a seed with a bent lattice, since crystalline quality only deteriorates further with growth.

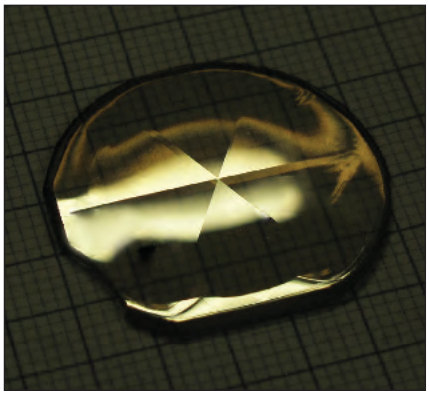


Fig. 3: A single growth center observed on the as-grown, 1-inch crystal surface (courtesy of T. Sochacki, IHPP PAS).

For the growth of epi-structures and the processing of devices, the wafer surface must be offcut uniformly with an accuracy of one to two tenths of a degree in a specific crystallographic direction, which produces a specific step structure on the wafer's surface. This low offcut promotes bilayer step flow, controls the composition of ternary alloys, and enables uniform incorporation of dopants. Lattice bow precludes all this. If substrates have a significant lattice bow, it is impossible to form homogeneous device layers across the wafer, and low production yield results. For a 2-inch wafer, for example, if the tolerance for the deviation of the offcut across the wafer is below 0.1°, which is a typical value, then the bow radius must be greater than 30 m to be able to meet this tolerance (see table 1 to understand the interplay between the deviation of the surface offcut and the bowing radius for wafers of various sizes).

A better foundation

The problem of lattice bow is not intrinsic to the HVPE process, but is rather a result of hetero-epitaxy. So, what is needed is to begin with a structurally perfect GaN seed – a requirement that can be fulfilled if this material is grown by the ammonothermal method, which involves forming GaN from a solution in supercritical ammonia.

The best partner in this approach, which is based on HVPE deposition on ultra-high-quality GaN seeds, is the world's leading grower of ammonothermal GaN, Ammono S.A. This Polish firm uses an approach that is analogous to the hydrothermal crystallization of quartz – but with supercritical ammonia replacing water – to produce GaN with many attractive attributes: exceptional lattice flatness, demonstrated by bowing radii of the (0001) crystallographic planes of around 100 m; dislocation densities of typically just 5 x 10^4 cm^{-2}; and a free carrier, *n*-type concentration that may be varied from 5 x 10^{17} cm^{-3} to 2 x 10^{19} cm^{-3} (see Figure 1a for a 2-inch GaN substrate).

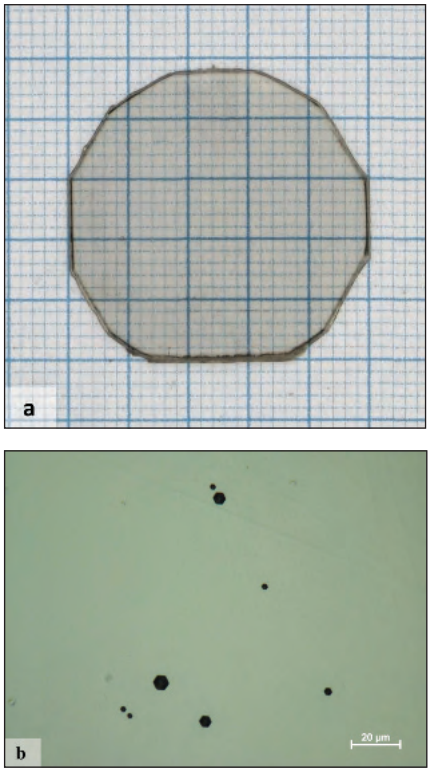


Fig. 4: a) A polished freestanding HVPE-GaN wafer sliced from the Ammono-GaN seed (courtesy of T. Sochacki, IHPP PAS); b) Wafer surface after the defect selective etching; the etch pit density was 5x10^4 cm^{-2} (courtesy of J.L. Weyher, IHPP PAS).

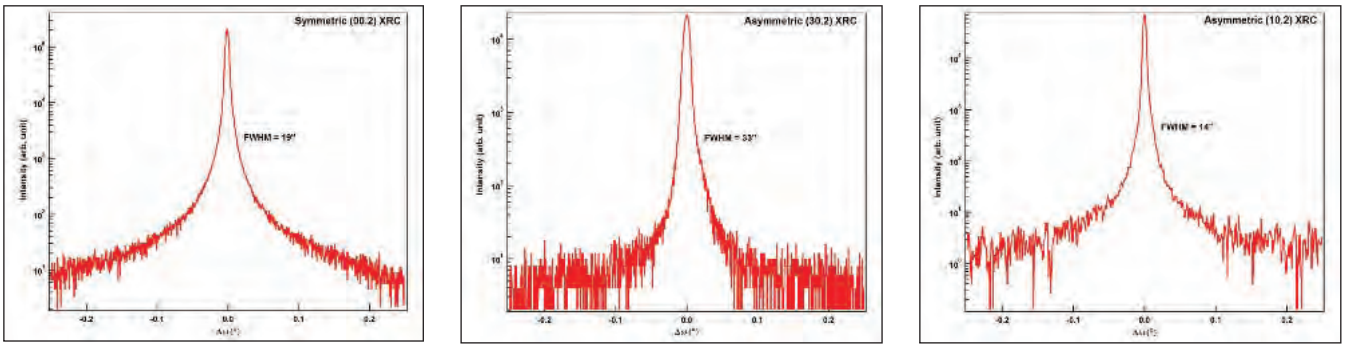


Fig. 5: X-ray rocking curves of the symmetric (0 0 2), and skew-symmetric (3 0 2) and (1 0 2) reflections for the freestanding HVPE-GaN (courtesy of M. Bobea, NCSU).

Making great use of these seeds, the part of our team based at the IHPP PAS has developed a combination of mechanical and chemo-mechanical processes for transforming the surfaces of these wafers into an epi-ready state. Using this technique, one can obtain surfaces with uniform bilayer steps and a root-mean-square (RMS) surface roughness below 0.1 nm (see Figure 1b).

To open the door to a new era of GaN bulk crystal and substrate production, the hybrid HVPE-ammonothermal growth technique has to succeed on two fronts: the perfection associated with the ammonothermal GaN seeds must be maintained in the HVPE-grown material; and it must be possible to grow thick HVPE boules to multiply the ammonothermal GaN crystals. IHPP PAS and Ammono S.A. have triumphed in both areas while working on a two-year project that finishes this July and has been backed by $1 million by the Polish National Center for Research and Development.

One of the highlights of this effort has been the formation of 1 mm-thick HVPE-GaN crystals, which were crystallized on 1-inch Ammono-GaN wafers in a few hours (see Figure 2). This additional GaN grown by HVPE is macroscopically flat and free from cracks or pits. HVPE conditions governed the growth rates, which ranged from 120 μm/h to 240 μm/h. As desired, only one growth center on the entire 1-inch crystal surface after the growth process was observed (see Figure 3).

By slicing the freestanding wafers of HVPE-grown GaN from the ammonothermally grown seeds, members of our team were able to form about 300 μm-thick GaN substrates that replicated the crystalline quality of the original Ammono seed, and were free from cracks and pits (see Figure 4a). Note that the Ammono-GaN seeds that were separated could be used for further HVPE crystallization without any limitations.

IHPP PAS has scrutinized the quality of the freestanding, HVPE-grown GaN substrates with a variety of techniques. Using a molten KOH-NaOH eutectic revealed an etch pit density, and thus a threading dislocation density, of 5×10^4 cm^{-2}, the same as the original seed. This effort also revealed three types of etch pits: large etch pits, which were correlated to the screw dislocations; small pits that were associated with threading edge dislocations; and medium-sized pits that originated from threading mixed dislocations (see Figure 4b). These insights showed that the structural properties of the freestanding HVPE-GaN do not differ from the structural properties of the Ammono-GaN seeds. However, IHPP PAS still needs to conduct further work to directly correlate the defects in Ammono-GaN with those found in HVPE-GaN.

Team members at NCSU have determined the structural and optical properties of the freestanding, HVPE-grown GaN. X-ray rocking curves of the symmetric (0 0 2) and skew-symmetric (3 0 2) and (1 0 2) reflections produced very intense, narrow Bragg peaks, indicative of excellent crystallinity and low dislocation density (see Figure 5). The full-width at half-maxima values of the (0 0 2), (1 0 2), and (3 0 2) reflections were 22, 17 and 35 arcsec, respectively; these values were close to the theoretical values for a perfect GaN crystal.

Meanwhile, low-temperature photoluminescence spectra acquired from the (0001) surface exhibited several well-defined bound and free exciton peaks. Dominating the spectra were two sharp donor-bound exciton emission lines at 3.471 eV and 3.472 eV that have values for the full-width at half maximum of 127 μeV and 167 μeV, respectively (see Fig. 6a). This width for the bound exciton peaks is the narrowest ever reported for GaN, confirming not only the

Table I. Deviation of the surface offcut as a function of bowing radius for wafers of various sizes.

Calculated miscut deviation over the wafer for different bow radii

Wafer Dia	Lattice Bow Radius			
	5 m	10 m	20 m	30 m
1”	0.3°	0.15°	0.07°	0.05°
2”	0.6°	0.3°	0.15°	0.1°
3”	0.9°	0.5°	0.2°	0.15°
4”	1.6°	0.6°	0.3°	0.2°

high crystalline quality of this material, but also its very high purity.

Additional measurements by the NCSU team revealed that the room-temperature transmission spectrum was relatively featureless up to the band edge (see Figure 6b). What was even more impressive was that, according to secondary ion mass spectrometry, oxygen and carbon contents were below 10^{16} cm^{-3}, while the silicon impurity level was 3 x 10^{16} cm^{-3}. In addition, the substrates had a high surface quality, according to low-temperature photoluminescence and high-resolution X-ray studies of the diffuse scatter and crystal truncation rods.

These measurements confirmed that the work has laid the foundation for the manufacture of high-quality, larger GaN crystals that can be cut into wafers with the well-defined and uniform offcut that device makers are looking for. However, that's not to say that the research in this area is over. Next, the scientists at IHPP PAS want to examine doping via HVPE, to see if it is possible to create semi-insulating and *n*-type substrates with controlled doping levels. It is also needed to transfer the process to 2-inch material. As IHPP PAS do all this, Ammono will be optimizing their ammonothermal GaN growth on these HVPE crystals, to increase the production and availability of ultra-high-quality GaN substrates.

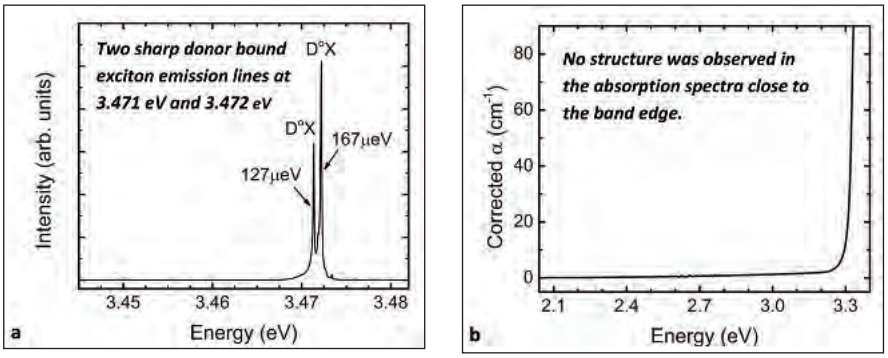
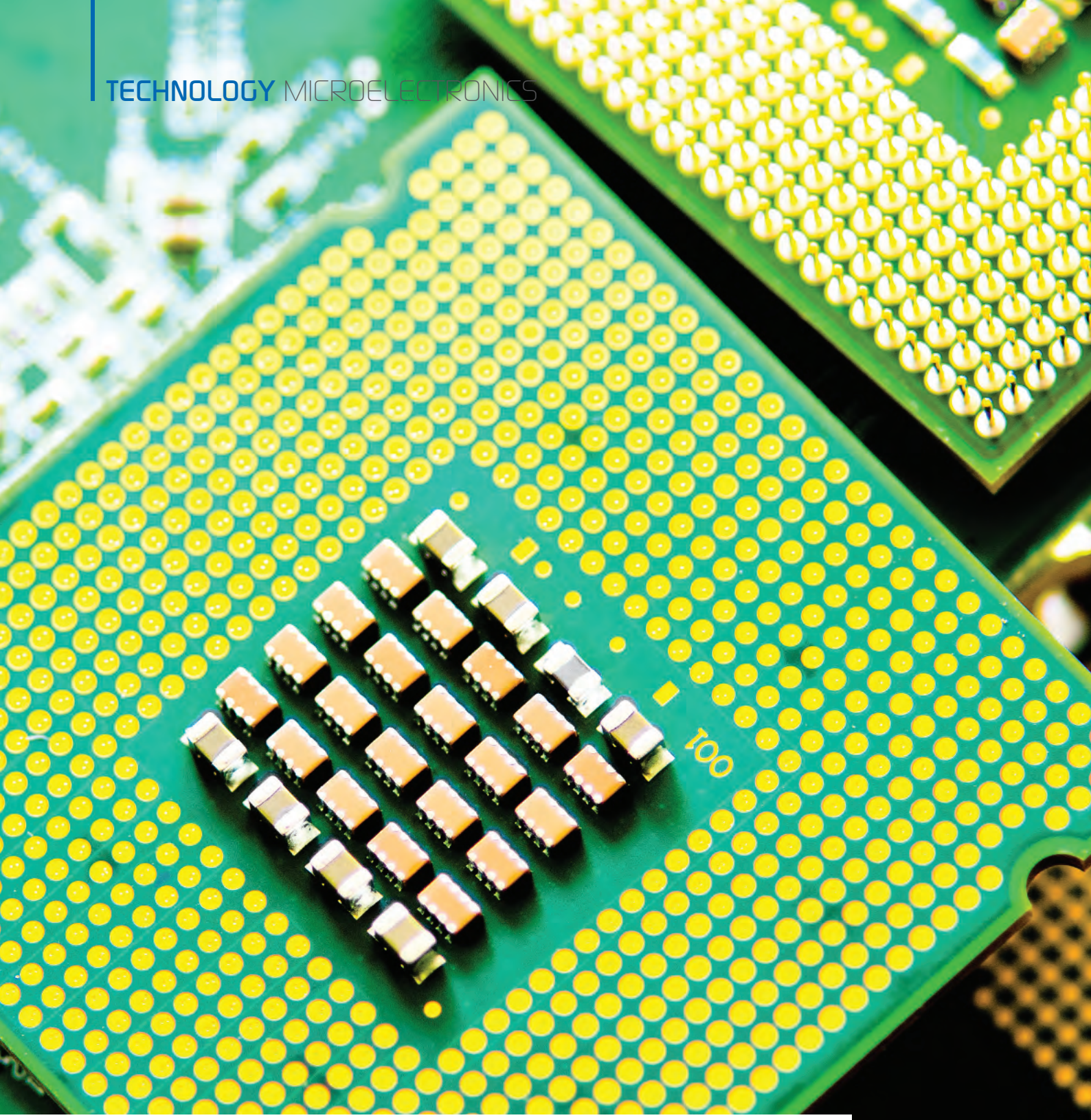


Fig. 6: Photoluminescence spectra obtained at 3K from the (0001) surface of the freestranding HVPE-GaN (linear scale); b) RT transmission spectrum of the freestanding HVPE-GaN (courtesy of Z. Bryan and I. Bryan, NCSU).

Further reading

T. Sochacki *et. al*. Appl. Phys. Express **6** 075504 (2013)

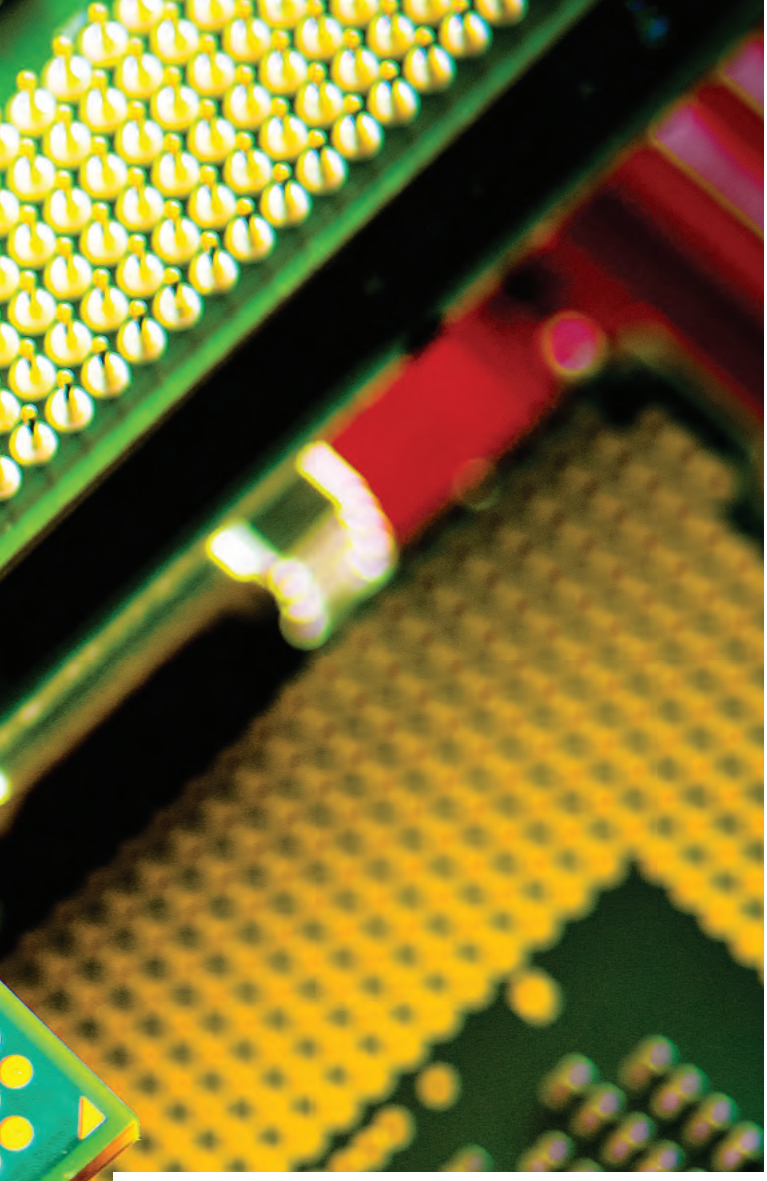
T. Sochacki *et. al.* Journal of Crystal Growth **394** 55 (2014)



GaAs: The logical successor to CMOS

MBE-grown GaAs can maintain the march of Moore's law by forming faster, low-power ICs with optical capabilities.

BY GEOFFREY TAYLOR FROM POET TECHNOLOGIES



THE END IS IN SIGHT for the scaling of silicon CMOS. From the 1990s until the first few years of this millennia, simply shrinking the dimensions of silicon transistors – the only viable digital technology of the time – wrought improvements in performance that were big enough to keep pace with Moore's Law. But since 2005, the law of diminishing returns has been more relevant: Although each additional shrink has increased performance, this has been minimal, while power increases have been significant. To blame are the parasitic resistances, capacitances and inductances that have failed to scale with reductions in device dimensions. Consequently, the power per chip is constantly pushing against the acceptable limit, while the clock rate in digital systems has stalled.

To relieve these constraints, the companies that are making processors and systems-on-a-chip have pursued different paths to superior performance. They have become more creative in managing circuit performance, while adding cores, innovating with on-chip interconnect approaches and employing better cache management. In addition, they have marketed their products in new ways, switching from traditional performance metrics such as the raw core frequencies of the processor, to alternative benchmarks that showcase their efforts in a better light.

On top of this, there has been innovation by the chipmakers. Although they are not keeping pace with Moore's Law, the economics of moving to each new, smaller node can be justified, and power consumption has been kept in check by trimming the transistor's operating voltage.

An example of the pioneering efforts made by this industry has been the development of a new breed of transistor with a fin protruding out of the device. This move to a three-dimensional structure, which made its commercial debut below the 28 nm node, increases device density and cut leakage. However, these advantages come at the expense of a lower yield, and the economics is challenging for fabless companies.

In addition to these economic issues, which stem from skyrocketing tapeout and wafer costs, performance gains are diminishing with every new node introduced below 28 nm. Performance figures indicate that the core voltage has saturated at 0.75-0.80 V, preventing power reductions associated with switching between on and off states, although it has been possible to trim leakage losses.

Optical CMOS

Another avenue being pursued by the silicon industry is to introduce optical capabilities onto the silicon IC. To do this in an economically viable manner, shrinking the dimensions of the transistors on the CMOS chip must go hand-in-hand with the introduction of a technology for connecting fibre to this device. The way forward that has attracted the most interest is that of silicon photonics: a low-loss silica waveguide connects modulators and detectors on a silicon platform. With this approach, there is the potential for CMOS drivers to co-exist on the platform.

In the past 10 years, IBM, the US government, VCs and others have spent between them more than $2 billion trying to fulfil this vision of creating optics within the CMOS IC. But even with this high level of investment – and several start-ups later – uniting photonics and electronics on a single chip is only a dream. Lack of progress has led to a consensus among the suppliers of optics, and the chips that drive them, that the economics dictates optics and logic in different processes – each optimized for their own function.

Despite this setback, the silicon industry is continuing its quest for a technology that will enable optical functions on the chip. This will have to be an alternative to CMOS technology, but one that is as similar to it as possible. Such a technology will prove essential as data rates migrate to 40 Gbit/s, 100 Gbit/s and then 400 Gbit/s, speeds that make the cost of packaging unmanageable. An additional requirement is that the IC will have to incorporate optical emitters and detectors. Attempts to develop such a platform that enables this transition from CMOS to optics are on-going, since no-one has yet to claim success.

Cutting power, boosting speed

To address the power and speed limitations associated with silicon CMOS, higher mobility materials must be introduced for the *n* and *p* channels. Electrons and holes can then zip through the channel faster if the voltage is maintained, or travel at speeds similar to those associated with silicon while being driven at a lower voltage – this latter mode of operation

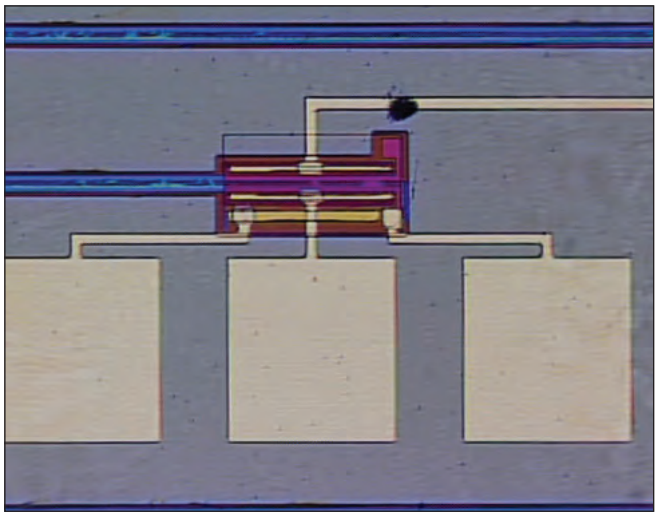


Figure 1. A range of devices, including the detector shown here that is formed from a HFET structure, can be fabricated with POET technology.

cuts power. To equip circuits with these new materials, the mainstream silicon industry is developing technologies to add InGaAs and SiGe channels to boost electron and hole mobility, respectively.

One option pioneered independently by imec and IBM involves the growth of InGaAs in narrow trenches etched in the silicon substrate. Although there is a high lattice mismatch, the vast majority of the dislocations that form are trapped on the sidewalls at the III-V-silicon interface. This means that there is the potential for acceptable densities at the top of the trench. However, because these trenches are very small, there can be high leakage paths along the walls between the source and the drain.

What's more, there is a very limited opportunity to vary the thickness and composition of the III-V layers that can be incorporated in the trenches, while their small size is impractical for making a laser. So it is not possible to combine high-performance InGaAs FET channels with high-performance optical emitters.

One further drawback of this approach is that the deposition of SiGe for the *n*-type channel requires a separate crystal growth step. Having to make two concatenated growth steps, using a rather complex process, does not bode well for acceptable yields.

An alternative approach that has been pioneered by IBM begins with the growth of III-V layers on a donor substrate. Bonding to an oxide layer transfers these high-mobility layers to a target silicon substrate. When the III-V layer is subsequently released from the donor wafer, a III-V-on-insulator structure is created on silicon. To enable the formation of *p*-type transistors, engineers grow an 8 nm-thick layer of SiGe on 25 nm of oxide prior to the bonding step.

Again, the fabrication of optical devices is precluded at the outset. That's because in this case the multiple layer requirements of a laser structure are too complex for a donor substrate.

There are also concerns relating to acceptable yields and costs. These arise due to the fundamentally different chemical natures of InGaAs and SiGe, which cause the etching sequences and thermal cycles for the two materials to be inherently incompatible.

Building on GaAs

Against this backdrop, POET Technologies of Toronto, ON, and Storrs, CT, is pioneering a new approach that leads to superior ICs: Planar OptoElectronic Technology (POET). This revolutionary CMOS-friendly process IP, which enables *p*-channel and *n*-channel devices to be integrated monolithically in a III/V semiconductor environment, has the potential to fully replace all silicon-based CMOS circuitry.

By turning to strained InGaAs quantum wells with indium channels of 70 percent or more, mobility and channel velocity increase, and operation of the circuit at 0.3 V should enable a ten-fold gain in performance at 80 percent lower power compared to a silicon CMOS IC.

Development of this technology started in the early 1990s in the labs of the University of Connecticut. Since then more than 18 years has been devoted to developing and proving out numerous components of the POET platform. In 2001 we formed the start-up, and we currently have 34 patents, plus another 7 pending.

Our business model is to license the III/V semiconductor process technology IP to customers and foundry partners to enable designs and produce devices that include analog,

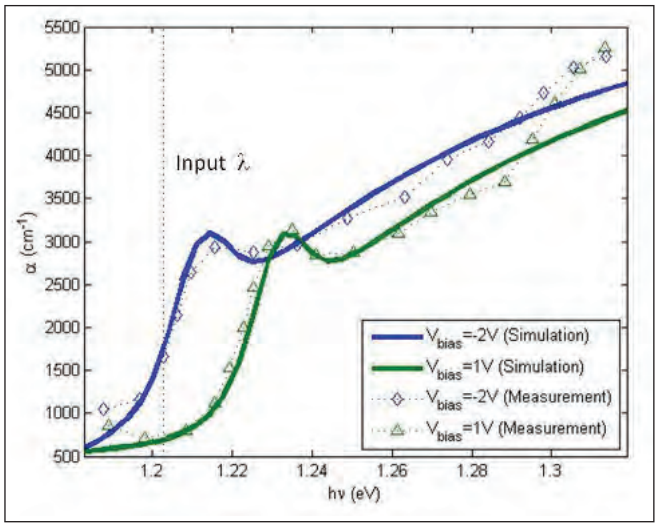


Figure 2. Injecting charges leads to a shift in the absorption edge.

digital and optical functions on the same die for a variety of markets including, but not limited to, hand-held smartphones and tablets, PCs, servers, data centres, military and industrial applications.

With our technology, the incompatibility issue between transistors and the optical devices disappears, and it is possible to form high mobility channels for both the *n*-type and *p*-type transistors. But to do this, we have to challenge the assumption that these high-mobility materials have to be introduced on a silicon substrate.

In our case, we use substrates made of GaAs. These are currently available in diameters up to 200 mm, and there is no fundamental barrier to the production of 300 mm equivalents. Our preferred growth technique for depositing III-V layers on this foundation is MBE, and this can be applied to substrates of this size.

Tier 1 fabs already use this approach to deposit material on 300 mm wafers, so the only barrier to a switch of substrate is cost. Differences between the price of silicon and GaAs substrates will shrink as shipments of the latter rise, and costs could be further reduced through innovations in substrate release techniques. Note that the POET fabrication process employs the same set of foundry tools currently used for silicon CMOS, so only a reconfiguration is required.

The idea of using GaAs rather than silicon to make digital circuits is not new. During the *n*MOS era that spanned the 1970s and early 1980s, GaAs MESFET technology was a contender for silicon E/D logic applications. And later, during the development of CMOS, the GaAs HEMT was also considered for high-speed logic circuits.

Two fundamental flaws prevented these GaAs devices from making a significant impact. The first is that both the MESFET and the HEMT are inherently normally on (depletion) devices, and although the threshold can be shifted marginally to the positive, the swing is too small to be well controlled. The second is that it is not possible to make *p*-channel MESFETs and HEMTs, which prevents the construction of a complementary technology.

Our POET technology is not held back by these issues. In our case, the p-type form of the FET is a natural component in the POET device family. Although the *p*FET and the *n*FET are grown as enhancement devices, they can be transformed to depletion devices with a suitable implant. Consequently, the complementary inverter is just as compact as it is when built with silicon CMOS technology, but it can operate with a smaller supply voltage.

All of the devices in the POET family are formed with a single epitaxial growth step that creates multiple-quantum-well or multiple-quantum-dot layers. This is followed by a comprehensive fabrication sequence, which produces electronic and optical devices simultaneously.

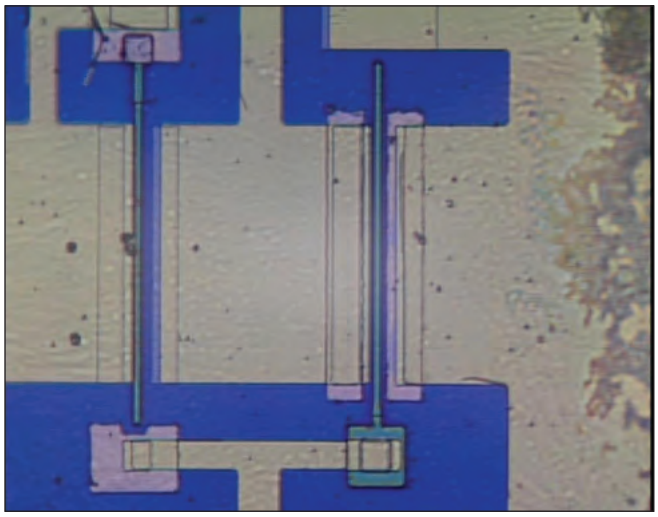


Figure 3. POET technology can be used to create a complementary inverter, a key building block for an IC.

Electronic devices are realized as bipolars, FETs and thyristors. For the HFETs, gates are formed by refractory metals, with the multiple quantum wells becoming the channels of *n*-type and *p*-type devices, and self-aligned ion implants defining the source and drain regions. Like MOSFETs, the HFETs have a back gate contact, which is the substrate.

The gate metal of the HFET forms an ohmic contact. This eliminates static conduction because the gate input logic swing is always maintained below the knee voltage of the input diode. In contrast, both the *pnp* and *npn* bipolars are in the form of bipolar inversion channel transistors (BicFETs), with the refractory ohmic contact behaving as the emitter terminal operating in the conductive region.

Meanwhile, in the bipolar devices, the multi-quantum well channels function as control electrodes, while the collectors are quantum-well regions contacted by ion implantation. Finally the thyristor utilizes both HFETs and BicFETs. This four-terminal digital device has a high resistance off-state and a low resistance on-state, which makes it useful in synchronous circuits and memory applications.

The same sequence of steps creates optical devices. To form a quantum-well laser from the HFET structure, the refractory emitter is contacted and also the channel. Laser operation is possible with either *p*-type or *n*-type contacts. Note that it is also possible to operate the thyristor as a laser when it is switched to its conducting state.

Thanks to the flexibility of the POET platform, lasers can be produced as either in-plane emitters or VCSELs. To fabricate the latter class of device, the transistor structure has to be designed to fit within an integer number of half wavelengths. This requirement is easier to fulfil when the laser operates at longer

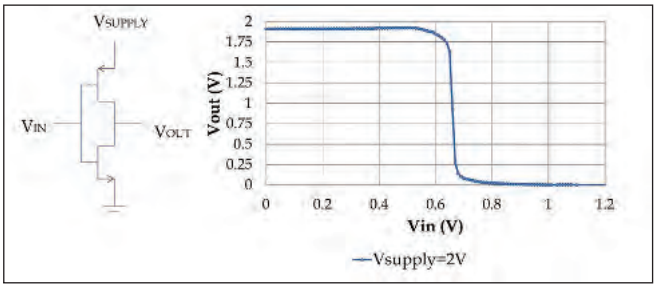


Figure 4. Transfer characteristics of a cHFET complementary invertor formed with POET technology.

wavelengths, such as those around 1.5 μm. For an in-plane laser, the preferred implementation is a closed loop resonator. Output is directed into a straight waveguide, which has losses that are trimmed through novel implant techniques.

One of the strengths of this design is the great flexibility of the resonator: It can be varied from a large perimeter, rectangular design that features conventional wave-guiding for increased laser output power to a small perimeter circular resonator, which is based on whispering gallery mode (WGM) wave-guiding, and delivers a greatly reduced output power. These structures are ideal for optical filtering, wavelength-division multiplexing operations and slow light control.

It is also possible to build absorption modulators, detectors and optical amplifiers from the HFET structure used for the laser. Typically, these are implemented in a linear waveguide geometry, because a cavity is not required (see Figure 1). However, it is essential to control the absorption profile via the applied voltage, because this enables voltage control of the refractive index. With the POET platform this requirement is met, because injection of charges leads to a blue shift in the absorption edge (see Figure 2).

Conventional processes

We produce our devices by MBE, the only deposition process providing precision doping, thickness control and laser quality. This particular epitaxial process is also unmatched in its ability to realize self-assembled quantum dots. To trim growth times, we use various approaches, such as the deposition of top mirrors.

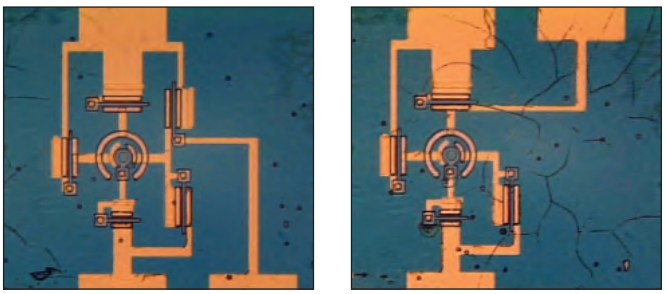


Figure 5. An integrated transmitter (a) and receiver (b) formed with POET technology.

The fabrication processes that we employ are very similar to those associated with silicon CMOS. For both *n*-type and *p*-type FETs, sputtering forms the refractory gates. After etching close to the quantum wells, ion implantation defines the source and drain regions and the laser apertures for VCSEL current steering. High-temperature annealing follows, before implants are metalized and interconnected.

Addition of the metal enables electrical devices, and also allows injection and extraction of carriers in a variety of optical waveguide devices, including detectors, modulators, amplifiers and directional couplers. Etching through to the bottom mirror isolates all devices.

When we started our development effort, we used a 1 μm gate size, but more recently we have scaled to 100 nm. Currently *n*FETs with an effective gate length of 0.6 μm and a cut-off frequency of 42 GHz.

Structures that we have made include an inverter (see Figure 3 for an example). This device can exhibit the ideal behaviour required for complementary operation (see Figure 4). Other efforts by us include integration of the laser and the detector to form the transmit and receive functions in a vertical cavity format (see Figure 5).

Our development programme has enabled stabilisation of the fabrication and growth platform, and we are now in a position to develop a full suite of optoelectronic devices. We can now fabricate logic blocks based on cHFET designs, while simultaneously developing optical input/output blocks, which require novel spot-size converters to realise low insertion loss to/from fibres in a low-cost package.

Further scaling of our device portfolio is required. That should not prove too tricky, as based on our preliminary work on logic devices with 100 nm feature sizes, it is clear that the our devices will also scale down to 15 nm and even 10 nm – just as silicon is doing now.

While scaling is important, it is by no means our only goal. It turns out that the modulation-doped interface formed with our technology, which is a normally off channel, is ideal for the implementation of the single electron transistor. This form of transistor can access engineered quantum dots at the interface, which have quantum levels differentiated by spin. It is possible that these single electron transistors could aid the development of quantum computing, with electron spin providing the quantum variable to form quantum computing logic blocks.

Thus our POET technology could provide a chip environment for conventional logic and optoelectronics that serves the computers of today, while providing a bridge between the quantum computing function with qubits and the real world of classic logic with its binary numbers.

Green emission rockets with nanorod array

Switching from a planar sample to a nanorod array increases efficiency by a factor of 88

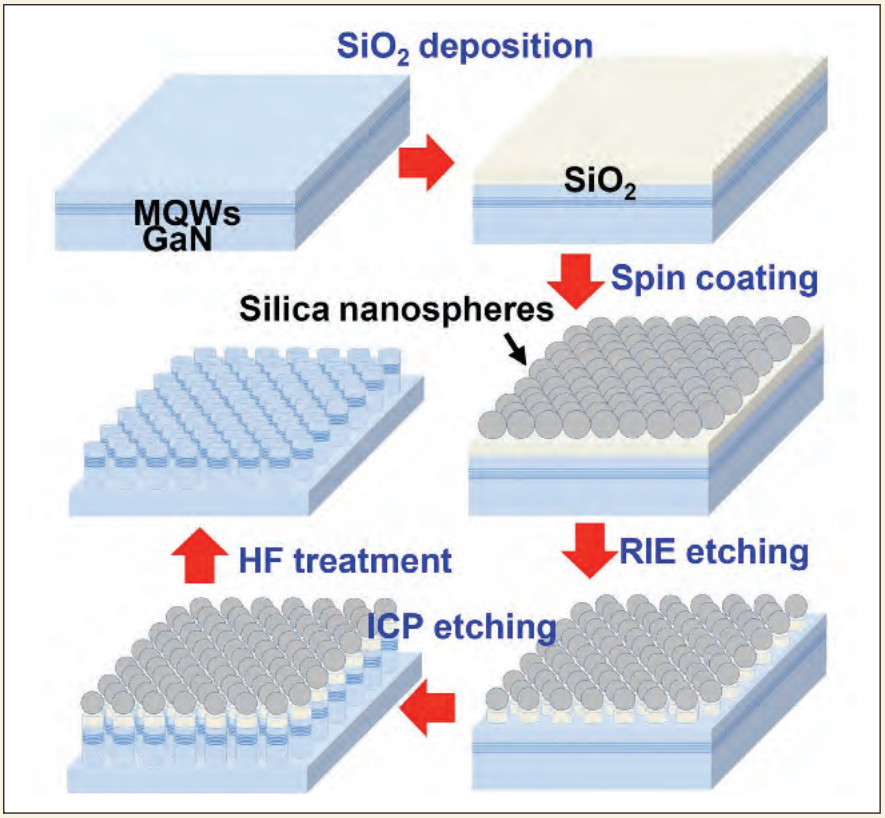
ENGINEERS at the University of Sheffield, UK, have constructed a novel nanorod array that delivers a tremendous enhancement to emission efficiency via a "coherent" nanocavity effect.

Introducing this nanoscale structure, which increases internal quantum efficiency by a factor of 88, promises to improve the performance of green LEDs.

Today, their performance falls a long way short of that of their blue-emitting cousins, due to the Quantum Confined Stark Effect. At the heart of the green LED is an indium-rich InGaN quantum well, which is surrounded by a GaN barrier with a significant lattice mismatch. This difference in atomic spacing creates strain in the heterostructure – and that introduces a strong internal electric field, which pulls electrons and holes apart and drives down LED efficiency.

"Our previous work has confirmed that nanorod structures can lead to significant strain relaxation, reducing the QCSE and thus improving optical performance," says Tao Wang, who explains that the recent, big breakthrough is the hike in the internal quantum efficiency through the introduction of a coherent nanaocavity effect in the green spectral region.

To realise this, the team carefully selected the diameter of the naorods and the geometry of the array. That's because if these rods, which have a diameter below 300 nm, are isolated or arranged in an array that does not give rise to a coherent nanaocavity effect, the only cavity modes that occur are deep within the ultraviolet.



Nanorod arrays are formed by depositing a silicon dioxide layer, spin-coating nanospheres, etching the sample, and then removing the spheres with hydrofluoric acid.

Arrays of nanorods were formed by taking a multiple quantum well structure with five 2 nm-thick InGaN wells sandwiched between 9 nm-thick InGaN barriers, and depositing silica nanospheres on the surface (see figure). Selective etching of this structure created an array of nanorods with a height of 350 nm.

The team used this approach to fabricate a range of structures. In all cases, separation of the nanodisks were 274 nm, but different nanosphere diameters were employed: 270 nm, 250 nm, 235 nm, 205 nm, 160 nm and 145 nm.

Excitation of these structures with a 375 nm laser produced photoluminescence, which was most intense for the sample with 205 nm-diameter nanorods. Measurements at 12K determined an enhancement factor – defined as the ratio of internal quantum efficiency in the nanodisk sample to that in the as-grown sample – of 88. Structures were also scrutinised by time-resolved photoluminescence. That with 205 nm-diameter rods had the shortest emission lifetime and the highest spontaneous emission rate, confirming the presence of a nanocavity effect in this sample.

To aid the launch of more efficient commercial green LEDs, the team will have to devise a way to put a high-quality *p*-type contact onto the surface of the nanostructures. However, they will *not* also need to come up with a new approach for making nanorod arrays, according to Wang, so long as a high degree of uniformity is possible across entire wafers. "Nano-imprinting and electron-beam lithography could be alternative options, but both are too expensive."

Manufacturers of green LEDs may crave even higher enhancement factors, but that may not be possible – and it would depend on the quality of the epiwafer.

"If the optical performance of the starting wafer would have been very good, the enhancement factor would not be so high," says Wang. "Therefore, the technique would be particularly useful for the fabrication of green emitters, as the optical performance of green emitters is far from satisfactory."

T. Kim *et. al.* Appl. Phys. Lett. **104** 161108 (2014)

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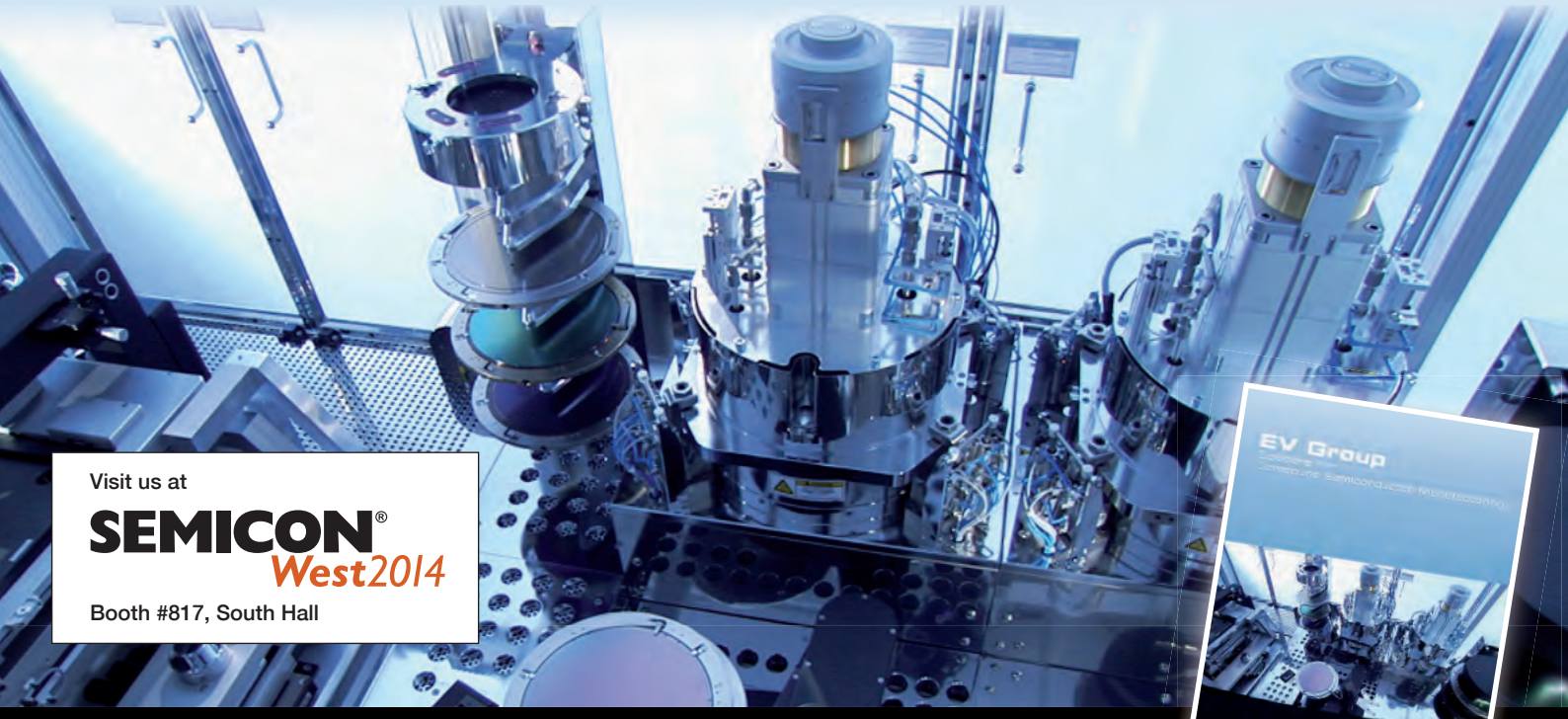

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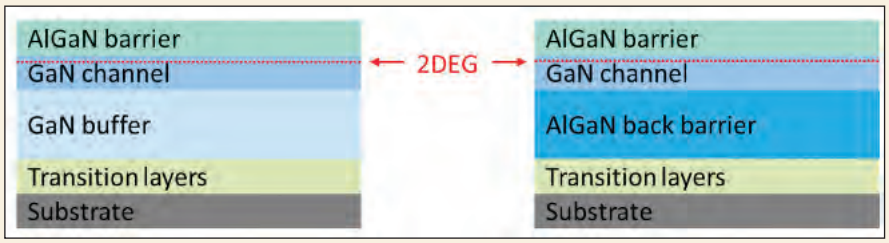
FETs: Double heterostructure boosts breakdown, cuts costs

Switching from a conventional FET to a AlGaN/GaN/AlGaN structure increases breakdown voltage and trims buffer thickness

RESEARCHERS from National Chiao-Tung University, Taiwan, are claiming to have reported the first device comparison of conventional and double-heterostructure GaN FETs fabricated on 150 mm silicon.

Corresponding author Edward Yi Chang claims that one of the key findings of this effort is the significant increase in the breakdown voltage resulting from the insertion of an $Al_{0.1}Ga_{0.9}N$ back barrier to form the double heterostructure FET.



The double-heterostructure has the same AlGaN barrier, but instead of a 2.6 μm-thick layer of GaN, it features a 1.4 μm-thick $Al_{0.2}Ga_{0.8}N$ back barrier and a 55 nm-thick GaN channel.

"Furthermore, the double heterostructure FET greatly reduces the buffer thickness needed for GaN power devices."

Turning to a thinner buffer, which reduces strain and simplifies control of wafer bow, could aid the manufacture of GaN-on-silicon FETs. "A recent study shows that it is difficult to consistently grow GaN on 6-inch silicon substrates, due to the thick buffer layer, which induces large strain on the 6-inch wafer," says Chang.

Options for increasing breakdown voltage are by no means limited to the insertion of a double heterostructure, and often involve different device designs or improvements to the epitaxial structure.

"From the aspect of device fabrication, field plates, ion implantation and local silicon substrate removal are complicated," argues Chang, adding that since the epitaxial structure governs device performance, it is this that should be optimised.

Like several other groups, the Taiwanese team investigated thicker epi-structures and carbon doping: "A thicker crack-free film is difficult to grow because of a large tensile stress," says Chang, "while a carbon-doped GaN buffer can improve breakdown voltage greatly, but a specific on-resistance increase of the device is another serious issue."

To evaluate their new design, the team formed conventional, single-heterostructure FETs and double heterostructure variants by growing epitaxial structures on 675 μm-thick, 150 mm diameter silicon substrates using a Thomas Swan MOCVD reactor. This tool was equipped with a Laytec EpiCurve TT system for measuring the curvature and temperature of the wafer.

Both types of device share the same foundation: a 200 nm-thick AlN nucleation layer and a 600 nm-thick section of various AlGaN transition layers. The conventional FET structure deposited on this consisted of a 2.6 μm layer of GaN, followed by a 27 nm $Al_{0.2}Ga_{0.8}N$ barrier; while the double-heterostructure contained a 1.4 μm-thick back barrier made from $Al_{0.2}Ga_{0.8}N$, a 55 nm-thick GaN channel, and a 27 nm-thick $Al_{0.2}Ga_{0.8}N$ barrier.

Room-temperature Hall measurements show that the control sample has a mobility of 1270 $cm^{-2}\ V^{-1}\ s^{-1}$ and a sheet carrier concentration of $8.5 \times 10^{12}\ cm^{-2}$, while the double-heterostructure variant has a mobility of 1110 $cm^2\ V^{-1}\ s^{-1}$ and a sheet carrier concentration of $8.7 \times 10^{12}\ cm^{-2}$.

Etching with an inductively couple plasma defined device mesa regions in the epiwafers. The addition of a Ti/Al/Ni/Au stack created source and drain contacts, and a combination of nickel and gold formed the Schottky gate contact. Transistors that resulted feature a gate with a width of 100 μm and a length of 1 μm, and have a gate-to-drain and gate-to-source spacing of 4.5 μm and 1.5 μm, respectively. Using isolation patterns with a 5 μm gap, and defining the breakdown voltage as that at which the leakage current exceeds 1 mA/mm, the team determined a breakdown voltage for the single heterostructure FET of 170 V. In comparison, the breakdown voltage of the double heterostructure FET was more than 200 V.

Turning to isolation patterns with a 20 μm gap enabled a comparison of leakage currents at 200 V. The double-heterostucture FET leaked 9.2×10^{-5} mA/mm, compared to 6×10^{-3} mA/mm for the control.

One weakness of the double-heterostructure FET is that its drain current density is just 475 mA/mm, which is more than 20 percent lower than that of the control. The team believes that this might be due to a lower carrier concentration.

Chang and his co-workers are planning to improve wafer uniformity, fabricate double-heterostructure devices with an 80 nm gate width that should produce high output currents, and compare the reliability of conventional and double-heterostructure FETs.

Y. -L. Hsiao *et. al.*
Appl. Phys. Express **7** 055501 (2014)

Air gap boosts LED extraction efficiency

Output power increases with the insertion of an air gap between the chip and the remote phosphor

ENGINEERS from Yonsei University in Korea have shown that the insertion of an air gap can significantly increase the extraction efficiency of a white LED.

The team produced two types of device – a relatively conventional LED structure with an epoxy layer between the chip and the quantum dot phosphor, and a second, more radical design that replaced the epoxy with an air gap. This latter LED had a 33 percent higher optical extraction efficiency.

Both these remote phosphor designs have advantages over the more common 'phosphor-in-a-cup' architecture, which has phosphors dispersed in a liquid resin that is in direct contact with the chip.

This design, which is widely used in industry, impairs light extraction and colour quality, due to isotropic emission from the phosphors and the relatively narrow range of re-emitted spectra. The Korean team introduced its air-gap structure to minimise light trapping in the phosphor layer of a remote-phosphor LED.

With their design, the light that is scattered or re-emitted from the quantum-dot-phosphor layer back towards the chip has a better chance of undergoing total internal reflection at the interface with air, due to the high difference in refractive index. This back-scattered light then has the potential to exit the device in the preferred direction. Calculations by the team suggest that when the quantum dot phosphors are embedded in a polymer with a refractive index of 1.53, about 45 percent of the re-emitted and scattered light heading in the backwards direction can be reflected at the air-polymer interface.

Further gains to the optical extraction efficiency are realised by adding a dome-shaped polymer lens on the LED surface. This increases the angle of the escape cone for the light emitted from the chip.

The team forms white-emitting LEDs by combining an InGaN-based chip emitting at 452 nm with two quantum dot polymer layers emitting at 597 nm and 530 nm. Driven at 2.8 V and 6 mA, the design with an airgap produced 1.66 mW, compared with 1.28 mW for the LED with an epoxy. The air-gap structure also had a slightly superior colour-rendering index of 81.8, compared with 80.7 for the control.

To determine the contribution made by the polymer lens on the LED, the team constructed a device without this optical element. Optical efficiency was then only 19.5 percent higher than that of the control, implying that the relative contributions from the air gap and the polymer lens were 66 percent and 34 percent, respectively.

M.-H. Shin *et. al.* Appl. Phys. Express **7** 052101 (2014)

High-temperature CVD to cut SiC costs

Researchers deposit high-quality 4H SiC at growth rates of more than 2 mm/hr

A JAPANESE PARTNERSHIP has significantly increased the growth rate for forming high-quality SiC by high-temperature CVD.

Growth rates of more than 2 mm/hour are now possible with this deposition technique, making it an attractive alternative to the standard method for forming SiC boules, physical vapour transport. The incumbent technology is only capable of growth rates of up to about 0.5 mm/hour, and the length of the SiC bulk crystal is limited, due to the use of sealed crucibles that make it tricky to replace the source material. These weaknesses partly account for the high cost of SiC substrates, which are an impediment to the growth of the SiC power electronics industry.

To cut SiC production costs, several research groups have investigated alternative methods for boule growth. A solution approach using a silicon-metal solvent can realise growth rates in excess of 2 mm/hour.

However, another alternative, high-temperature CVD, is preferable – it allows a continuous source supply and reduces metal contamination by employing high-purity source gases.

However, prior to the work of the Japanese partnership between CRIEPI, FUPET and Denso, the downside of high-temperature CVD was the growth rate, which was limited to below 1 mm/hr.

Higher growth rates are possible in the Japanese team's vertical CVD reactors that combine upward gas flow with a gas injector at the bottom and a hot zone surrounded by a graphite cylinder in the middle.

In the team's smaller reactor, a growth rate of 1.4 mm/hr for the 4H polytype of SiC was possible at 2200 °C, using a mixture of H_2, SiH_4, C_3H_8 and HCl, with the latter at a flow rate of 2 m/s. Removing the HCl enabled an increase in the growth rate to 2.1 mm/hr at a growth temperature of 2350 °C, while maintaining the low threading screw dislocation density of the seed.

Armed with this knowledge, the researchers scaled up growth, moving to a larger reactor and a 3-inch seed. In this chamber, growth rates in the centre of the seed could reach 1.3 mm/hr when using HCl and a temperature of 2230 °C, and 2.4 mm/hr without HCl at 2300 °C.

N. Hoshino *et. al.* Appl. Phys. Express **7** 052101 (2014)

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News Digest Contents

LEDs

Tyndall and CIT renew relationship

The Cork Institute of Technology and Tyndall National Institute research and industry collaboration is valued at almost €50 million to date. An important focus of the relationship is photonics

Tyndall National Institute and Cork Institute of Technology (CIT) have signed a new Memorandum of Understanding to renew and expand their existing partnership.

The partnership forms part of a broader collaboration between the two institutions which is valued at over €50 million to date. The new agreement will focus on delivering world-class research, providing highly skilled industry relevant graduates to the workforce and generating new businesses from innovative technologies.

Tyndall, UCC and CIT have had tremendous success in the last series of EU funding, reaching €75 million between them in over 260 research projects with an average success rate of 20 percent, and are actively pursuing the government's target of winning €1.2 billion in EU Horizon 2020.

Photonics, the study of the generation and manipulation of light, is an important focus of collaboration and research of CIT at Tyndall. The CIT research group CAPPA (Centre for Advanced Photonics and Process Analysis), based at Tyndall, undertakes work on a diverse number of applications across telecommunications, lighting, medicine, agriculture and robotics. An integral part of the SFI-funded Irish Photonic Integration Centre (IPIC) at Tyndall, CAPPA joins the 100 researchers from four institutes developing new light-enabled technologies.

CAPPA recently announced its participation in the pan-European NISTAS project. Working with Irish industry partners, Epilight Ltd and Open Innovation Partners, and six other European partners, the project aims to develop a new light based medical instrument for the non-invasive and rapid diagnosis of cardiovascular illnesses that is inexpensive and portable. By 2050, the population aged over 80 is expected to have increased by 170 percent, and cardiovascular diseases are by far the greatest cause of death (over 50 percent) in this age group.

Tyndall National Institute and CIT's NIMBUS Centre for Embedded Systems Research have worked on several national and international projects which have looked to improve energy efficiency and demand using technologies such as wireless sensor networks and embedded systems, energy harvesting, auto-commissioning and simulation models. These have taken advantage of the extensive test beds established in the city, including CIT's national test bed for micro-generation.

Seán Sherlock TD, Minister for Research & Innovation comments, "This partnership is another example of Irish academics and institutions excelling in the area of research and industry innovation. The work of the CIT and Tyndall partnership has shown what collaboration can achieve at a national and international level. The Government has targeted €1.25 billion in EU funding under the European Horizon 2020 programme and it will be programmes such as CIT@Tyndall that will play an important role in securing this funding to drive research and innovation both nationally and internationally."

Kieran Drain, CEO Tyndall National Institute says; "After fifteen years of collaboration which has enabled us to utilise the existing infrastructure of both institutions we are delighted to have renewed and expanded our partnership with CIT. The programme has proved very successful and collaborations with Centres such as CAPPA and NIMBUS have a proven track record of delivery since their inception. We are focused on delivering programmes that will drive maximum economic impact and accelerate the growth of new business. With 10 currently active projects worth over €5 million we are looking forward to building for the future."

Michael Murphy, President, University College Cork, adds; "The CIT@Tyndall programme has enjoyed great success and has gone from strength to strength since it was signed in 2008. We are the only two Irish academic institutions that offer a joint degree programme, and the existing Memorandum of Understanding has enabled CIT and UCC to collaborate closely on EU projects, clear indications of the synergies and close working relationships of both institutions."

Brendan Murphy, President, Cork Institute of Technology concludes, "The CIT, Tyndall collaboration and broader spirit of cooperation has been extremely important in furthering the research capabilities and industry partnerships of both CIT and UCC. It has enabled both institutions to build links and further enhance their international reputations as evidenced by the recent U-Multirank University rankings which positioned both in the top 10 percent."

Bridgelux expands V series of COB LEDs

The Chip on Board modules are available in variety of CCT and CRI options and are compatible with optics, drivers, and holders readily available from third party suppliers

Bridgelux is to introduce its new V10 and V15 LED array products at Light Fair International (LFI) 2014 in Las Vegas.

These devices further expand the company's V Series line of LED Chip on Board (COB) light sources. These products extend the technology and performance of Bridgelux's Vero line of LED arrays, featuring high flux density in small light source size packages.

The V10 and V15 products are particularly well suited for commercial and residential lighting markets requiring high quality and tight beam control.

Since the launch of the V Series product line in September 2013 the technology has seen big adoption,shipping millions of units in seven months on the market, in more than twenty countries, representing a quarterly growth rate of 52 percent.

In addition to providing high quality light with high flux density, the Bridgelux V10 and V15 LED light source products offer a compelling total cost of ownership advantage over incandescent, halogen, and fluorescent technologies with greater energy efficiencies and a projected lifetime of over twenty years. The V10 and V15 products produce up to 118 nominal lumens per watt (lm/W).

Typical applications for the V10 and V15 light sources include down lights, track and spot lighting, and landscape lighting with V15 being an ideal replacement for 35W ceramic metal halide luminaires. Nominal lumen outputs range from 1,000 to 3,000 lumens for V10 and V15 respectively.

"Bridgelux is laser focused on paying close attention customer needs and anticipating market requirements," says Brad Bullington, CEO of Bridgelux, "the V10 and V15 additions to the V Series product line demonstrate once again our responsiveness and commitment to expanding the growth of LED lighting across application segments."

The V10 and V15 COB modules are available in variety of CCT and CRI options and are compatible with optics, drivers, and holders readily available from third party suppliers.

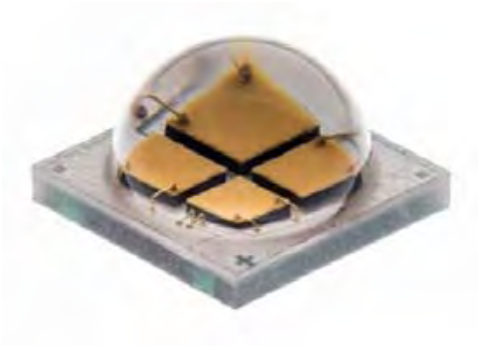
With more than 9,000 hours of LM80 test data and R9 values that exceed California Energy Commission requirements for luminaires and lamps, these new V Series arrays support Energy Star and other rebate programs. At the same time, they also include ANSI compliant 3-step binning, thereby reducing SKUs while bringing consistent high quality white-point light to this new segment.

Cree XLamp LED performance boosted 38 percent

This is purported to be the first LED of its size that enables colour-consistent 50-Watt halogen performance

Cree has launched the XLamp XM-L2 EasyWhite LED, delivering more than 1,100 lumens of colour-consistent light from a 5mm x 5mm package.

It enables a 38 percent gain in light output and efficacy as a drop-in upgrade to the first-generation XM-L EasyWhite LED.



XLamp XM-L2 EasyWhite LED

Built on Cree's EasyWhite technology, which combines tight colour binning and intense light output from a single LED, the XM-L2 EasyWhite LED is optimised to replace halogen technology.

"The new XLamp XM-L2 EasyWhite LED offers greater optical control and an immediate performance boost to our existing designs using the XM-L EasyWhite LED," explains Tom Tang, Chairman, Tons Lightology Inc. "Having a drop-in replacement eliminates the need to redesign existing products, which lowers costs and helps speed our time to market."

Developed to be used as a single component in small form factor lighting designs, the XM-L2 EasyWhite LED is designed to emulate the appearance and match the colour consistency of halogen lamps.

Cree sas this LED offers 2-step and 4-step MacAdam ellipse bins to deliver one of the industry's best colour consistencies, which is required for retail, residential, museum and hospitality applications.

"Cree continues to lead the way in optimising LEDs for optical performance and colour consistency," says Paul Thieken, director of marketing, LED Components, Cree, Inc. "We were the first to introduce an LED optimised for 50-watt halogen performance with the XLamp MT-G EasyWhite LED. Now with the XM-L2 EasyWhite LED, Cree delivers the same amount of light with the best colour consistency in a package that's 70 percent smaller, reducing the system cost for LEDs in halogen replacement applications."

Characterised at 85°C, the XM-L2 EasyWhite LED is available with 80 and 90 minimum CRI options, colour temperatures ranging from 5000K to 2700K and forward voltage configurations of 6V or 12V.

Lighting manufacturers seeking ENERGY STAR qualification can take advantage of the XM-L2 EasyWhite LED's "successor" status to the XM-L EasyWhite LED and use just 3,000 hours of LM-80 data - half of what is normally required - for ENERGY STAR qualification.

Product samples are available now and production quantities are available with standard lead times.

SPTS bestows Swansea Uni with £600k BluGlass shares

The semiconductor equipment maker is supporting the university's Department of Research and Innovation

SPTS Technologies UK has made a gift to research led Swansea University, of over £600,000 worth of shares in BluGlass Limited.

BluGlass is a green Australian public company established to commercialise innovative semiconductor technology. The company, which evolved out of Sydney's Macquarie University, has developed a novel semiconductor technology called remote plasma chemical vapour deposition (RPCVD), for the production of high efficiency devices such as LEDs and concentrated solar cells.

RPCVD has several potential advantages over current manufacturing techniques and through its low temperature deposition offers manufacturers higher performing devices and lower cost manufacturing. The company is currently developing GaN-on-silicon based LEDs.

BluGlass, last November, bought a Thomas Swan MOCVD reactor. The company is aiming to improve LED performance by growing low temperature RPCVD *p*-GaN on top of MOCVD grown multi-quantum wells. Growing the *p*-GaN layer at lower temperatures with RPCVD instead of MOCVD should reduce the InGaN MQW degradation, resulting in a brighter LED.

"SPTS has strong ties with Swansea University, and has benefited from the knowledge exchange projects through the University's Department of Research and Innovation (DRI)," states William Johnson, CEO at SPTS.

"The DRI which acts as the bridge between industry and academia has enabled us to extend the scope of our research beyond our existing markets and gain access to funding, which has proven invaluable to our R&D teams. This gift of shares in BluGlass is our way to pay back by 'paying it forward' to the University in not just the current value of the shares but the potential future value of BluGlass and the opportunities for potential collaboration between Swansea University, BluGlass and Sydney's Macquarie University."

Current collaboration with Swansea University includes a Technology Strategy Board (TSB) funded project for the development of micro-needles for bio-medical applications. The project which includes process equipment from SPTS for the University's clean room facility was instrumental in developing a design for manufacturing quality packaged micro-needles which are achieving a 100% success rate in initial testing.

"Swansea University are absolutely delighted by this gift and indeed with the highly successful and ongoing collaboration with SPTS and the University's College of Engineering, particularly the work being done with Dr Owen Guy, Associate Professor," comments Gerry Ronan, Head of IP at Swansea University. As a University we pride ourselves on our ability to collaborate with industry and this is an enlightened and most welcome way of strengthening such relationships."

Johnson added, "SPTS is at the forefront of micro-device process and manufacturing technology, and we remain committed to investing in R&D to ensure market competitiveness and industry sustainability. Our gift to Swansea University underpins our ongoing commitment to supporting the success of the Department of Research and Innovation, and we are proud to be able to support future generations of engineers and researchers at this world-class research-led institution."

BluGlass, which evolved out of Sydney's Macquarie University, has developed breakthrough semiconductor technology called remote plasma chemical vapour deposition (RPCVD), for the production of high efficiency devices such as light emitting diodes (LEDs) and concentrated solar cells. RPCVD has several potential advantages over current manufacturing techniques and through its low temperature deposition offers manufacturers higher performing devices and lower cost manufacturing.

AFMs take a tip from GaN nanowires

Using gallium nitride nanowire probes in a custom-built, four-probe instrument, could reveal new aspects of composition and performance in nanoelectronics materials and devices

A team of PML researchers has demonstrated that atomic force microscope (AFM) probe tips made from its "near-perfect" GaN nanowires are superior to standard silicon or platinum tips in the measurements of critical importance to microchip fabrication, nanobiotechnology, and other appliations.

What's more, the scientists have invented a means of simultaneously using the nanowire tips as LEDs to illuminate a tiny sample region with optical radiation while it is scanning. This, they say, adds an entirely new dimension to the characterisation of nanoelectronics materials and devices.

By itself, an AFM provides topographical information at nanometre resolution as its probe tip - in the range of 100 nm wide and suspended from a cantilever arm - scans across a sample surface. When the tip is used at the same time to continuously transmit and receive a microwave signal, the system becomes capable of revealing charge-carrier concentrations or defect locations in specific regions of nanoscale materials and devices.

That technique, called near-field scanning microwave microscopy (NSMM), it is claimed, had never before been attempted using a nanowire probe. But as the team showed in a recent paper in *Applied Physics Letters,* nanowire probe tips substantially outperformed commercial platinum tips in both resolution and durability.

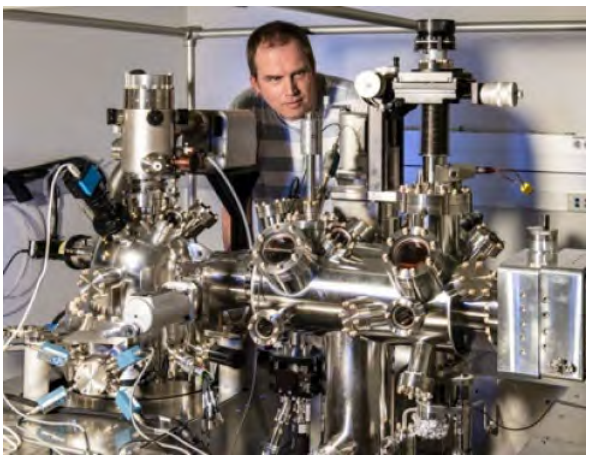
"A big issue for platinum probes," says Kris Bertness, Project Leader for Metrology and Synthesis of 3D Nanostructures in the Quantum Electronics and Photonics Division, "is that if you deform them even a little bit, and their shape changes, your calibration is lost. Because they're capacitively coupled to the sample, shape is everything."

"By contrast, our nanowire probe tips have a calibration lifetime about ten times longer than any commercial tip. We see no visible wear after performing tens of scans, whereas platinum deforms, losing resolution and calibration, after five to ten scans."

In a series of twelve scans, the platinum tip radius changed from ~ 50 nm to ~150 nm. The nanowire, however, retained its original dimensions. Moreover, the GaN tips exhibited improved sensitivity and reduced uncertainty compared to a commercial platinum tip.

NSMM can produce very detailed imaging of the local density of positive and negative charge carriers inside a nanostructure - information of great practical significance to microdevice fabricators - and scientists from PML's Electromagnetics Division have made notable progress in the technique.

They believe that the use of nanowire probes, in conjunction with the recent arrival of a brand-new, custom-built, four-probe NSMM instrument, will reveal new aspects of nanostructure composition and performance.

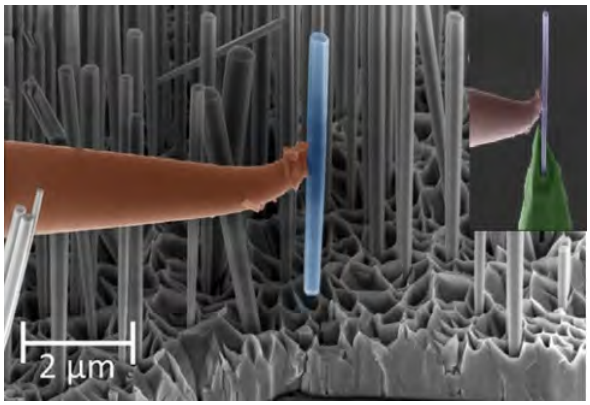


The new, four-probe NSMM instrument has four tips, permitting simultaneous comparisons of materials. The probes are enclosed in an ultra-high vacuum chamber to minimise interference and contamination

For example, in biological materials, it could locate the attachment of chemical agents or particles that are bound to a cell, and aid in the study of protein dynamics.

Deploying a nanowire as a probe tip sounds deceptively simple. The researchers obtain a conventional AFM cantilever and probe, remove the existing tip, and use a focused ion beam to drill a hole about 5 µm deep in the tip mount.

Then, using a minuscule manipulator, they break off a single nanowire from a "forest" of them grown by MBE, insert the wire into the hole, and weld it in place. Finally, the wire is coated with thin layers of 20nm thick titanium and 200nm thick aluminium in order to conduct the microwave signal all the way to the end of the tip and back.



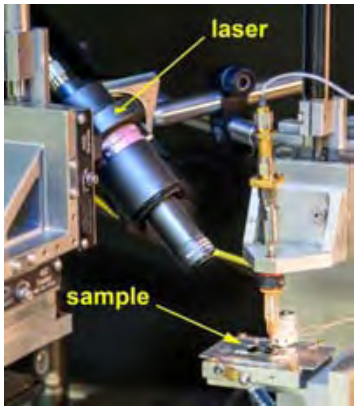
A single GaN nanowire is removed from a "forest" of wires grown by MBE. Inset: The nanowire is being placed into a hole drilled in an AFM probe. Both images are false-coloured for clarity

The researchers tested their tip against a silicon tip, a platinum tip, and an uncoated GaN nanowire, each of which was scanned across an array of microcapacitors of different sizes. The coated nanowire proved about twice as sensitive as the platinum probe, and four times as sensitive as the others, with superior mechanical performance.

"That can be extremely important for s the next generation of advanced electronic and optoelectronic devices," Bertness says. At present only a few GaN probes can be made at once, but the team is at work on developing ideas for producing them in wafer-scale quantities.

At the same time, the researchers are preparing to test a new technology for which they were awarded a patent in July, 2013. This regards using the nanowire tip as a light source by doping it so that it functions as an LED. Optical radiation can serve to excite the sample in a different way from the microwave signal, and scientists are already using lasers to illuminate nanoscale samples during AFM scans.

"The problem with that approach," says NSMM researcher Pavel Kabos of the Advanced High-Frequency Devices Program in PML's Electromagnetics Division, "is that the laser has to shine in from the side. As a result, you get cast shadows and significant uncertainty as to exactly what area is being illuminated. And, of course, the laser and its mounting take up a great deal of space.



Illuminating an NSMM sample with a conventional laser brings

light in at an angle and greatly increases the space occupied by apparatus

"With the new design, the illumination will be applied directly over the probe tip at the same place on the sample that is being exposed to the microwave signal. That could be particularly beneficial in characterising photovoltaic materials where you could apply a light and get the carrier concentration at the same time. The whole unit can be much smaller, and the nanoscale light source enables you to inject some carriers very locally, in a way you can't do with other methods."

In order to research the next generation of photovoltaic materials, Bertness says, "We've been using flood illumination. But what we want to see is how individual grains respond to light. The LED technique can make that possible. In biological applications, we expect it to provide an order of magnitude improvement in the ability to investigate processes such as protein dynamics."

Reaching that goal will require more research into how to dope the GaN nanowires so as to increase efficiency of light output, and how to coordinate and integrate measurements from topographic, microwave, and optical modalities.

But Bertness is optimistic. He says, "It took ten years of hard work learning how to fabricate and characterise these materials, and we developed a lot of important metrology techniques along the way. But we really weren't able to test nanowires as probe tips until a few months ago when the Boulder lab's Precision Imaging Facility gained a focused ion beam. These initial results give us confidence that this technology will impact a broad range of science and technology problems where knowing the properties of materials on the micrometer and nanometre scale is crucial, from semiconductor electronics to biochemistry and medicine."

The International Technology Roadmap for Semiconductors (ITRS), a periodic assessment of the semiconductor industry's future technology requirements, has repeatedly called for progress in this area.

The 2011 ITRS believes, "There is a need for characterising the structure and local properties of current CMOS devices as they scale down… Recent developments in Scanning Probe Microscopy involving frequency-dependent signals on the sample and tip, and simultaneous perturbation with more than one frequency and/or probe expand the range and resolution of the measurements."

The 2013 edition comments, "Commercial vendors have developed a large toolbox of specialized SPM cantilevers and tips. Reproducibility is often an issue; in some cases yields of good tips are on the order of 30%. More important is the gap between commercially available cantilevers/tips and those required for tool development. … The lack of calibration standards for nm sized physical structures is a significant problem."

Osram Duris S 5-LEDs have a CRI over 90

The two new III-nitride based LEDs are suited for general illumination and solid state lighting

Osram Opto Semiconductors has added two further models with excellent colour rendering to the Duris S 5 family. The new LEDs are ideal for the home, for example installed in downlights or LED retrofit lamps.

Osram Duris S 5 LED

"The Duris portfolio has been expanded with the addition of two new LEDs with an impressive CRI of more than 90. This product family now offers customers even greater flexibility in terms of performance, areas of application and technology than ever before," says Janick Ihringer, Product Manager for General Illumination at Osram Opto Semiconductors.

The previous Duris S 5 versions already had a high colour rendering index of more than 80, but the additions are even better in this respect.

The new LEDs are ideal particularly for applications where the colours have to appear as natural as possible. Their main use will therefore be in the home. The light from the new Duris S 5 models make the colours of wooden dining tables and flooring for example look rich and natural. Natural colour rendering also plays an important role in shop lighting, whether for clothing or food.

The new Duris S 5 also offers impressive output. The two-chip version has a high luminous flux value of 83 lm at 150 mA (typically at 3000 K). Its typical forward voltage is 6.35 V.

The E, P and S Duris series contain LED versions in different qualities of light and for all output ranges (high-power, mid-power, and low-power) which are suitable for numerous lighting applications.

A robust plastic package, a compact design and a particularly homogeneous distribution of light are other properties common to all members of the family. All the products in the Duris S range also have an impressive price performance ratio, coupled with enormous versatility and efficiency.

With two chips, the 3.2 mm x 3.0 mm GW PSLPS1.CC has a luminous flux of 83 lm at 150 mA at typically 3000 K and 6.35 V and a minimum CRI of 90

The single chip GW PSLMS1.CC also comes in a 3.2 mm x 3.0 mm package. It has a luminous flux of 20.5 lm at 65 mA at typically 3000 K and 2.9 V and a minimum CRI of 90.

Seoul Semi launches warm and cool LEDs

The compact III-nitride based Acrich LEDs result in designs where fewer LEDs are used, leading to smaller and lighter fixtures

Seoul Semiconductor has announced the release of a new generation of Acrich MJT 5050 LEDs, with high lumen output, reliability, and cost performance optimised for the outdoor lighting market.

This new Acrich series has dimensions of 5.0mm x 5.0mm delivering a typical luminous flux of 180 lumens at 20mA, 64V, 25° C, 5000K and can be driven to a maximum current of 60mA delivering up to 440lm.

Seoul Semi says the new Acrich series delivers a combination of high lumen output, efficacy, outstanding reliability and lm/$ all in one package.

This package results in designs where fewer LEDs are used, which leads to smaller and lighter fixtures enabling cost savings on a system level. This Acrich series delivers high performance without sacrificing on reliability or cost. It is an ideal LED for the outdoor lighting market where high efficacy and lifetime are critical.

Utilising Seoul Semiconductor's high voltage architecture, Acrich MJT "Multi-Junction chip Technology," the Acrich LED eliminates the trade-off between size and efficacy. Designers can take advantage of the high efficiency of high-voltage DC drivers or eliminate the driver by driving the LEDs directly of AC using the Acrich IC.

The SAW8LH0A (Warm) LED works at a typical temperature of 3000K. At 20mA, the LED has a typical luminous flux of 155 lm, an efficiency of 121 lm/W, and a minimum CRI of 80 with a typical forward voltage of 64V.

The SAW0LH0A (Cool) LED works at a typical temperature of 5000K. At 20mA, the LED has a typical luminous flux of 180 lm, an efficiency of 141 lm/W, and a minimum CRI of 70 with a typical forward voltage of 64V.

SAW8LH0A LED (Warm) SAW0LH0A LED (Cool)

Seoul Semiconductor Executive Vice President of Lighting sales division, Jay Kim has says, «In addition to high efficacy and reliability the TCO (Total Cost of Ownership) is an important metric for the street and area lighting market. This product will enable the market to come up with the next generation of high quality, efficient and competitively priced LED lamps.»

He adds, "The payback period especially for streetlights can be significantly reduced with new Acrich LED without compromising on reliability or efficiency. In the future, Seoul Semiconductor will introduce more products to penetrate the outdoor area lighting market."

Plessey buys another reactor for GaN-on-silicon LEDs

This is the second 7 x 6" Aixtron reactor delivered to Plessey

Plessey Semiconductors has purchased another CRIUS II-XL MOCVD system for use in the manufacture of GaN LEDs on silicon wafers.

The company is further expanding its production capacities in this area. The Close Coupled Showerhead system recently delivered with a 7 x 6 inch configuration will supplement an existing production system from Aixtron.

Keith Strickland, Chief Technology Officer for Plessey says, "Our MaGIC (Manufactured on GaN-on-Si I/C) LED product in particular has been successfully launched this past year. As a result, we now plan to step up our production. To this end, and given our positive experience with Aixtron's CRIUS II-XL system, we have purchased a further system of this type and are thus maintaining our successful cooperation with Aixtron."

CRIUS II-XL reactor

"CRIUS II-XL convinced us with its high throughput rates and low operating costs for GaN layer growth on 6 inch silicon substrates. Moreover, Aixtron is actively supporting us in further optimising our production processes," adds Mike Snaith, Operations Director for Plessey.

"We are delighted by the renewed order from Plessey," comments Frank Schulte, Vice President Aixtron Europe. "It offers further confirmation that GaN-on-silicon, a high-performance, efficient epitaxy process, is becoming increasingly established as an alternative to growth on sapphire. The associated potential production cost savings will further promote the establishment of LED as a light source. Aixtron is well prepared for this market development and will also be supporting Plessey in further optimising its GaN-on-silicon technology."

Plessey Semiconductors is a developer and manufacturer of semiconductor products used in lighting, sensing, measurement and control applications. Plessey's products are found in a wide range of markets, including communications, medical technology, aerospace and space travel, as well as in the defence and automotive industry.

Emcore settles Nichia LED patent lawsuit

Due to Emcore licensing Everlight some of it patents, the suit, is principally a dispute between Everlight and Nichia

Emcore has settled the patent infringement case brought by Nichia before the U.S. District Court for the Eastern District of Texas.

In November 2011, Emcore exclusively licensed several of its non-core LED patents to Taiwanese company Everlight Electronics.

In April 2012, Everlight filed suit against Nichia Corporation alleging infringement of Emcore's U.S. Pat No. 6,653,215 ('215) it licensed.

Because Emcore still owned the '215 patent, the complaint named Emcore as a mandatory co-plaintiff. The suit, however, is principally a dispute between Everlight and Nichia. Following a petition initiated by Nichia, on February 11th, 2014, the U.S. Patent and Trademark Office issued a Final Written Decision in which it found all claims of the '215 Patent to be unpatentable. In March 2014, Nichia and Everlight agreed to dismiss the claims pertaining to the Emcore '215 patent from the lawsuit without prejudice.

In June 2013, Nichia filed a complaint against Emcore before the U.S. District Court for the Eastern District of Texas alleging infringement of Nichia's U.S. Pat No. 7,295,587 ('587) entitled "Semiconductor Laser Having Optical Guide Layer Doped for Decreasing Resistance."

The current settlement agreement resolves the Eastern District of Texas lawsuit regarding the '587 patent. Under the settlement, Emcore acknowledges the validity of the '587 patent, and makes a payment of damages to Nichia and Nichia agrees to grant Emcore a non-exclusive, royalty-bearing license to the asserted patent. The details of the settlement agreement are confidential.

"We greatly respect Nichia's intellectual property and feel this settlement and license agreement is proof of that," said Alfredo Gomez, Emcore's General Counsel.

GTAT to produce large capacity sapphire furnaces

The new ASF165 furnace offers a 40 percent increase in boule Size compared to its current ASF115

GT Advanced Technologies (GTAT) will be making its next generation ASF165 sapphire growth furnace, for the production of high volume and high quality sapphire material, commercially available in Q3 2014.

Sapphire substrates are extensively used in the production of LED chips.

The new system will deliver a 40 percent increase in boule size when compared to the ASF115, extending GT's capability of producing low cost high quality sapphire production tools.

The ASF165 is expected to be the only commercially available sapphire production furnace capable of producing high quality 165 kilogram boules in high volume.

The product is currently in the beta testing stage and is expected to be ready for volume shipments beginning in Q3 2014. Customers with installed ASF units, or those who opt to take delivery of new ASFs out of backlog prior to the general availability of the ASF165, will be able to upgrade to the larger capacity system when they become available. ASF165 units will also be available to new customers targeting the LED and industrial markets.

"The ASF165 gives customers a competitive advantage and lower cost of ownership by providing a sapphire furnace that significantly increases capacity and reduces cost," says Tom Gutierrez, GT's president and CEO. "Several industry analysts are forecasting an increase in demand for sapphire material and we believe that ASF customers who take advantage of the larger capacity ASF165 will be well positioned to serve this anticipated demand."

The company indicated that it has developed more advanced ASF technology capable of producing boules significantly greater than 165 kg. The company intends to keep this more advanced ASF system captive for some extended period of time.

Soraa wins Red Dot Design Award again

The firm's GaN on GaN based SNAP System LED lamp/ accessory solution has won an award following the firm's win for its VIVID MR16 LED lamp last year

reddot award 2014
winner

Soraa, a specialist in GaN on GaN LED technology, has announced its SNAP System has received the Red Dot Award: Product Design 2014.

The forty person jury featured renowned specialists tasked with selecting products that excel in design innovation, functionality and ecological compatibility.

The Soraa SNAP System is a set of innovative, easy-to-use magnetic lamp attachments which allow the user to flexibly adjust the colour, shape, and (in the near future) direction of the beam.

Soraa SNAP System

Due to their bright, point source GaN on GaN LED and prismatic optic, Soraa's lamps can accept a magnet in the centre of the lens without major impact on light output or efficiency, enabling a simple attachment mechanism.

With the SNAP System, light can be customised directly on lamps at the application site, opening up a new and exciting world of design possibilities for lighting.

"Accessories are an important tool in lighting designers' palettes as they allow designers to configure and fine-tune lighting scenes with dedicated light distributions, colours, and directions," said George Stringer, Senior VP of North American Sales at Soraa.

"Designers love the SNAP System, because it provides them with endless possibilities and enormous flexibility to change beam characteristics without having to change the light source. It's a real honour that the Red Dot judges chose to recognise its innovative design."

The annual Red Dot Award: Product Design is one of the world's largest design competitions. In 2014, the Red Dot jury received 4,815 entries from fifty-three countries, but only the best 1,120 received an award. This year only seventeen LED lamp products received an award.

This is the second year in a row that Soraa has won a Red Dot Award. Last year, the company received the award for its VIVID MR16 LED lamp.

Cree increases its Stock Repurchase Program

The aggregate purchase price has been increased to $300 million

On May 6th, 2014, the board of directors of Cree, Inc. approved an increase in the amount of the company's stock repurchase program.

Pursuant to the program, the company is now authorised to repurchase shares of its common stock having an aggregate purchase price not exceeding $300 million for all purchases from June 20th, 2013 through the new expiration of the program on June 28th, 2015.

The company recently repurchased 2.1 million shares of its common stock under the program at an average price of $47.11 per share with an aggregate value of $99.6 million. After this repurchase, there is $200.4 million in aggregate purchase price value remaining in the company's stock repurchase program through June 28th, 2015.

The repurchase program can be implemented through open market or privately negotiated transactions at the discretion of the company's management. Cree will continue to determine the time and extent of any repurchases based on its evaluation of market conditions and other factors.

In addition, the board of directors of Cree, Inc. authorised the company securing an up to $150 million working capital line of credit facility. The working capital line of credit will provide the company short term flexibility to optimise its net investment return on its cash and investments while funding its general business needs.

LED technology advancements slash fixture costs

As commercial & industrial LED lighting becomes mainstream, Precision-Paragon customers can take advantage of significantly lower costs

Lighting manufacturer Precision-Paragon [P2] has announced that in the past three years, the cost difference between LED and fluorescent lighting has shrunk dramatically, thanks to substantial reductions in the cost of LED technology.

"We've seen the installation costs for LED lighting cut by more than 60 percent since 2010," says Joe Martin, [P2]'s vice president and general manager. "This drop has made the energy savings of a LED lighting retrofit attainable for many businesses."

In 2010, the average cost per lumen of a commercial or industrial LED fixture was approximately 12 cents per lumen. Today, that cost has dropped to approximately 5 cents per lumen installed. While comparable fluorescent fixtures might cost 3 cents per lumen, the optical efficiency of LED lighting allows us to achieve the same lighting results with fewer lumens.

The cost reduction in LED lighting has been driven by several factors. "There are three primary sources behind the cost of a commercial or industrial LED fixture," explains Martin. "The cost of the LED light engine itself, the cost of the mechanical heat sink and fixture body, and the cost of the LED driver. By taking advantage of reductions in all three cost-sources, we're now able to offer LED lighting at significantly lower costs."

As the market for LED lighting expanded dramatically over the past few years, economies of scale helped the costs of both LED light engines and drivers to come down. At the same time, new developments in LED technology made the light engines more efficient than ever.

The increased efficiency of a LED light engine not only increases the lumen output per watt of electricity; it also reduces the amount of heat produced by the fixture. This in turn allows for fixtures to be designed with smaller, less expensive mechanical heat sinks.

When they were originally introduced to the market, the high initial cost for LED fixtures meant that they were limited to specialty applications where the characteristics of LED lighting provided a notable advantage. Today, with the cost of LED lighting reduced significantly, the technology has become a viable option for many energy-efficient lighting retrofits.

"LED lighting still generally has a slightly higher initial cost than fluorescent lighting," says Martin. "But to pick the right technology, you have to evaluate more than just the initial costs."

Over the course of a fixture's lifespan, LED lighting can often provide maintenance cost savings by requiring fewer relamp cycles than fluorescent systems. Also, some energy efficiency rebates can be tied to a specific technology, providing an incentive for business owners to pick one technology over another.

"Just a few years ago, LED lighting was a new technology with narrow applications," notes Martin. "Today it's something our customers consider in nearly every energy-efficient lighting retrofit they perform."

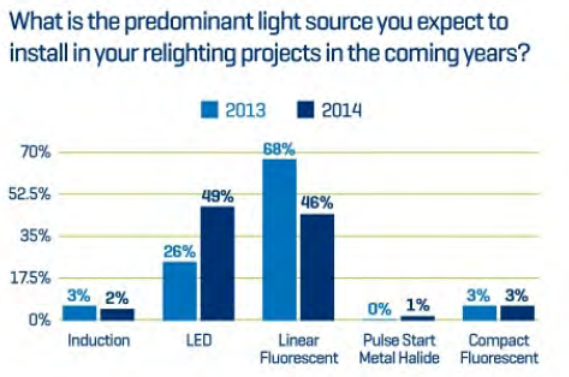
Fixtures: LEDs to overtake fluorescents for the first time

Precision-Paragon survey shows lighting professionals expect LED fixtures should increase from 26 percent in 2013 to 49 percent in 2014

For the first time, lighting professionals expect to install more LED than fluorescent fixtures over the coming year, according to energy-efficient lighting manufacturer Precision-Paragon [P2].

This is estimated in [P2]'s recently released 4th Annual Lighting Survey.

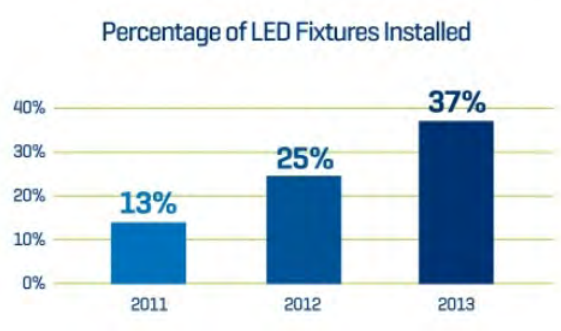
When asked what is the dominant lighting technology they expect to install in 2014, 49 percent of respondents selected LED, and 46 percent indicated fluorescent. In last year's survey, 26 percent of respondents selected LED, and 68 percent indicated fluorescent, as the dominant lighting technology they expected to install in 2013.



Conducted annually since 2010, this year's survey was distributed in December to over 5,000 energy-efficient lighting industry professionals. The survey's topics covered the industry's performance in the past year, as well as expectations for 2014.

"Our industry has seen steady growth in LED lighting performance and sales in recent years," says Joe Martin, [P2] vice president and general manager. "Picking the right technology is an important part of any lighting retrofit, and LED technology has advanced to the point that it can compete with fluorescent lighting in many applications."

Survey respondents indicated that in 2013, LEDs accounted for 37 percent of the fixtures they installed. That's up from 27 percent in 2012, and 13 percent in 2011.



The lighting manufacturer has developed a number of innovative products to keep pace with the increased demand for LED lighting, like the newly released TKD fluorescent-to-LED retrofit kit.

Overall, the survey respondents reported a positive outlook for the energy-efficient lighting industry. Sixty-four percent indicated that they had experienced either modest or substantial growth in 2013, and 82 percent expect the overall energy-efficient lighting industry to experience growth in 2014.

“Our respondents have reported growth every year since we started conducting our annual lighting survey,” concludes Martin. “Our customers are out there saving businesses money, and improving their lighting. It’s no surprise that they’re experiencing continued growth.”

Osram’s compact LEDs make it easier to implement design ideas

The low-profile compact mid-power III-nitride based LEDs are suited for injecting light into light guides

The low-profile rectangular shape of the new Synios E4014 from Osram Opto Semiconductors enables the light from this LED to be injected into light guides.

This means that a wide range of design ideas can be turned into reality.

Osram says these mid-power LEDs also have an impressively robust plastic package, a particularly uniform distribution of light and an excellent price performance ratio.

Low-profile shape to meet tough design demands: the new Synios E4014

The LEDs are intended primarily for visually enhancing white goods and for lighting systems in vehicles and displays.

The low height of the Synios of 0.57 mm and its footprint of 4 mm x 1.4 mm provide a basis for low-profile elongated luminaire and lighting designs - such as ones for backlighting displays. As the LEDs are not equipped with a lens, they can easily be used for injecting light into light guides.

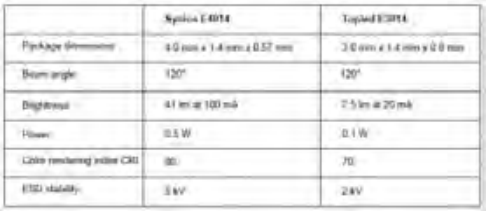
The new E4014 opens up a whole range of design-oriented lighting solutions, such as integration in the glass shelving in refrigerators and other white goods, car interior lighting, and strip lighting on the floors of buses and trains.

The Synios E4014 can be used in refrigerators

“Refrigerators and washing machines are not exactly renowned for their exciting designs. The new Synios is ideal for enhancing their looks and even meeting high requirements in terms of lighting design. For similar lighting tasks, but at a lower performance level, we already have the Topled E3014 in our portfolio,” says Volker Mertens, Marketing LED at Osram Opto Semiconductors.

Where each of the two LEDs is used depends on the requirements of the particular application. If brightness and colour fidelity are needed then Synios at 41 lm and a colour rendering index (CRI) of 80 is the right choice. If brightness is not as important then the Topled with 7.3 lm at 20 mA is ideal.

The colour temperatures of Synios are between 4000 and 5000 K and can therefore be tailored to the particular application. The robust plastic package is one of the benefits of the new Synios in addition to the extremely uniform distribution of light, high efficiency, excellent flexibility and long life of around 50,000 hours. In view of the intended applications, the ESD stability is 5 kV.



Looking at 2D molybdenum disulphide in a new way

Researchers have observed the 1D edge states vital to nanoelectronic and photonic applications

The drive to develop ultra-small and ultrafast electronic devices using a single atomic layer of semiconductors, such as transition metal dichalcogenides, has received a significant boost.

Researchers at the U.S. Department of Energy (DOE)'s Lawrence Berkeley National Laboratory (Berkeley Lab) have recorded the first observations of a strong nonlinear optical resonance along the edges of a single layer of molybdenum disulphide.

The existence of these edge states is key to the use of molybdenum disulphide in nanoelectronics, as well as a catalyst for the hydrogen evolution reaction in fuel cells, desulphurisation and other chemical reactions.

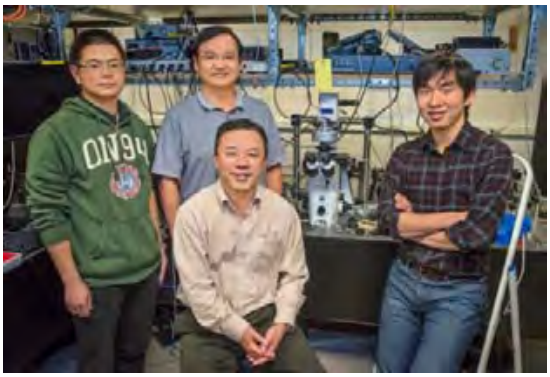
"We observed strong nonlinear optical resonances at the edges of a two-dimensional crystal of molybdenum disulphide" says Xiang Zhang, a faculty scientist with Berkeley Lab's Materials Sciences Division who led this study. "These one-dimensional edge states are the result of electronic structure changes and may enable novel nanoelectronics and photonic devices. These edges have also long been suspected to be the active sites for the electrocatalytic hydrogen evolution reaction in energy applications. We also discovered extraordinary second harmonic light generation properties that may be used for the *in situ* monitoring of electronic changes and chemical reactions that occur at the one-dimensional atomic edges."

Zhang, who also holds the Ernest S. Kuh Endowed Chair Professor at the University of California (UC) Berkeley and directs the National Science Foundation's Nano-scale Science and Engineering Centre, is the corresponding author of a paper in *Science* describing this research.

Emerging two-dimensional semiconductors are prized in the electronics industry for their superior energy efficiency and capacity to carry much higher current densities than silicon. Only a single molecule thick, they are well-suited for integrated optoelectronic devices.

Until recently, graphene has been the unchallenged superstar of 2D materials, but today there is considerable attention focused on 2D semiconducting crystals that consist of a single layer of transition metal atoms, such as molybdenum, tungsten or niobium, sandwiched between two layers of chalcogen atoms, such as sulphur or selenium.

Featuring the same flat hexagonal "honeycombed" structure as graphene and many of the same electrical advantages, these transition metal dichalcogenides, unlike graphene, have direct energy bandgaps. This facilitates their application in transistors and other electronic devices, particularly LEDs.

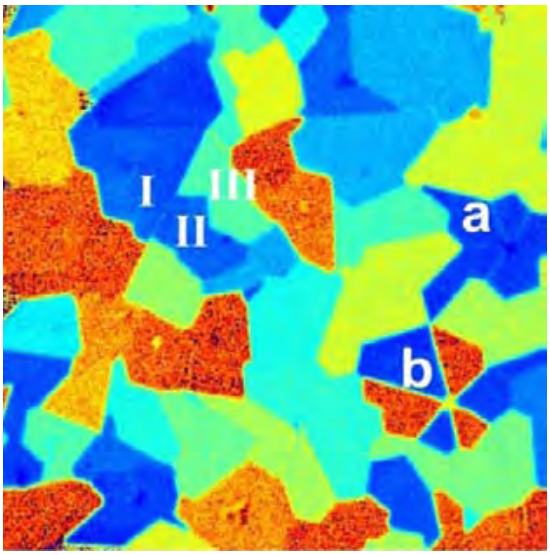


(From left) Yu Ye, Xiaobo Yin, Xiang Zhang and Ziliang Ye used second-harmonic generation imaging to discover strong nonlinear optical resonance along the edges of single layers of molybdenum disulphide. (Photo by Roy Kaltschmidt)

Full realisation of the vast potential of transition metal dichalcogenides will only come with a better understanding of the domain orientations of their crystal structures that give rise to their exceptional properties.

Until now, however, experimental imaging of these three-atom-thick structures and their edges have been limited to scanning tunnelling microscopy and transmission electron microscopy, technologies that are often difficult to use.

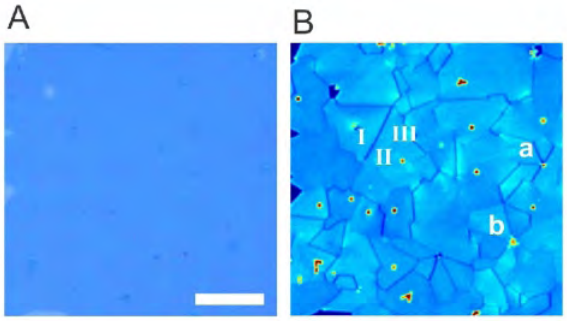
Nonlinear optics at the crystal edges and boundaries enabled Zhang and his collaborators to develop a new imaging technique based on second-harmonic generation (SHG) light emissions that can easily capture the crystal structures and grain orientations with an optical microscope.



A new SHG imaging technique allows rapid and all-optical determination of the crystal orientations of 2D semiconductor membranes at a large scale, providing the knowledge needed to use these materials in nanoelectronic devices

"Our nonlinear optical imaging technique is a non-invasive, fast, easy metrologic approach to the study of 2D atomic materials," says Xiaobo Yin, the lead author of the *Science* paper and a former member of Zhang's research group who is now on the faculty at the University of Colorado, Boulder.

"We don't need to prepare the sample on any special substrate or vacuum environment, and the measurement won't perturb the sample during the imaging process. This advantage allows for in-situ measurements under many practical conditions. Furthermore, our imaging technique is an ultrafast measurement that can provide critical dynamic information, and its instrumentation is far less complicated and less expensive compared with scanning tunnelling microscopy and transmission electron microscopy."



(A) Optical image of a large area of monolayer MoS2 and (B) an SHG image of the same area revealing grains and grain boundaries where translational symmetry is broken to form 1D edge states

For the SHG imaging of molybdenum disulphide, Zhang and his collaborators illuminated sample membranes that are only three atoms thick with ultrafast pulses of infrared light.

The nonlinear optical properties of the samples yielded a strong SHG response in the form of visible light that is both tuneable and coherent. The resulting SHG-generated images enabled the researchers to detect "structural discontinuities" or edges along the 2D crystals only a few atoms wide where the translational symmetry of the crystal was broken.

"By analysing the polarised components of the SHG signals, we were able to map the crystal orientation of the molybdenum disulphide atomic membrane," says Ziliang Ye, the co-lead author of the paper and current member of Zhang's research group. "This allowed us to capture a complete map of the crystal grain structures, colour-coded according to crystal orientation. We now have a real-time, non-invasive tool that allows us explore the structural, optical, and electronic properties of 2D atomic layers of transition metal dichalcogenides over a large area."

This work is described in detail in the paper, "Edge Nonlinear Optics on a MoS2 Atomic Monolayer," by Xiaobo Yin *et al* in *Science*, Vol. 344 no. 6183 pp. 488-490, (2 May 2014). DOI: 10.1126/science.1250564

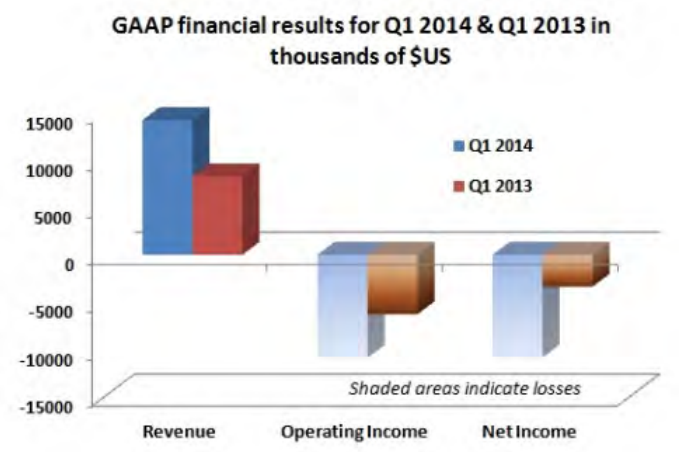
This research was supported by the DOE Office of Science through the Energy Frontier Research Centre program, and by the U.S. Air Force Office of Scientific Research Multidisciplinary University Research Initiative.

Rubicon revenues boosted but losses increase

Idle plant and development costs at the firm's wafering facilities were the main cause of its negative margins

Rubicon Technology, Inc,. a provider of sapphire substrates and products to the LED, semiconductor, and optical industries, has reported financial results for its first quarter ended March 31st, 2014.

The company reported first quarter revenue of $14.3 million as compared with $11.5 million in the prior quarter.



The general lighting segment of the LED market continued to strengthen in the first quarter as adoption of this disruptive technology continues to gain momentum.

Overall LED growth in the quarter was tempered by seasonality associated with the backlighting market. Demand from this market is typically lower at the beginning of the year. As a result, overall demand in the first quarter was similar to the prior quarter and sapphire pricing, therefore, remained fairly consistent with the previous quarter.

Rubicon reported progress in growing the wafer side of its business. It received its first production order for its recently introduced patterned sapphire substrates which will be delivered in the second quarter. The firm also received its first production order of four-inch polished wafers which started in the latter part of the first quarter.

Raja Parvez, President and CEO of Rubicon, commented, "Patterned sapphire substrates (PSS) and polished wafers are an important part of our strategy and I am pleased with the sales progress we made in the quarter."

However, costs in the wafering operations were high in the quarter resulting in an increase in pre-tax loss from $9.1 million in the fourth quarter to $10.9 million in the first quarter.

Wafer costs were higher than normal due to the large number of PSS samples produced and the cost of establishing a four-inch polishing line

Furthermore, due to the increased number of wafers in

inventory at the end of the period and wafer costs exceeding market price, there was a $1.1 million adjustment to align wafer inventory to market value.

William Weissman, Rubicon's CFO, commented, "Idle plant and development costs at our wafering facility are the main cause of our negative margins. However, utilisation will be improving with the recent sales activity and we expect wafer costs to come down over the course of this year as we move from development to production."

The company's net loss in the first quarter was $0.43 per share. Rubicon established a tax valuation allowance in the fourth quarter and consequently does not currently record a tax benefit on its Statements of Operations.

Second Quarter 2014 Guidance

Commenting on the outlook for the second quarter of 2014, Parvez said, "We expect the LED market to continue to strengthen in the second quarter resulting in some pricing improvement, particularly for four-inch material."

He continued, "Core sales volumes in the second quarter will decline somewhat as we have exhausted our excess boule inventory. We also believe we will see meaningfully higher wafer revenue in the second quarter which will improve utilisation but, in the near-term, will not improve margins. With reduced core revenue offsetting increased wafer revenue, we expect total revenue in the second quarter to be similar to the first quarter. We expect our loss per share in the second quarter to be between $0.38 and $0.46, based on a share count of 26.1 million shares."

Parvez also commented, "We are building momentum in the wafer business and with increasing volume and experience, and as customer specifications are defined, we will reduce our idle plant costs and our wafer product cost. The higher wafer sales mix will allow us to generate significant growth without adding crystal growth capacity and improve margins as our utilization and efficiency increase."

Conference Call Details

Rubicon hosted a conference call to review the first quarter 2014 results and the second quarter 2014 outlook. The conference call is available to the public through a live audio web broadcast via the Internet via the Investor Relations section of Rubicon's website at http://ir.rubicontechnology.com.

Yole: Substrates influencing LED front-end industry

Large sapphire substrates are still in the reckoning and may dominate marketshare over GaN and GaN-on-silicon substrates

There are a number of factors affecting the LED market . According to Yole Développemen, the main one is substrates.

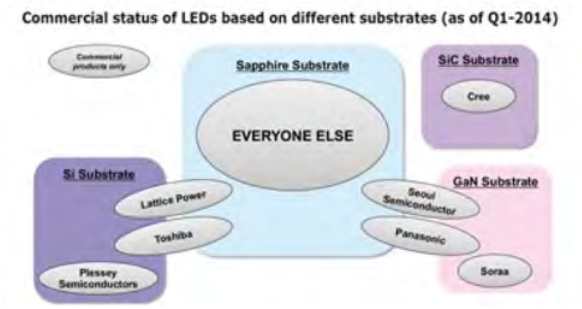
Increased demand for larger size sapphire wafers with big players, such as LG, Sharp and Osram are moving to 6" wafers and Taiwanese players are moving to 4" wafers.

Also, increased demand for PSS (patterned sapphire substrates) that has now become mainstream in the industry (87 percent share as of Q1-2014), even if some questions remain concerning key patent holders' strategies.

What's more, the penetration of these alternative substrates will be secondary to future improvements in terms of performance and cost. Otherwise, GaN-on-silicon and GaN-on-GaN LEDs will not be able to fully compete with sapphire-based LEDs.

The impact of the sapphire industry on the LED industry is likely to become bigger in the future because of the recent partnership between GTAT and Apple (Q4-2013) to set up a large sapphire manufacturing plant ($1 billion).

The plant, having a rough capacity of double the current qualified sapphire capacity, could totally modify the structure and evolution of the sapphire and LED industries in the next few years.



INCREASED COMPETITION WILL ACCELERATE NEW LED MOCVD REACTOR DEVELOPMENT

LED epitaxy has also been of central interest to the LED Front-End industry that has seen the entry of several new players in the MOCVD reactor market since 2011 / 2012.

Even if increased competition has not really affected the market's top leaders (Aixtron, Veeco and Taiyo Nippon Sanso), it has forced them to accelerate development of the next generation of MOCVD tools to lever market entry barriers.

This generation of MOCVD reactors should focus on Cost of Ownership, with the emergence of enhanced designs, including new heating systems, new gas-flow designs, and increased automation.

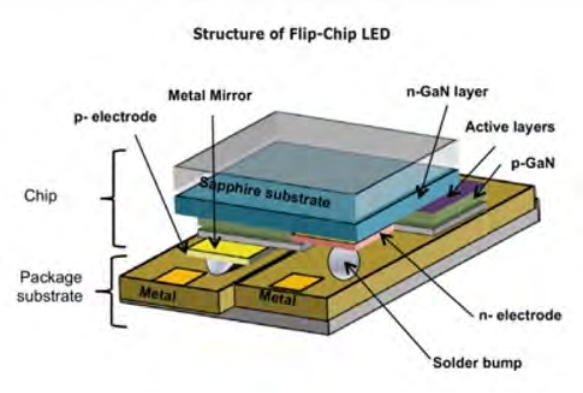
Regarding lithography, plasma etching and deposition, PVD and testing, mostly incremental evolutions have occurred, such as improvement of throughput, and ASP decrease, reflecting a saturation in technological development.

FLIP-CHIP TECHNOLOGY AS THE NEW BATTLEGROUND

As flip chip gradually matures, LED manufacturers are actively developing this technology as it provides several advantages: larger light-emitting area and highest luminosity, better heat dissipation, adjustable dimensions and no wire-bonding.

While this design was mostly in the hands of a few big LED manufacturers (such as Cree or Lumileds), in 2013, Taiwanese manufacturers also started to develop it (Epistar, FOREPI and Genesis Photonics mostly).

In 2014, flip-chip technology should also make its way into the middle e LED market. Lumileds announced in Q3-2013 that it plans to introduce flip-chip technology into the middle power LED market; as the devices in this market have drawn the most attention from the 2013 general lighting applications market. Indeed, middle power LEDs (following the 2011 / 2012 overcapacity) have become mainstream in interior lighting applications.



FROM TECHNOLOGY-ORIENTED TO COST-ORIENTED MANUFACTURING

LED manufacturing still uses methods and practices that would be considered outdated in most semiconductor industries (e.g., manual wafer handling, with operators moving wafers with tweezers in (not so) clean rooms…). However, emergence of LED "giants" (such as Cree, Osram, Lumileds, Samsung or LG) have facilitated and speed up adoption of manufacturing paradigms from the IC industry to reduce overall manufacturing cost and increase product quality:

Yole believes the gap will widen between Tier-1s and other players, pushing forward for industry consolidation.

QuantumClean achieves single ISO 9001:2008 certification

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

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

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

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

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

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

Lumileds rates Mouser top of the sales

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

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

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

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

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

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

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

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

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

Telecoms

Hittite and Xilinx to demonstrate SiGe based radio Solutions

The complete 60GHz small cell backhaul demonstration will utiliseHittite's 60GHz silicon germanium transceiver chip set

Hittite Microwave Corporation and Xilinx are to demonstrate complete radio solutions for 60 GHz millimetre wave small cell backhaul and 1024QAM microwave radio cellular backhaul at MTT-S. Tampa, June 3rd to 5th, 2014.

The Complete 60GHz Small Cell Backhaul Demonstration:

Hittite's 60GHz SiGe transceiver chip set interfaces directly to the Xilinx 256 QAM Millimetre Wave ModemSmartCORE IP to support up to 750 Mbps data throughput capacity and configurable channel bandwidths from 50 to 250MHz with FDD and TDD modes to formulate an ideal lower power consumption small cell backhaul radio solution.

Hittite's 60GHz transceiver chip set is a complete millimetre wave to baseband solution. The transceiver incorporates universal IQ interfaces for direct modulation and demodulation and chip set implements the entire transmitter and receiver chains with on-chip frequency synthesizers, frequency converters and the transmit power amplifier and receive low noise amplifier.

Hittite will release its next generation 60 GHz transmitter and receiver chipset later this year with increased output power (>15 dBm), a new frequency synthesizer with support for 64-QAM modulation and covering 57 - 66 GHz in 250 MHz step size, an integrated power detector, analogue or digital gain control, all in 4 x 6 mm surface mount packages.

Xilinx's 256-QAM millimetre wave modem, part of Xilinx SmartCORE IP portfolio, is highly configurable point to point and point to multipoint capable modem. It consumes less than 5W of power at >1 Gbps data rates and incorporates all the key features and capabilities customers require to accelerate development of next generation backhaul solutions.

It supports RS and LDPC FEC, CPRI for front haul or 10GbE for backhaul, as well as the JESD204B interface for emerging data converter devices. The core can be extended to support also wider band supports such as 500MHz with up to 3.5Gbps throughput.

The 1024QAM Microwave Radio Split-Mount Outdoor Unit (ODU) Backhaul Demonstration:

Hittite's transceiver chip sets interfaces directly to the Xilinx QPSK to 1024QAM SmartCOREIP Modem to construct a fully functional Split-Mount Outdoor Unit (ODU) microwave radio. Hittite's 6 - 42GHz transceiver chip set is a simplified, cost effective solution consisting of highly integrated IF transceiver ICs, high linearity microwave IQ transmitter and receiver ICs, low phase noisemicrowave synthesisers ICs and the transmit power amplifier, all with industry leading performance and surface mount packaging.

The Xilinx modem implements all the features of a modern microwave radio backhaul including QPSK to 1024QAM modulation with software configurable bandwidths from 3.5 - 112MHz. The modem supports Gigabit Ethernet with software configurable features including closed loop digital pre-distortion, automatic correction of TX and RX IQ impairments, equalisation, XPIC and ATCP configuration support.

MACOM`s compact mixers come in standard plastic packaging

The new 1.5mm x 1.2mm high IP3 mixer, image reject mixer, and low noise active mixer all incorporate GaAs. They provide an optimal balance of performance, space savings, and cost effectiveness

M/A-COM Technology Solutions (MACOM) has added three new discrete mixers to its portfolio.

The ultra small mixers provide a broad frequency bandwidth in standard surface mount, plastic packages, enabling system developers to achieve new levels of design versatility and cost efficiency for applications spanning test and measurement, electronic warfare, point to point wireless and more.

The MAMX-011021 high IP3 mixer supports high linearity for applications including high bit rate transmitters and receivers. This mixer covers the 5-33 GHz RF frequency range and DC-5 GHz IF frequency range, integrating a single ended cold FET structure and diplexer for approximately 9 dB of conversion loss with +22 dBm IIP3 to ensure low distortion. This mixer incorporates GaAs integrated circuits.

The MAMX-011022 image reject mixer is targeted at medium data rate, long haul, low noise systems, and is optimized for upconversion and downconversion. This mixer provides image rejection of 18 dB and covers the 5-28 GHz RF frequency range and DC-5 GHz IF frequency range, with conversion loss of 12 dB typical. This mixer incorporates GaAs and silicon Integrated circuits.

The MAMX-011023 low noise active mixer is designed for down frequency conversion and supports very low noise of 7 dB typical. This mixer covers the 4-23 GHz RF frequency range and DC-8 GHz IF frequency range, and supports conversion gain of 7 dB typical and low power consumption at 3v/15mA. This mixer is fabricated using a GaAs process which features full passivation for increased performance and reliability.

All three of MACOM's new mixers are available in surface mount, industry standard plastic TDFN packaging, and are sized at 1.5mm x 1.2mm.

"These new additions to MACOM's growing portfolio of mixers are ideally suited for wideband applications for which performance, ease of use and cost effectiveness are key considerations," says Tom Galluccio, Product Manager, MACOM. "The frequency bandwidth coverage, small size and design flexibility enabled by these new mixers is unmatched by competing plastic packaged products."

MACOM's new mixers are sampling to customers today.

Northrop Grumman sampling tiny InP ultra LNAs

The indium phosphide devices are designed for commercial and military use

Northrop Grumman has developed two high performance Monolithic Microwave Integrated Circuit (MMIC) broadband ultra-low-noise amplifiers (LNA) that are in production for immediate delivery.

The InP high electron mobility transistor (HEMT) LNAs are for use in E-band and W-band commercial, civil and military applications such as communication links, sensors, millimetre-wave imaging, radars and digital microwave radios.

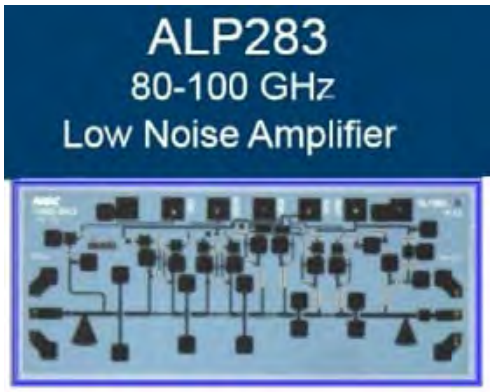
The compact die design of each LNA considerably reduces footprint size and exhibits very good ultra-low-noise performance and high gain.

"The LNAs are the initial release of products designed with the company's InP process, a powerful semiconductor technology that has successfully been used in Northrop Grumman's advanced military communication systems," says Frank Kropschot, general manager, Microelectronics Products and Services at Northrop Grumman. "For the first time, Northrop is offering products for similarly demanding commercial applications."

Product descriptions

ALP283:

The ALP283 is a W-band 1.7 mm2 InP HEMT low-noise amplifier that operates between 80 and 100 GHz. This power amplifier provides 29 dB of linear gain, 2.5 dB typical Noise Figure and 1dB gain compression power (P1dB) of 3 dBm (2 mw). It has a 2 dB typical average noise figure from 80 - 100 GHz. It is ideally suitable for W-Band millimetre-wave imaging applications, sensors and communication links.



ALP275:

The ALP275 is W-band 2.125 mm2 InP HEMT ultra-low-noise amplifier that operates between 71 and 96 GHz. This power amplifier provides greater than 26 dB of linear gain, 3 dB typical Noise Figure and P1dB of 4 dBm (2.5 mw). It is suited to E-Band and W-Band communications links.

To ensure rugged and reliable operation, both LNAs are fully passivated. Both bond pad and backside metallisation are Ti/Au, which is compatible with conventional die attach, thermocompression and thermosonic wire bonding assembly techniques.

JDSU announces $100 million stock repurchase program

The company expects to invest in future growth and in strategic business development opportunities

JDSU's Board of Directors has authorised a program to repurchase up to $100 million of the company's common stock through open market or private transactions until June 27th, 2015, the end of the Company's fiscal year 2015.

JDSU had $926.2 million in total cash as of March 29th, 2014 and generated $58.3 million in free cash flow during the first nine months of fiscal year 2014. The timing of repurchases and the number of shares repurchased will depend upon business and financial market conditions.

"We have achieved thirty consecutive quarters of positive operating cash flow in varying macroeconomic and industry conditions," states Tom Waechter, JDSU's president and chief executive officer. "We believe our strong balance sheet and our expectations for future cash flow generation provide JDSU the flexibility to enhance shareholder value through share repurchases while continuing to invest in future growth and in strategic business development opportunities."

Microsemi moves into GaAs and GaN MMIC market

The products include wideband and Low Noise Amplifiers and switches for a broad range of applications

Microsemi has announced its entry into the monolithic microwave integrated circuit (MMIC) market space.

Building on its history in RF, microwave and millimetre wave solutions, this new portfolio initially comprises sixteen products spanning DC-40GHz. It includes wideband amplifier, low noise amplifier and switch products designed for the defence, communications, instrumentation and aerospace industries.

Microsemi has active MMIC product developments using both established GaAs and emerging GaN semiconductor technologies.

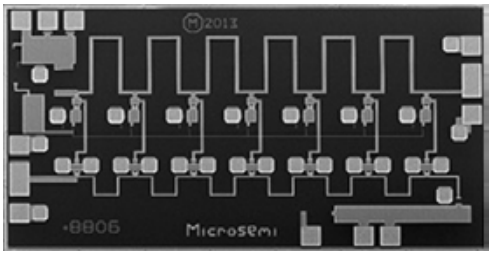
According to Strategy Analytics the addressable market for GaAs MMICs in Microsemi's targeted markets such as defence and communications will be approximately $500 million by 2015. ABI Research also estimates the market for GaN MMICs to be approximately $100 million by 2018.

Microsemi's highly-differentiated MMIC product attributes lead to faster design cycle times and smaller overall solution sizes in electronic warfare (EW), signal intelligence (SIGINT), military communication and other applications such as instrumentation equipment.

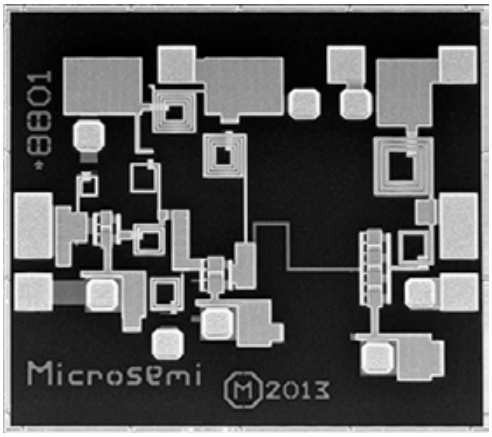
"Leveraging Microsemi's extensive experience and capabilities in these markets has allowed us to work closely with industry-leading customers to define and develop products that solve engineer's problems in new and creative ways," says Ray Crampton, MMIC product line director, Microsemi. "Response to our initial MMICs has been exceptional and we are aggressively working to expand our offering with numerous active developments in both GaAs and GaN-on-SiC technologies."

Microsemi's new MMIC products include several differentiating factors that include:

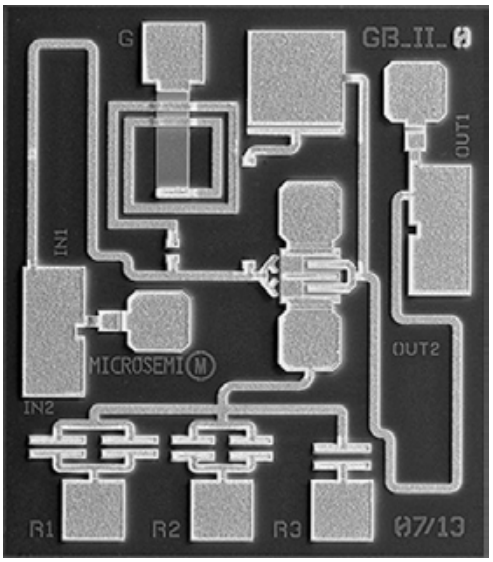
The MMA001AA DC-20GHz wideband amplifier has positive gain slope with over 17dB gain at 20GHz.



The MMS002AA single-pole, double-throw switch features approximately 45dB of isolation from DC-20GHz.



The MMA016AA DC- 15GHz amplifier has a power-selectable feature that allows customers to adjust power consumption based on the requirements of a particular application.



Availability and Pricing

Products are currently available for orders.

Anadigics expands InGaP based WiFi product portfolio

The new 802.11ac power amplifier uses the firm's patented indium gallium phosphide technology

Anadigics has introduced the AWL5910 power amplifier optimised for WiFi infrastructure and multimedia applications, including access points, routers, media gateways, set-top boxes, and smart TVs.

The new AWL5910 5 GHz power amplifier (PA) supports the 802.11a/n/ac standards and delivers a combination of good linearity, efficiency and gain, while minimising external component requirements.

This level of performance and integration enables manufacturers to reduce both time-to-market and bill of materials while developing WiFi-enabled products that provide higher throughput with greater range, as well as consume less power. The AWL5910 has been adopted for use in multiple high-performance connectivity solutions which are expected to ramp in the upcoming quarter.

The firm also says it has secured design wins from a key OEM.

"We continue to set a higher standard by leveraging our RFIC design expertise, advanced technology, and manufacturing prowess to deliver industry-leading WiFi solutions with measurably superior performance and integration," says Jonathan Griffith, vice president of WiFi Products at Anadigics.

"The new AWL5910 provides world-class linearity, efficiency and gain to ensure high speed WiFi connectivity, all while reducing BOM costs and minimising PCB space requirements. Leading OEMs recognise the strategic value our AWL5910 provides, and this is generating excellent design-win traction in a critical growth segment for Anadigics," Griffiths continues.

Anadigics' 802.11ac WiFi power amplifiers for infrastructure applications utilise the company's patented InGaP-Plus technology and unique design architectures to enhance performance and integration. The AWL5910 PA is claimed to provide world-class linearity, 31 dB of linear power gain and 1.8 percent EVM at 22 dBm output power to ensure stable, reliable high-throughput WiFi connectivity in the toughest modulation formats.

The AWL5910 power amplifier integrates additional functionality by removing unnecessary surface mount passives and integrating a digital PA enable interface that eliminates the need for an external buffer amplifier.

This 4 mm x 4 mm x 0.8 mm QFN package also features an integrated detector that facilitates accurate power control over varying load conditions (3:1 VSWR) and extends the usable detector dynamic range from 5 dBm to 26 dBm. These performance and integration advantages, coupled with industry-leading efficiency and thermal characteristics, enable multiple input multiple output (MIMO) designs that consume less power and are more thermally efficient.

Samples of the AWL5910 are available now for qualified programs.

AJC completes multi-terabit Infinera network upgrade

The firm's indium phosphide (InP) PIC 100G based Intelligent Transport Network will be deployed in Australia, Guam and Japan

Infinera, a provider of Intelligent Transport Networks, and Australia Japan Cable (AJC) have announced the completion of a multi-terabit upgrade to AJC's network.

This second and final phase of deployment completes a multi-terabit, high-capacity ring providing diverse fibre paths into cable landing stations in Australia, Guam and Japan, where Infinera DTN-X packet optical transport networking platforms enable an Intelligent Transport Network for AJC.

AJC offers connectivity and bandwidth to its customers across a 12,700 km submarine fibre optic cable network linking Australia, Guam and Japan. AJC is owned by some of the world's leading service providers including Telstra, AT&T, NTT, Verizon and Softbank.

"This network upgrade with Infinera's Intelligent Transport Network has enabled the retirement of AJC's original 10G transport equipment and the transfer of traffic to the more capable Infinera DTN-X platform," says Philip Murphy, Head of Engineering at AJC. "The original AJC 10G technology served us well but the efficiency, flexibility and speed of deploying the Infinera DTN-X to deliver 100G allows AJC to be more responsive to our customers in terms of client interfaces and traffic switching."

The Infinera Intelligent Transport Network, featuring the DTN-X packet optical networking platform, delivers what it says is the only commercially available single-card 500 gigabit per second (Gb/s) super-channel solution. This unique capability is made possible by Infinera's widely deployed 500 Gb/s photonic integrated circuits.

An Intelligent Transport Network is designed to enable AJC to easily scale to terabits of transmission capacity, integrating DWDM optical transmission and in the future up to 12 terabits per second of non-blocking OTN switching into a single platform.

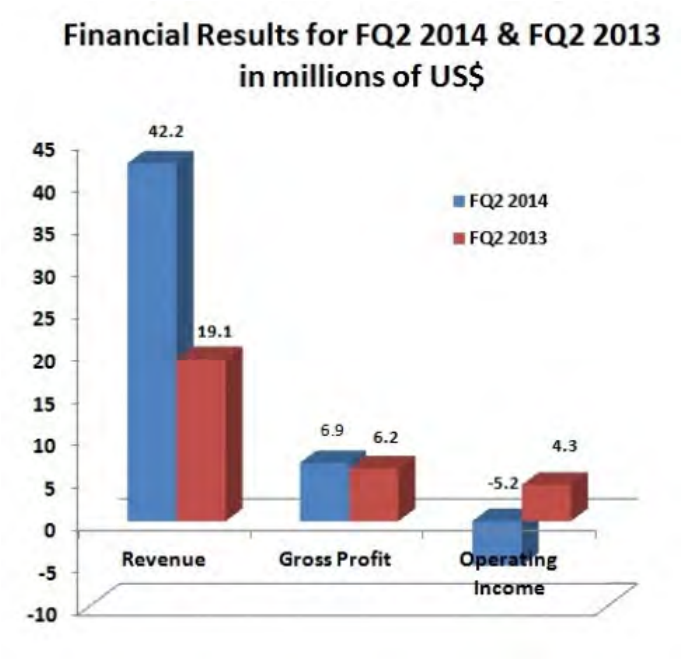
Infinera's intelligent software combined with this converged platform automates network operations to reduce both operational cost and service delivery times. The Infinera DTN-X is designed to scale without compromise enabling future upgrades to single-card terabit super-channels.

"We are honoured to work with AJC to complete their deployment of an Intelligent Transport Network," enthuses Andrew Bond Webster, Vice President Sales at Infinera. "Now, AJC may rapidly deliver high-capacity services to their customers across a highly resilient network."

Emcore revenues more than double

The firm expects an increase in Fibre revenue and a decrease in Photovoltaics revenuein the next quarter

Emcore Corporation, a provider of compound semiconductor-based components, subsystems, and systems for the fibre optics and space solar power markets, has announced its financial results for its fiscal second quarter ended March 31st, 2014.



Consolidated Results

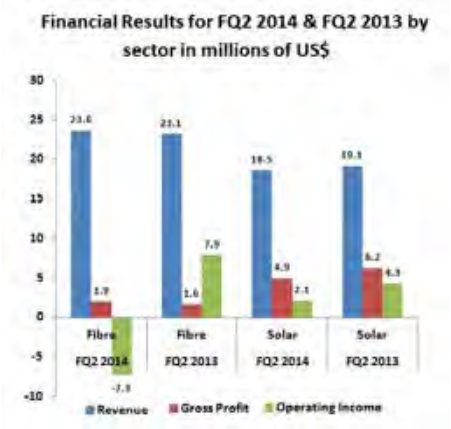
Revenue was $42.2 million, representing a decrease from the immediately preceding quarter but more than double compared to the same period last year. Gross margin was 16.3 percent, a decrease from the 22.9 percent gross margin reported in the previous quarter.

Operating loss was $5.2 million, a $3.0 million higher loss when compared to the preceding quarter. Net loss was $5.4 million, a $3.4 million higher loss when compared to the last quarter. Net loss per share was $0.18 compared to a net loss per share of $0.07 in the preceding quarter.

Cash and cash equivalents increased $0.1 million to $18.2 million at the end of the second quarter, compared to $18.1 million at the end of the first quarter

Financial results by sector

Fibre Optics revenues increased 1.4 percent over the immediate preceding quarter to $23.6 million, and Photovoltaics revenue decreased 11.0 percent to $18.6 million over the immediate preceding quarter.



On a segment basis, Fibre Optics gross margin declined to 8.2 percent from the 10.3 percent gross margin reported in the immediate preceding quarter and Photovoltaics gross margin decreased to 26.5 percent from the 37.0 percent gross margin reported in the immediate preceding quarter. A $1.0 million warranty reserve related to the previously divested Enterprise business was recorded this period.

Order backlog for the firm's Photovoltaics segment totaled $51.4 million as of March 31st, 2014, representing a 7.1 percent decrease from $55.3 million reported as of December 31st, 2013

Business Outlook

On a consolidated basis, Emcore expects revenue for our third quarter ended June 30th, 2014 to be in the range of $40 to $44 million with an increase in Fibre revenue and a decrease in Photovoltaics revenue.

Conference Call

Emcore discussed its financial results in a conference call and the webcast is available for replay on the company's website.

Anadigics wins orders from multiple Chinese smartphone OEMs

The ProEficient and ProVantage solutions are based on the firm's InGaP (indium gallium phosphide) technology. They are claimed to deliver differentiated performance and exceptional value in support of next generation of smartphones

Anadigics' ProEficient and ProVantage power amplifiers (PAs) have been selected by multiple Chinese OEMs to enable wireless connectivity in new smartphone designs.

ProEficient solutions deliver high levels of performance and efficiency across all power levels. ProVantage power amplifiers offer a blend of performance, integration and lower overall system cost.

Examples of ProVantage and ProEficient PAs

"We are extremely pleased with our design-win progress at multiple OEMs in China," says Dave Cresci, president of Anadigics. "According to a recent report by DigiTimes Research , the sequential annual growth rate in smartphone shipments from Chinese OEMs is expected to exceed 30 percent in 2014."

"Anadigics is well positioned to capitalise on this expected growth with design wins at several key OEMs, including Huawei, ZTE, Coolpad and Innos. We anticipate that these new design wins for our ProEficient and ProVantage power amplifiers should enable a significant increase in our mobile products revenue at Chinese OEMs."

Anadigics' ProEficient and ProVantage solutions utilise the company's patented InGaP-Plus technology.

ProEficient power amplifiers also leverage Anadigics' unique design architectures to offer one of the highest efficiencies across all power levels, enabling greater talk time and longer data application use.

ProVantage power amplifiers are designed to provide manufacturers with excellent value by combining high performance with space-saving integration and lower overall system cost.

Both ProEficient and ProVantage solutions are designed for use with an external switch mode power supply (SMPS) to support average power tracking (APT), which further increases efficiency and reduces current consumption at low and medium operating powers.

G&H optical fibre amplifiers for satellite comms very robust

Following positive results of recent gamma radiation tests, on its optical fibre amplifiers, Gooch & Housego have proclaimed the robustness of both the design and components

Fibre optic systems are beginning to penetrate satellite payloads and photonic technology is expected to play a critical role in next generation space missions, enabling high-speed inter-satellite and satellite to ground laser communications.

An integral part of these laser communication terminals is the optical fibre amplifier which is used to boost the signal optical power and enable long reach in free-space. Gooch & Housego (G&H) company Constelex and the G&H (Torquay, UK) based Systems Technology Group (STG) is focused on the design and development of next generation space photonics components and systems, including optical fibre amplifiers.

These amplifiers are applicable to satellite laser communications, within the Advanced Research in Telecommunications Systems (ARTES) program of the European Space Agency (ESA).

Optical amplifiers are built with high-reliability G&H active and passive fibre optic components. Modules with the optical circuit design and device specifications follow future mission

requirements provided by satellite system vendors.

Gamma radiation tests on the optical fibre amplifiers were carried out in March by G&H to assess their performance in space conditions and under total irradiation doses found in Low-Earth and Geostationary orbit satellites.

The radiation results verified the robustness of the design and the components used, as minimal degradation was observed and the performance characteristics of the amplifier remained within the stringent End of Life specifications.

G&H space erbium doped fibre amplifier (EDFA) during radiation testing

Efstratios Kehayas, Vice President, Space Photonics comments, "G&H continues to push the performance envelope of photonics and now works towards the design and development of low noise pre-amplifiers as well as high power amplifier devices for use in long range inter-satellite laser communication links."

G&H's STG, founded in early 2013 has a remit to design, develop and prototype systems-level products. The objective is to build a multi-disciplinary team with expertise in mechanical, electronic and software design and to integrate these technologies with G&H's expertise in photonics and fibre optics.

The STG is accelerating G&H's move up the value chain by providing a strong pipeline of component and sub-systems development, and offering customers a complete system design, development and manufacturing service. In addition to developing erbium doped fibre (EDFA) systems for satellite communication, the STG is currently focused on innovative Optical Coherence Tomography (OCT) fibre systems for medical imaging.

Infinera to take on ex Juniper networking expert to its Board

Marcel Gani is joining the indium phosphide (InP) PIC telecom specialist

Infinera has appointed Marcel Gani to the board of directors of Infinera effective June 9th, 2014.

Gani is currently an independent consultant. Prior to this role, he held numerous executive positions at technology companies including Juniper Networks, Inc., where he served as Chief of Staff from 2005 to 2006 and Chief Financial Officer from 1997 to 2005. Gani was instrumental in taking Juniper through its hyper-growth phase from a small start-up to its position in IP networking with over $2 billion in revenues.

"I am honoured to join the Infinera board of directors," says Gani. "I have followed this company for several years and am delighted to support Infinera as it continues to deliver Intelligent Transport Networks around the world and define what the network will be."

"We are very pleased to welcome Marcel to our board," comments Kambiz Hooshmand, Chairman of the Board of Infinera. "With his years of experience in the networking industry, he will bring valuable insights and perspective to Infinera as we continue to grow market share and take Infinera to the next level as a company."

It was also announced that effective May 15th, 2014, Kenneth A. Goldman would be departing from the board of directors, after nine years of service, to fulfil other obligations and to devote additional time to his other responsibilities.

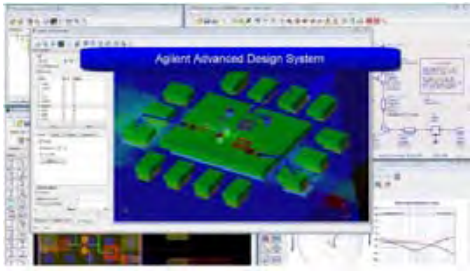
"On behalf of the entire board, and everyone at Infinera, I would like to thank Ken for his numerous contributions to Infinera over the years," says Infinera CEO Tom Fallon. "Ken's extensive experience in technology companies as a respected leader and financial expert provided a great foundation for Infinera."

RF Electronics

GIT Japan to use Agilent software for GaAs/GaN RFIC/ MMIC design

ADS provides a complete RFIC design flow that is crucial for a successful implementation of wireless III-V MMIC design front-ends

GIT Japan has selected Agilent EEsof EDA's Advanced Design System (ADS) electronic design automation platform for complete GaAs/GaN- and silicon-based RFIC/MMIC implementations.



GIT Japan is a provider of advanced interface technologies

between people and information, and a competence centre for ultrawideband (UWB) chipset and module development.

"We successfully used the ADS front-to-back design flow for UWB power amplifier MMIC design in a WIN pHEMT process," says Shogo Ida, president and chief executive officer at GIT. "We also used it when expanding our portfolio to include silicon-based designs using IBM's high-performance SiGe BiCMOS technology. We chose ADS because it delivers proven RF circuit simulation, integrated EM solvers and RF-relevant backend support. It was key to our first-time-right tape-outs and enabled us to introduce unique products on time."

Agilent says ADS is the most widely used platform for III-V MMIC design but also provides a complete RFIC design flow - including layout, enhanced foundry-certified PDKs, LVS and DRC - that is crucial for a successful implementation of wireless front-ends.

The scalable front-to-back solution not only facilitates the job of the MMIC and RFIC designer from the beginning, but also directly integrates with other domains, such as RF modules and RF system-in-package (SiP) design.

Key ADS features like ADS Layout and Desktop DRC and LVS help simplify and speed the design flow. ADS Layout, for example, features an RFIC toolbar for easier, more efficient physical design and trace routing. Desktop DRC and LVS help verify and correct layouts against foundry DRC rules prior to tape out and catch errors early in the design cycle, all from the users' desktop. In addition, ADS' integrated 3D planar EM simulator Momentum combines full-wave and quasi-static EM solvers for simplified passive, interconnect and parasitic modelling.

"As a leader in the GaAs MMIC world, we have seen the popularity of the ADS platform for silicon-based RFIC design grow tremendously over the years," says Juergen Hartung, RFIC marketing manager for Agilent EEsof EDA. "Customers can now use these kits for a variety of RF CMOS, RF SOI and SiGe BiCMOS technologies to enjoy full back-end support that includes schematic-driven layout creation, layout-versus-schematic check, and integrated 3D planar electromagnetic and 3D-FEM simulators."

Skyworks CEO David J. Aldrich elected Board chairman

With Liam K. Griffin promoted to president, the new organisational structure has been designed to enhance the next phase of Skyworks' long term strategic development

Skyworks Solutions, Inc. has announced that its board of directors has elected David J. Aldrich chairman of the board and CEO of Skyworks.

David J. McLachlan, prior chairman, will remain a member of Skyworks' board of directors and has been designated as lead independent director.

McLachlan has been a director at Skyworks since 2000 and has been chairman since 2008. "It has been a privilege to serve as chairman of the board of Skyworks," says McLachlan.

"This is an exciting time for the company as it enters into the next phase of growth - capitalising on the tremendous opportunity within the Internet of Things. Dave Aldrich has been instrumental in Skyworks' advancement into a leading analogue company within the semiconductor industry. I look forward to continuing to work with him as lead independent director."

In addition, Liam K. Griffin has been promoted to the role of president. He had previously served as executive vice president and general manager. "This structure will enable us to hone our focus on long term strategic growth opportunities during this transformative time for Skyworks," says Aldrich.

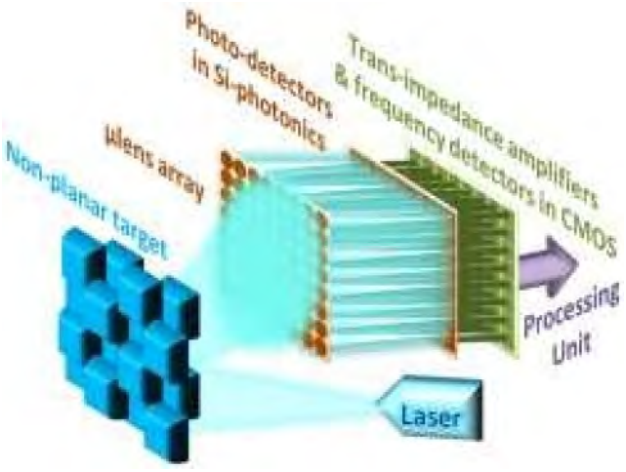
"Liam has a proven track record of results and I am confident that in his new role, he will continue to provide strong leadership and direction as we accelerate our evolution into a larger and more diversified analogue semiconductor company."

Lasers

VCSELs and MEMS unite to enhance 3-D imaging

A new low power compact laser combining III-Vs and silicon could provide exceptional range for potential use in self-driving cars, smartphones and interactive video games

A new twist on 3-D imaging technology could one day enable your self-driving car to spot a child in the street half a block away, let you answer your smartphone from across the room with a wave of your hand, or play "virtual tennis" on your driveway.



A conceptual vision for an integrated 3D camera with multiple pixels using the FMCW laser source (Credit: Behnam

Behroozpour)

The new system, developed by researchers at the University of California, Berkeley, can remotely sense objects across distances as long as thirty feet, ten times farther than what could be done with comparable current low-power laser systems.

With further development, the technology could be used to make smaller, cheaper 3-D imaging systems that offer exceptional range for potential use in self-driving cars, smartphones and interactive video games like Microsoft's Kinect, all without the need for big, bulky boxes of electronics or optics.

"While metre-level operating distance is adequate for many traditional metrology instruments, the sweet spot for emerging consumer and robotics applications is around ten metres," or just over thirty feet, says UC Berkeley's Behnam Behroozpour."This range covers the size of typical living spaces while avoiding excessive power dissipation and possible eye safety concerns."

The new system relies on LIDAR (light radar), a 3-D imaging technology that uses light to provide feedback about the world around it. LIDAR systems of this type emit laser light that hits an object, and then can tell how far away that object is by measuring changes in the light frequency that is reflected back. It can be used to help self-driving cars avoid obstacles halfway down the street, or to help video games tell when you are jumping, pumping your fists or swinging a racket at an imaginary tennis ball across an imaginary court.

In contrast, current lasers used in high-resolution LIDAR imaging can be large, power-hungry and expensive. Gaming systems require big, bulky boxes of equipment, and you have to stand within a few feet of the system for them to work properly, Behroozpour says. Bulkiness is also a problem for driverless cars such as Google's, which must carry a large 3-D camera on its roof.

The researchers sought to shrink the size and power consumption of the LIDAR systems without compromising their performance in terms of distance.

In their new system, the team used a type of LIDAR called frequency-modulated continuous-wave (FMCW) LIDAR, which they felt would ensure their imager had good resolution with lower power consumption, Behroozpour says. This type of system emits "frequency - chirped" laser light (that is, whose frequency is either increasing or decreasing) on an object and then measures changes in the light frequency that is reflected back.

3-D schematic showing MEMS-electronic-photonic heterogeneous integration (Credit: Niels Quack)

To avoid the drawbacks of size, power and cost, the Berkeley team exploited a class of lasers called MEMS tuneable VCSELs. MEMS (micro-electrical-mechanical system) parts are tiny micro-scale machines that, in this case, can help to change the frequency of the laser light for the chirping, while VCSELs (vertical-cavity surface-emitting lasers) are a type of inexpensive III-V integrable semiconductor lasers with low power consumption. By using the MEMS device at its resonance - the natural frequency at which the material vibrates - the researchers were able to amplify the system's signal without a great expense of power.

"Generally, increasing the signal amplitude results in increased power dissipation," Behroozpour says. "Our solution avoids this tradeoff, thereby retaining the low power advantage of VCSELs for this application."

The team's next plan includes integrating the VCSEL, photonics and electronics into a chip-scale package. Consolidating these parts should open up possibilities for "a host of new applications that have not even been invented yet," Behroozpour says - including the ability to use your hand, Kinect-like, to silence your ringtone from thirty feet away.

Behnam Behroozpour will describe the team's work at CLEO: 2014, in presentation AW3H.2, titled, "Method for Increasing the Operating Distance of MEMS LIDAR beyond Brownian Noise Limitation," which will take place on Wednesday, June 11th at 4:45 p.m. in Room 210H of the San Jose Convention Centre

The Conference on Lasers and Electro - Optics (CLEO) is being held from June 8th to 13th in San Jose, California, USA at San Jose Convention Centre.

Daylight delivers first laser-based IR microscopy platform

The Spero microscope uses the firm's Quantum Cascade Laser technology. It is suited specifically for the mid-infrared spectral imaging analysis of biomedical and materials research samples

Daylight Solutions, a manufacturer of molecular detection and imaging solutions in the mid-infrared, has announced delivery of what it claims is the world's first commercially available laser-based infrared microscopy platform.

The company's advanced microscope was delivered to Rebekah Drezek's Optical Molecular Imaging and Nanobiotechnology Laboratory at Rice University in Houston, Texas.

The system will initially be used to conduct cutting-edge research into laser-based infrared microscopy for the optical diagnosis of breast cancer.

"We are delighted to have received the Spero IR microscopy system," states Drezek. "The combination of spectral tuneability and rapid imaging in these wavelength ranges is

unprecedented and we are very excited to begin using the system to develop enhanced optical cancer diagnostics."

The award-winning microscope, marketed under the brand name Spero, opens up a new world of research possibilities with breakthrough chemical imaging and analysis on a real-time basis.

Powered by Daylight's broadly tuneable Quantum Cascade Laser (QCL) technology, Spero offers a combination of excellent visibility, instantaneous results in "live mode," and a small resource footprint to easily fit into any lab or clinical setting.

Spero microscope

The system's capabilities are further augmented by automated computational algorithms that enable identification and segmentation of complex chemical signatures. Applications for Spero range from label-free tissue and cell diagnostics in Life Sciences to materials analysis in industrial markets.

Drezek's initial phase of research, funded by the National Science Foundation's Small Business Engineering Research Centre Collaborative Opportunity (SECO) program, will seek to demonstrate the unique advantages of a tuneable, mid-infrared laser-based system over that of a conventional Fourier Transform Infrared (FTIR) microscope.

The program will also include an evaluation of the Spero's full and sparse data collection modes. In full data collection mode, a complete spectral scan can be collected in five minutes. This will be compared to the sparse data collection mode, in which only a small subset of key wavelengths are rapidly collected in seconds.

During the second phase of the research, the MCF10A and SKBR3 breast cell lines will be analysed with the system to assess the predictive value of the infrared spectral data for normal, cancer, and cancer sub-types.

"We have always appreciated our close collaboration with Drezek and Rice University and are proud to deliver our Spero microscope to her lab," says Daylight Solutions President, Paul Larson. "We know that her talented team will leverage the advanced capabilities of the instrument to make a very significant impact on the continuing fight against breast cancer."

Laser Components expands III-V portfolio

The DFB lasers are suited for use in spectroscopic measurements

Laser Components is introducing new higher power range of SPECDILAS-D DFB lasers for spectroscopic measurement technology.

They come in wavelength ranges of 1278 - 1296nm, 1389 - 1398nm, 1504nm - 1512nm, and 1649 - 1654nm with power outputs of up to 25mW (compared previously to 11mW peak output powers).

SPECDILAS-D DFB laser modules

The SPECDILAS-D series is directed toward users in the area of diode laser spectroscopy. Selected wavelengths are available on a standard basis. These diodes are manufactured by a German company with more than thirty years of experience in III-V technology.

The PREMIUM option comprises lasers in an SOT5.6, SOT9, or TO8 housing (the last one has an integrated micro Peltier cooler) with an output power level of ≥ 15 mW (compared to 6 mW before) as well as lasers in a butterfly housing with an output power of ≥8 mW.

Lasers in butterfly housings feature an integrated micro Peltier cooler, monitor diode, and single-mode fibre with an FC/APC

connector.

The output power level of the PREMIUM PLUS option is specified at ≥25 mW (compared to 11 mW before) for lasers in an SOT5.6, SOT9, or TO8 housing. The PREMIUM PLUS version is now also available in a butterfly housing with an output power level of ≥13 mW.

Solar

TSMC Solar takes on CIGS & CdTe expert Noufi

The Taiwanese subsidiary has taken on US NREL veteran to push its CIGS development

TSMC Solar has engaged Rommel Noufi in a long-term consulting capacity, to augment its CIGS R&D program.

Noufi is a 33-year veteran of the US National Renewable Energy Laboratory (NREL) where he was Principal Scientist and lead the team driving CIGS and CdTe cell research. He has authored over 190 publications and has eight patents.

TSMC Solar has a track record of R&D achievement, having produced a TUV-SUD verified, 15.7 percent efficient module with production equipment on its production line in mid-2013. The company is currently expanding its capacity from 40MW to reach 120MW in Q4 of this year.

Commenting on the decision to engage Noufi, TSMC Solar President Ying-Chen Chao says, “Dr. Noufi played a key role in the development of CIGS as a leading photovoltaic material. The addition of his deep CIGS experience to our R&D effort puts us on solid footing to maintain our rapid improvement of module efficiency over the next several years.”

Noufi sees great potential for CIGS efficiency improvements, “CIGS efficiencies in the lab have reached 20.9 percent, with a clear path to achieving 23 percent. With its strong R&D, manufacturing and equipment engineering skill set TSMC Solar is uniquely equipped to develop this potential and bring it into production.”

Stabilising GaAs and GaP in solar fuel generators

Scientists have devised a method to protect materials such as gallium arsenide and gallium phosphide in a solar-fuel generator

Researchers around the world are trying to develop solar-driven generators that can split water, yielding hydrogen gas that could be used as clean fuel. Such a device requires efficient light-absorbing materials that attract and hold sunlight to drive the chemical reactions involved in water splitting.

Semiconductors like GaAs and silicon are excellent light absorbers - as is clear from their widespread use in solar panels. However, these materials rust when submerged in the type of water solutions found in such systems.

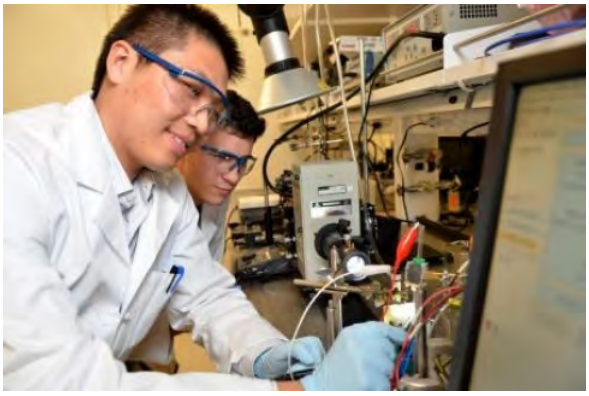
Now Caltech researchers at the Joint Centre for Artificial Photosynthesis (JCAP) have devised a method for protecting these common semiconductors from corrosion even as the materials continue to absorb light efficiently. The finding paves the way for the use of these materials in solar-fuel generators.

The research, led by Shu Hu, a postdoctoral scholar in chemistry at Caltech, appears in the May 30th issue of the journal *Science*.

“For the better part of a half century, these materials have been considered off the table for this kind of use,” says Nate Lewis, the George L. Argyros, professor of chemistry at Caltech, and the principal investigator on the paper. “But we didn’t give up on developing schemes by which we could protect them, and now these technologically important semiconductors are back on the table.”

In the type of integrated solar-fuel generator that JCAP is striving to produce, two half-reactions must take place - one involving the oxidation of water to produce oxygen gas; the other involving the reduction of water, yielding hydrogen gas.

Each half-reaction requires both a light-absorbing material to serve as the photoelectrode and a catalyst to drive the chemistry. What’s more, the two reactions must be physically separated by a barrier to avoid producing an explosive mixture of their products.



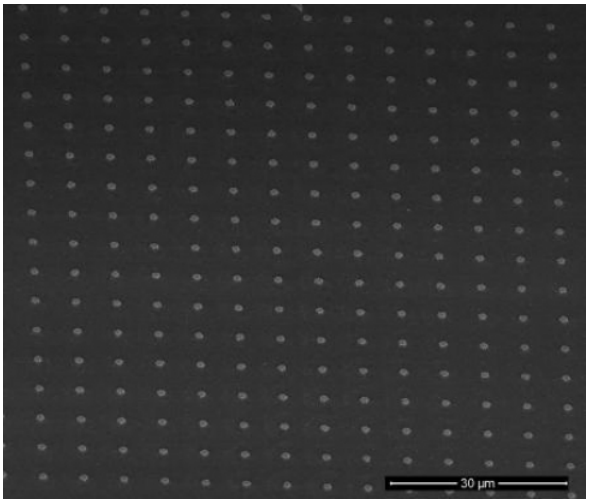
Postdoctoral scholar Shu Hu (foreground) demonstrates how to make photoelectrochemical measurements of a solar-fuels cell (Credit: Robert Paz)

Historically, it has been particularly difficult to come up with a light-absorbing material that will robustly carry out the oxidation half-reaction. Researchers have tried, without much success, a variety of materials and numerous techniques for coating the common light-absorbing semiconductors.

The problem has been that if the protective layer is too thin, the aqueous solution penetrates through and corrodes the

semiconductor. If, on the other hand, the layer is too thick, it prevents corrosion but also blocks the semiconductor from absorbing light and keeps electrons from passing through to reach the catalyst that drives the reaction.

At Caltech, the researchers used a process called atomic layer deposition to form a layer of titanium dioxide (TiO2) - a material found in white paint and many toothpastes and sunscreens - on single crystals of GaAs, GaP or silicon.



Scanning electron microscope (SEM) image of nickel islands on silicon protected by a titanium dioxide film (Credit: Shu Hu/ Caltech)

The key was that they used a form of TiO2 known as "leaky TiO2" - because it leaks electricity. First made in the 1990s as a material that might be useful for building computer chips, leaky oxides were rejected as undesirable because of their charge-leaking behaviour.

However, leaky TiO2 seems to be just what was needed for this solar-fuel generator application. Deposited as a film, ranging in thickness between 4 and 143nm, the TiO2 remained optically transparent on the semiconductor crystals - allowing them to absorb light - and protected them from corrosion but allowed electrons to pass through with minimal resistance.

On top of the TiO2, the researchers deposited 100nm-thick "islands" of an abundant, inexpensive nickel oxide material that successfully catalyzed the oxidation of water to form molecular oxygen.

The work appears to now make a slew of choices available as possible light-absorbing materials for the oxidation side of the water-splitting equation. However, the researchers emphasise, it is not yet known whether the protective coating would work as well if applied using an inexpensive, less-controlled application technique, such as painting or spraying the TiO2 onto a semiconductor. Also, thus far, the Caltech team has only tested the coated semiconductors for a few hundred hours of continuous illumination.

"This is already a record in terms of both efficiency and stability for this field, but we don't yet know whether the system fails over the long term and are trying to ensure that we make something that will last for years over large areas, as opposed to weeks," says Lewis. "That's the next step."

The work is described in the paper, "Amorphous TiO2 Coatings Stabilize Si, GaAs, and GaP Photoanodes for Efficient Water Oxidation," by Hu *et al* in *Science*, 344 (6187), pp. 1005-1009. DOI: 10.1126/science.1251428

The research was supported by the Office of Science of the U.S. Department of Energy through an award to JCAP, a DOE Energy Innovation Hub. Some of the work was also supported by the Resnick Sustainability Institute and the Beckman Institute at Caltech.

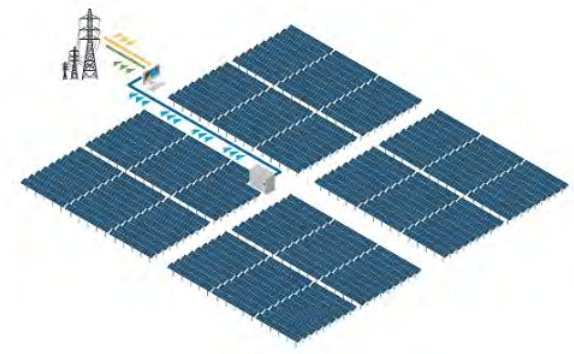
First Solar to introduce pre-engineered CdTe plant products

The new offerings focus on customers' need for enhanced, reliable energy output and will be introduced at Intersolar Europ

First Solar has launched its modular AC Power Block solar power plant solution and its next generation First Solar Series 4 thin film photovoltaic (PV) module.

Purpose-built for power plant owners and developers seeking to minimise project risk and maximise energy production and revenue, the AC Power Block is a configurable system solution that can be scaled to address a wide range of project conditions.

The pre-engineered system is available in modular units ranging from 800 kilowatts (kW) to 3.8 megawatts (MW). Based on First Solar's PV plant design and energy prediction model, the AC Power Block is backed by a first year energy performance guarantee and a 25-year capacity warranty.



AC Power Block solution

First Solar's new Series 4 PV module offers up to eight percent more energy than conventional crystalline silicon modules with the same power rating, and is compatible with advanced 1500-volt plant architectures. The Series 4A variant features a new anti-reflective coated glass, which enhances energy production. The module is backed by First Solar's 25-year Linear Performance Warranty.

"What matters most to our customers is reliable energy output achieved through proven technology," says Thomas Kuster, First Solar Senior Vice President of Product Management. "The AC Power Block and the Series 4 module are designed to deliver on those expectations. As solar energy secures its place in the global energy mix, these offerings demonstrate First Solar's ability to deliver solutions that address our customers' specific needs. We are confident that our commitment to innovation and continuous improvement position First Solar as a leading provider of comprehensive solar energy solutions."

"The underlying principle behind these new offerings and our existing power systems portfolio is an unwavering focus on a goal that we share with our customers in Europe and around the world: reliable generation of solar energy that is competitive within the framework of the region's energy generation portfolio," Christopher Burghardt, Vice President for Europe at First Solar, explains. "Showcasing our industry-leading range of solutions at the region's premier solar energy exhibition underscores the market's importance to our growth strategy."

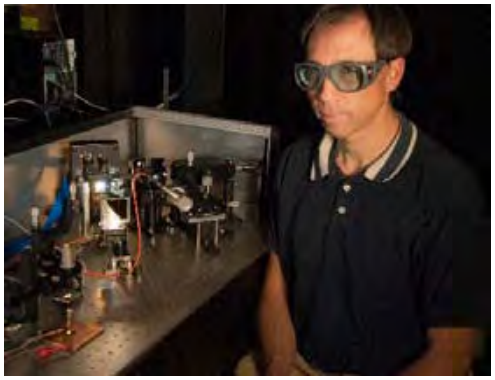
First Solar will also spotlight its Modules Plus System at Intersolar. This offering features fixed-tilt and single-axis tracker designs that are optimised for installation ease, project value, and operational reliability with First Solar's advanced thin film PV modules.

Laser mimics sunlight to assess cell efficiency

In a new tool, a white light laser can be focused down to a small beam spot to analyse GaAs, CIGS and silicon based solar cells

Researchers at the National Institute of Standards and Technology (NIST) have developed a laser-based instrument that generates artificial sunlight to help test solar cell properties and find ways to boost their efficiency.

NIST says the system simulates sunlight well across a broad spectrum of visible to infrared light. More flexible than conventional solar simulators such as xenon arc-lamps or LEDs, the laser instrument can be focused down to a small beam spot - with resolution approaching the theoretical limit- and shaped to match any desired spectral profile.



NIST engineer Tasshi Dennis with NIST's solar simulator based on a white light laser. The instrument simulates sunlight to help measure the properties of solar cell materials. The instrument's beam is illuminating a GaAs solar cell (yellow diamond) in the lower left corner of the photo (Credit: J. Burrus/NIST)

The new simulator is based on a white light laser that uses optical-fibre amplifier technology to boost the power and a photonic crystal fibre to broaden the spectrum. NIST researchers used the simulator to measure the efficiency of thin-film solar cells made of GaAs, CIGS, crystalline and amorphous silicon and the results agreed with independent measurements.

"We can focus the light down to a spot less than 2 micrometres in diameter, despite the wide spectral content. You can't do this with sunlight," NIST researcher Tasshi Dennis says. "We then used this focused spot to scan across solar cell materials while monitoring the current the light generated. This allowed us to create spatial maps (images) of the response of a solar cell at the micrometre level."

The NIST scientists believe the new instrument may help researchers to understand solar cells' optical and electrical characteristics, including defects and the impact of unusual designs. In particular, the new simulator's capability to make rapid, accurate spectrum adjustments will help characterise the most efficient solar cells, which use multi-junction materials in which each junction is tuned to a different part of the spectrum.

The instrument is designed to probe small research samples, individual concentrator solar cells and microstructures, not to determine the efficiencies of large solar cell panels and modules. NIST researchers have been working to make the new simulator programmable and portable for use outside NIST.

First Solar sells 250MW Nevada project

The CdTe vertically integrated modules offer tracker technology, EPC services, modules and a balance of system solution

First Solar has completed the sale of the 250-megawatt (MW) AC Silver State South Solar Project to a subsidiary of NextEra Energy Resources.

Terms of the transaction were not disclosed.

Silver State South is located on approximately 3,000 acres of federally managed land in Clark County, Nevada. The project is adjacent to the 50MWAC Silver State North project, which was developed and built by First Solar and commissioned in 2012.

First Solar developed and designed the Silver State South project, and will provide Engineering, Procurement and Construction (EPC) services to NextEra. All the power from Silver State South will be sold to Southern California Edison under a long-term power purchase agreement.

"Silver State South demonstrates the deep value First Solar

provides through our vertically integrated capabilities," says Tim Rebhorn, First Solar's Senior Vice President of Business Development for the Americas. "We have an unmatched ability to offer industry-leading module technology, best-in-class design and construction that includes single-axis tracker and proven balance of system components."

"We are pleased to have completed the acquisition of the Silver State South solar project," comments NextEra Energy Resources Senior Vice President of Development Mike O'Sullivan. "This is another important milestone as we continue to build our solar business, and we look forward to working with the First Solar team to make this project a reality."

Pre-construction activity has begun at the site, and the project is expected to be complete in late 2016. At construction peak, the project will create approximately 500 local full-time jobs.

Advancing quantum dot solar cells

ZnO/PbS quantum dot solar cells have set a new record for efficiency in devices, which could unlock new uses. The solar cell has been added to the NREL's listing of record-high efficiencies for each kind of solar-cell technology

Solar-cell technology has advanced rapidly, as hundreds of groups around the world pursue more than two dozen approaches using different materials, technologies, and approaches to improve efficiency and reduce costs.

Now a team at MIT says it has set a new record for the most efficient quantum-dot cells - a type of solar cell that is seen as especially promising because of its inherently low cost, versatility, and light weight.

While the overall efficiency of these ZnO/PbScells is still low compared to other types - about 9 percent of the energy of sunlight is converted to electricity - the rate of improvement of this technology is claimed, by the researchers, to be one of the most rapid seen for a solar technology.

Researcher displays a sample of the record-setting new solar cell on the MIT campus (Photo courtesy of Chia-Hao Chen)

The development is described in a paper in the journal *Nature Materials*, by MIT professors Moungi Bawendi and Vladimir Bulović and graduate students Chia-Hao Chuang and Patrick Brown.

The new process is an extension of work by Bawendi, the Lester Wolfe Professor of Chemistry, to produce quantum dots with precisely controllable characteristics - and as uniform thin coatings that can be applied to other materials. These minuscule particles are very effective at turning light into electricity, and vice versa.

Since the first progress toward the use of quantum dots to make solar cells, Bawendi says, "The community, in the last few years, has started to understand better how these cells operate, and what the limitations are."

The new work represents a significant leap in overcoming those limitations, increasing the current flow in the cells and thus boosting their overall efficiency in converting sunlight into electricity.

Many approaches to creating low-cost, large-area flexible and lightweight solar cells suffer from serious limitations - such as short operating lifetimes when exposed to air, or the need for high temperatures and vacuum chambers during production.

By contrast, the new process does not require an inert atmosphere or high temperatures to grow the active device layers, and the resulting cells show no degradation after more than five months of storage in air.

Bulović, the Fariborz Maseeh Professor of Emerging Technology and associate dean for innovation in MIT's School of Engineering, explains that thin coatings of quantum dots "allow them to do what they do as individuals - to absorb light very well - but also work as a group, to transport charges." This allows those charges to be collected at the edge of the film, where they can be harnessed to provide an electric current.

The solar cell produced by the team has now been added to the National Renewable Energy Laboratories' listing of record-high efficiencies for each kind of solar-cell technology.

The overall efficiency of the cell is still lower than for most other types of solar cells. But Bulović points out, "Silicon had six decades to get where it is today, and even silicon hasn't reached the theoretical limit yet. You can't hope to have an entirely new technology beat an incumbent in just four years of development." And the new technology has important advantages, notably a manufacturing process that is far less energy-intensive than other types.

Chuang adds, "Every part of the cell, except the electrodes for now, can be deposited at room temperature, in air, out of solution. It's really unprecedented."

The system is so new that it also has potential as a tool for basic research. "There's a lot to learn about why it is so stable. There's a lot more to be done, to use it as a testbed for physics, to see why the results are sometimes better than we expect," Bulović says.

A companion paper, written by three members of the same team along with MIT's Jeffrey Grossman, the Carl Richard Soderberg Associate Professor of Power Engineering, and three others, appears this month in the journal *ACS Nano*, explaining in greater detail the science behind the strategy

employed to reach this efficiency breakthrough.

The new work represents a turnaround for Bawendi, who had spent much of his career working with quantum dots. "I was somewhat of a sceptic four years ago," he says. But his team's research since then has clearly demonstrated quantum dots' potential in solar cells, he adds.

Arthur Nozik, a research professor in chemistry at the University of Colorado who was not involved in this research, says, "This result represents a significant advance for the applications of quantum-dot films and the technology of low-temperature, solution-processed, quantum-dot photovoltaic cells. … There is still a long way to go before quantum-dot solar cells are commercially viable, but this latest development is a nice step toward this ultimate goal."

This work is described in detail in the papers,

"Improved performance and stability in quantum dot solar cells through band alignment engineering," by Chia-Hao M. Chuang *et al* in *Nature Materials*.

doi:10.1038/nmat3984

and

"Energy Level Modification in Lead Sulfide Quantum Dot Thin Films Through Ligand Exchange," by Patrick R. Brown *et al* in *ACS Nano.* DOI: 10.1021/nn500897c

The work was supported by the Samsung Advanced Institute of Technology, the Fannie and John Hertz Foundation, and the National Science Foundation.

This article was adapted from one written by David L. Chandler at the MIT News Office.

5N Plus to deal with all First Solar`s compound semiconductor needs

The producer of specialty metal and chemical products will benefit from the continued growth associated with the CdTe solar cell manufacturer until 2019

5N Plus, has entered into new supply agreements with First Solar, covering its compound semiconductor needs until March 31st, 2019. The company has renewed its existing CdTe supply agreement and the compounds' by-products recycling agreement.

In addition, a new supply agreement broadly covering all of First Solar's other compound semiconductor needs up to March 31st, 2019, has also been concluded.

Under the new agreements, First Solar has agreed to exclusively purchase from 5N Plus, all the CdTe required by First Solar on a worldwide basis for the manufacturing of solar photovoltaic modules.

"We are very pleased to have extended our agreements with First Solar until 2019, enabling us to bring our relationship with this important customer to another level. While we conceded competitive pricing, we believe that this will be largely compensated over the course of the next quarters by the increase of sales volume providing us with a solid and predictable revenue stream for the next five years," says Jacques L'Ecuyer, President and Chief Executive Officer of 5N Plus.

"First Solar remains committed to reducing solar module cost and improving efficiency, and we intend to be their preferred solution for doing so through our close technical and commercial relationship. We strongly believe that these new supply agreements will allow 5N Plus to benefit from continued growth associated with First Solar's leading position in the solar market," he adds.

"5N Plus has been and continues to be a critical supplier to First Solar. These agreements support our plans to increase the competiveness of CdTe based solar modules and are in line with our corresponding roadmap aimed at achieving this," notes Tymen de Jong, Senior Vice President of Global Operations of First Solar, Inc.

Midsummer CIGS cells up the ante with 16.2 percent efficiency

This increased energy efficiency further strengthens the business case and attractiveness of thin film CIGS solar cells

Swedish solar developer Midsummer, a supplier of production lines for the manufacturing of flexible thin film CIGS solar cells, has increased the efficiency of its solar cells from 15 percent to 16.2 percent aperture area of the full 156 × 156 mm solar cell.

The solar cell was manufactured in a regular production run and the process is already implemented in the production line.

"Considering that the solar cell is made on stainless steel, contains no cadmium and that the production process is an all-dry, all vacuum process where all layers (including the buffer layer) are deposited by sputtering, this achievement by our engineers is truly impressive," says Sven Lindström, CEO Midsummer.

Inexpensive lightweight flexible modules

With the production system from Midsummer the solar cells are manufactured individually and then stringed together into modules just like crystalline solar cells. This way, lightweight flexible modules can easily be made in any size and shape.

A dry, all-vacuum process has less stringent requirements for cleanrooms. Avoiding cadmium in the manufacturing process is

desirable for the sake of the production staff and also makes it easier to begin low cost manufacturing of CIGS solar cells.

Market shifts towards rooftop installations

"The global solar cell market is facing a paradigm shift," adds Sven Lindström, CEO, Midsummer. "Fewer large solar energy parks are being built in Europe. Instead, focus is moving to installations on large buildings in cities. The lightweight and flexible thin film solar cells are ideal for this use. It is economically and environmentally more beneficial to use solar energy locally, where it is produced."

"Midsummer's objective is that our technology shall be a leader in the market segment lightweight, flexible solar panels, and that the company shall grow in tandem with this rapidly growing segment."

Market shifts towards rooftop installations

According to Sven Lindström, CEO, Midsummer, "The global solar cell market is facing a paradigm shift". "Fewer large solar energy parks are being built in Europe. Instead, focus is moving to installations on large buildings in cities. The lightweight and flexible thin film solar cells are ideal for this use. It is economically and environmentally more beneficial to use solar energy locally, where it is produced."

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XsunX revenues boosted

The CIGS solar cell provider has seen increased sale of its new solar systems

XsunX, Inc., a provider of CIGS solar energy solutions, has accelerated the sale of new solar systems, resulting in increased revenues.

The company says it has also met its gross margins target.

Tom Djokovich, CEO of XsunX, comments, "Everything we are doing appears to be headed in the right direction, which has allowed the company to begin to record revenue from completed systems with initial gross margins in excess of 30 percent. At the same time, we have nearly halved our operational costs and losses. With the sales through project delivery cycle requiring about three to six months for commercial systems, we are pleased to see that our early efforts are now resulting in so much positive momentum."

XsunX works directly with new business customers to document the financial benefits available from solar PV for their businesses, and then provides project design, engineering, and turnkey warranted installation.

In addition, and dependent on the client's ability to monetise the substantial tax benefits provided through solar investments, the company offers zero down financing programs that allow customers to save through substantial tax benefits or immediate and meaningful monthly reductions to cash flows delivered through a low cost lease-to-own option.

Djokovich adds, "Our system designs, technology, pricing, and finance options are exceptional and we have been addressing an under serviced area of the solar industry - commercial system sales - with growing success. Our goal now is to add to the millions we have in bids, close more sales, and grow revenues exponentially. We are hiring sales executives to help accelerate our project bid volume. With our added financing programs, and the addition of new sales personnel, we hope to continue our progress towards profitability."

Ascent Solar CIGS fly aboard Silent Falcon unmanned aircraft

The aircraft is designed for domestic and international commercial, public safety and defence applications

Ascent Solar's CIGS modules have been employed in the first successful flights of the production Silent Falcon Unmanned Aircraft Systems (SFUAS).

Silent Falcon UAS, jointly developed by SFUAS, Bye Aerospace and Ascent Solar, is a tactical drone designed to be easily deployed, and integrates proprietary, disruptive technology to deliver superior UAS performance.

The patent-pending Silent Falcon is a solar/electric powered, all composite and modular small Unmanned Aircraft System (sUAS) equipped with an interchangeable wing configuration designed for commercial, public safety and defence applications both domestically and internationally.

The Silent Falcon sUAS system

The combination of efficient aerodynamic design, lightweight composite construction and Ascent's monolithically integrated and ultra-lightweight thin film photovoltaic modules, enables the 25 lb. Silent Falcon UAS a remarkable six to twelve hour flight endurance.

"These first flights represent the culmination of tremendous collaboration between Ascent Solar, Bye Aerospace, and Silent Falcon UAS," states Joseph Armstrong, Chief Technology Officer of Ascent Solar.

"Overcoming technological challenges, our teams have

demonstrated the ability to integrate our flexible photovoltaics with appropriate power management systems into a feature-rich small unmanned aircraft system enabling extended mission flight time and, as a result, enhanced mission flexibility. More importantly, the photovoltaic modules integrated into the wings represent a lightweight version of our production materials, and as such, are immediately available," continues Armstrong.

"The Silent Falcon's unprecedented performance and value is ready for the market place as we transitioned from prototype and commenced low rate initial production," adds John Brown, President of SFUAS. "Our sales teams are targeting domestic, Latin America and the Asia Pacific region."

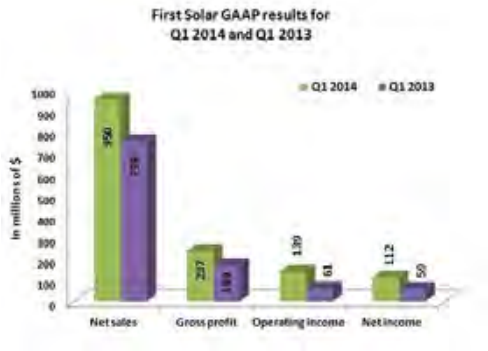
Silent Falcon UAS Technologies was established in 2010 to introduce disruptive technological UAV innovation to global defence, intelligence and national security agencies, the domestic public safety agency market and U.S.-based private security contractors. The company is headquartered in Albuquerque, New Mexico.

First Solar Q1 results shining bright

Net sales went up from $755 million in Q1 2013 to $950 million in Q1 2014

First Solar, Inc. has announced financial results for the first quarter of 2014. Net sales were $950 million in the quarter, an increase of $182 million from the fourth quarter of 2013. The sequential increase in net sales is primarily attributable to achieving revenue recognition on our Campo Verde project.

The company reported first quarter GAAP net income per fully diluted share of $1.10, compared to $0.64 in the prior quarter. The increase in net income compared to the prior quarter was primarily due to higher net sales, project cost improvements, and lower restructuring and asset impairment charges.



Cash and marketable securities at the end of the first quarter were approximately $1.4 billion, a decrease of approximately $385 million compared to the end of the fourth quarter of 2013. Cash flows used in operations were $318 million in the first quarter. The use of cash in the quarter is primarily related to ongoing construction of projects which have not yet been sold.

Based on the results of the first quarter the company is increasing full-year 2014 guidance as follows:

Gross Margin percentage of 17-18 percent, compared to prior guidance of 16-18 percent

Operating Income of $290 to $340 million, compared to prior guidance of $270 to $320 million

Earnings per fully diluted share guidance of $2.40 to $2.80, compared to prior guidance of $2.20 to $2.60

Operating cash flow guidance of $300 - $500 million, compared to prior guidance of $250 - $450 million

«In the first quarter we demonstrated significant progress towards achieving the financial and operational targets we outlined at our recent Analyst Day,» said Jim Hughes, CEO of First Solar. «We delivered strong earnings in the first quarter and are increasing our financial guidance for the year based on these results. We have also made significant progress in new bookings and continue to execute on our technology roadmap.»

First Solar held a conference call to discuss this announcement. A replay of the webcast will be available on the Investors section of the company›s web site and will remain available for approximately 90 calendar days.

First Solar to build 42.76MW for EDF Renewable Energy

The firm has been selected for two CdTe projects in California

First Solar has been chosen as the turnkey Engineering, Procurement and Construction (EPC) contractor for two projects under development by EDF Renewable Energy in California.

First Solar and EDF Renewable Energy have signed EPC agreements for the 19.76 Megawatt (MW) AC CID Solar Project, located in Kings County; and the 23MWAC Cottonwood Solar Project, consisting of two sites, one located in Kings County and the other in Kern County.

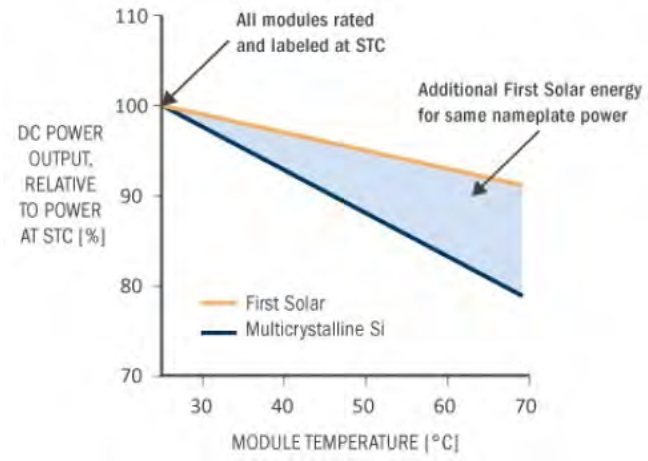
The CID Solar Project has a Power Purchase Agreement (PPA) with Pacific Gas and Electric Company. The Cottonwood project has a PPA with Marin Clean Energy.

"We are proud to be selected by EDF Renewable Energy as a builder of choice," says Christopher Houghton, First Solar's Senior Manager of US Business Development. "With these projects, First Solar continues to bring value to customers counting on our proven experience and reliability in providing cost-effective energy solutions."

Both CID Solar and Cottonwood projects will be built with First Solar's Series 3 Black Plus PV thin-film solar modules, and will provide enhanced grid reliability and stability using the company's advanced PV plant controls.

First Solar Series 3 Black Plus PV modules

Construction on the projects is expected to begin in the second quarter of 2014, with CID Solar anticipated completion in October 2014 and Cottonwood anticipated completion in the first quarter of 2015.



2D self-assembling material may produce solar cells

Ni3(HITP)2 shares graphene's hexagonal honeycomb structure for flat semiconductors and has a useable bandgap

Researchers around the world have been working to harness the unusual properties of graphene, a two-dimensional sheet of carbon atoms.

But graphene lacks one important characteristic that would make it even more useful: a property called a bandgap, which is essential for making devices such as computer chips and solar cells.

Now, researchers at MIT and Harvard University have found a two-dimensional material whose properties are very similar to graphene, but with some distinct advantages - including the fact that this material naturally has a useable bandgap.

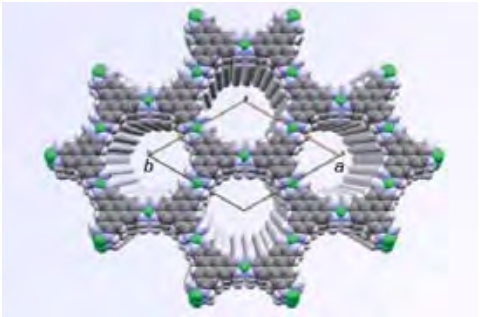
The research, published online in the *Journal of the American Chemical Society*, was carried out by MIT assistant professor of chemistry Mircea Dincă and seven co-authors.

The new material, a combination of nickel and an organic compound called HITP, also has the advantage of self-assembly: Its constituents naturally assemble themselves, a "bottom-up" approach that could lend itself to easier manufacturing and tuning of desired properties by adjusting relative amounts of the ingredients.

Research on such two-dimensional materials, which often possess extraordinary properties, is "all the rage these days, and for good reason," Dincă says.

Graphene, for example, has extremely good electrical and thermal conductivity, as well as great strength. But its lack of a bandgap forces researchers to modify it for certain uses - such as by adding other molecules that attach themselves to its structure - measures that tend to degrade the properties that made the material desirable in the first place.

The new compound, Ni3(HITP)2, shares graphene's perfectly hexagonal honeycomb structure. What's more, multiple layers of the material naturally form perfectly aligned stacks, with the openings at the centres of the hexagons all of precisely the same size, about 2 nanometres across.



A diagram of the molecular structure o Ni3(HITP)2 is pictured at the top of this story. The new material shows how it naturally forms a hexagonal lattice structure, and its two-dimensional

layers naturally arrange themselves so that the openings in the hexagons are all perfectly aligned. (Image is courtesy of the researchers)

In these initial experiments, the researchers studied the material in bulk form, rather than as flat sheets; Dincă says that makes the current results - including excellent electrical conductivity - even more impressive, since these properties should be better yet in a 2-D version of the material. "There's every reason to believe that the properties of the particles are worse than those of a sheet," he says, "but they're still impressive."

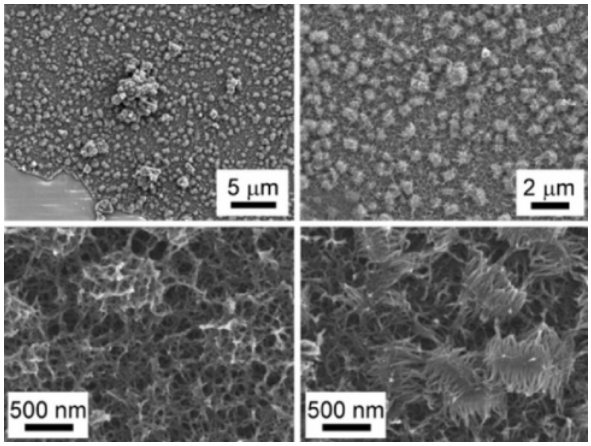
What's more, this is just the first of what could be a diverse family of similar materials built from different metals or organic compounds.

"Now we have an entire arsenal of organic synthesis and inorganic synthesis," Dincă says, that could be harnessed to "tune the properties, with atom-like precision and virtually infinite tuneability."

Such materials, Dincă says, might ultimately lend themselves to solar cells whose ability to capture different wavelengths of light could be matched to the solar spectrum, or to improved supercapacitors, which can store electrical energy until it's needed.

In addition, the new material could lend itself to use in basic research on the properties of matter, or to the creation of exotic materials such as magnetic topological insulators, or materials that exhibit quantum Hall effects.

"They're in the same class of materials that have been predicted to have exotic new electronic states," Dincă says. "These would be the first examples of these effects in materials made out of organic molecules. People are excited about that."



Scanning electron microscope images show the particles of Ni3(HITP)2 material at various levels of magnification. While the material in this study was in the form of nanoparticles, the analysis show that these particles are actually formed of collections of two-dimensional flakes (Image courtesy of the researchers)

Pingyun Feng, at the chemistry department at the University of California at Riverside who was not involved in this work, says the approach used by this team is "novel and surprising," and that "the quality of this work, from the synthetic design strategy to the probing of the structural details and to the discovery of exceptional electrical conductivity, is outstanding." She adds that this finding "represents a major advance in the synthetic design of novel semiconducting materials."

The work was supported by the U.S. Department of Energy and the Centre for Excitonics at MIT.

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http://web.mit.edu/newsoffice/

Ascent Solar delivers over $750,000 single EnerPlex shipment

The CIGS based modules are designed for the consumer market

Ascent Solar Technologies says it has shipped over $750,000 of its EnerPlex series of consumer products to Fry's Electronics for its upcoming anniversary sale.

The shipment is made up of multiple EnerPlex flagship and accessory product lines, all of which will be available for sale in Fry's stores beginning May 12th.

The completion of this single large order surpasses not only the company's entire Q4 2013 revenue by 30 percent, but also exceeds its EnerPlex Q1 2014 product revenue.

Richard Hashim, GM of Ascent Solar's EnerPlex Division, says, "EnerPlex is extremely pleased to be able to provide support for the demand we have seen for our EnerPlex products through our largest retailer, Fry's Electronics. This order is yet another example of the continuing increase in demand for EnerPlex's ultimate portable power solution, from solar chargers to rechargeable batteries and accessories."

"Ascent is set to achieve yet another milestone this quarter in terms of product revenue," continues Victor Lee, President & CEO of Ascent Solar. "We are extremely pleased with the momentum and acceleration of our EnerPlex brand building and product acceptance; factors which hopefully will be the catalyst of Ascent's rapid growth moving forward."

Fry's Electronics, founded in 1985 in Silicon Valley, is one an electronics retailer and says it is the go-to place for savvy and trend-setting technology consumers.

With thirty-four retail locations in nine states, Fry's provides an avenue for EnerPlex to connect with a knowledgeable, affluent and influential end-user customer base.

Power Electronics

Cree launches discrete 20A and 50A 650V SiC

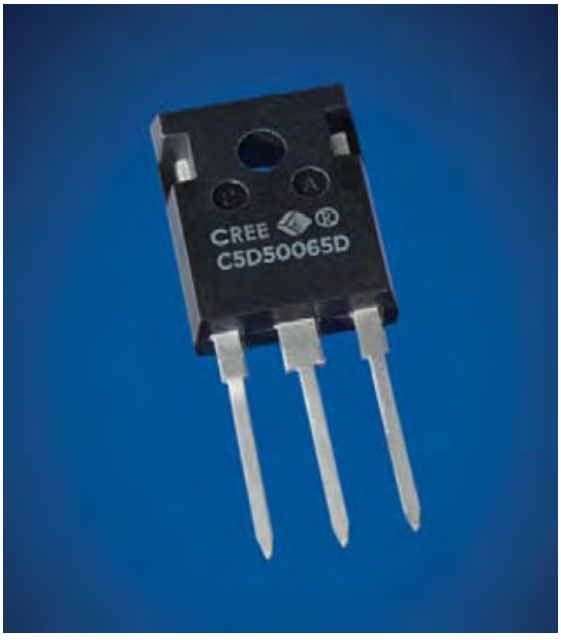
First member of Cree's high-power CPW5 diode family to be released in packaged form

Cree, Inc has announced the addition of two new discrete 650V SiC rectifiers to its Z-Rec Schottky diode portfolio.

Rated at 650V blocking voltage and 50A continuous forward current, Cree's C5D50065D Schottky diode is the first member of Cree's high power CPW5 diode family to be released in packaged form.

Available in a TO-247-3 package, the C5D5065D provides up to 2000A of non-repetitive surge capability at 25 degrees C, combined with the high continuous current-carrying capability of the CPW5 family. The 50A rectifier is suited for automotive on-board chargers, server power supplies, power conditioning, and high-reliability aerospace and military power systems.

Developed to provide increased switching efficiency through a reduced forward voltage, the CVFD20065A Schottky diode provides 20A of forward current capability with a nominal voltage drop of only 1.35V at 25 degrees C and is the first product to be released as part of Cree's new family of Low VF Z-Rec Schottky diodes.



Cree has also taken additional steps to bolster the surge capability of the CVFD20065A, resulting in a forward surge rating of 1400A at 25 degrees C (10µs pulse) – which the company says is the highest among all commercially available 20A, 650V SiC Schottky diodes.

Equipment and Materials

POET issues update on III-V based initiatives

The firm says the scale-down to sub-100-nm scale will demonstrate its ability to fabricate competitive digital devices with III-V materials for the first time

POET Technologies has provided a progress update on the 100-nm initiative, on the upgrade of its MBE system and on the technology design kit for the Planar Electronic Technology (PET) subset of the POET process.

POET Tech is a developer of the III-V based Planar Optoelectronic Technology (POET) platform for monolithic fabrication of integrated circuit devices containing both electronic and optical elements on a single semiconductor wafer.

100-nm Initiative

This milestone (M-8) is associated with reducing the feature size of key POET devices to the 100-nm range in scale. The firm had previously achieved sub-200-nm scaling as announced in the first quarter of this year. While work progresses to drive down feature size further, POET Tech says its technical team now believes that it will achieve this milestone in the near-term.

Among the technical challenges addressed by the team are short-channel effects and the development and implementation of a novel technique based on using a non-gold based contact, without liftoff, to achieve self-alignment. This results in a general digital device format for III-V technologies. Many of these processes have been captured as new intellectual property for the company by submission of patent applications.

Peter Copetti, Executive Chairman and interim CEO, notes, "The team has worked relentlessly through multiple hurdles on its way to completion of the 100-nm milestone. The scale-down to sub-100-nm scale will demonstrate our ability to fabricate competitive digital devices with III-V materials to a point that has never been demonstrated before."

The technical team has targeted the end of the second quarter 2014 for completion of this milestone.

Upgraded MBE

The MBE system is a key piece of process equipment on the POET pilot line. Earlier this year, the company announced that there was a requirement for the MBE system to be taken off-line for maintenance, as well as for source material replenishment and a major upgrade. In anticipation of this, it had used the MBE reactor to produce all material required for the 100-nm initiative, ahead of the scheduled outage.

As anticipated, the upgrade work required a total of two months of off-line work. This scheduled work is now completed, and the MBE system is back in service, growing wafers for use in further POET device work.

Geoff Taylor, Chief Scientist of the Company, notes, “With the old MBE system, we had demonstrated the short wavelength optical capabilities of our process, mainly for datacentre applications. With our newly upgraded MBE system, our capabilities have expanded to fabricating optical devices with long wavelengths. This is critical for our POET offerings in the long-haul, networking and optical equipment market.”

PET Technology Design Kit (TDK)

This PET/TDK milestone (MS-12) focuses on devices requiring only the electronic subset of the POET process; PET offers lower cost and simpler process fab options for applications that do not require the full POET optical feature set. The PET/TDK allows the company to deliver its technology to fab partners and customers, and enable further innovation to integrate both analogue and digital functions together – an application that is said to be not possible today using silicon CMOS.

The PET/TDK milestone is progressing well, and as planned. As noted previously, the addition of Daniel DeSimone to the team has allowed this activity to remain on track, while other activities progress in parallel.

Moving PET/TDK forward requires optimising POET Tech’s process technologies and devices using computer-aided design (TCAD) simulation. Specific TCAD efforts focus on complementary hetero-structure field-effect transistors (HFETs) and bipolar transistors (HBTs). This design basis will support complementary HFET (CHFET), bi-CHFET, bipolar and thyristor device fabrication.

CMOS technologies, both existing today and on the industry roadmap. PET/TDK models will be available to third parties around the end of the third quarter 2014.

Copetti notes, “Thanks are due to Dr. Taylor and the entire technical team for their dedication and relentless focus on the multiple milestones the Company has set for them.”

He adds, “While timelines have had to accommodate challenges in our drive to 100-nm, I am encouraged by the significant recent progress, especially in parallel with our PET/TDK achievements. Our potential partners and customers have noted this significant progress, and this has allowed me and my executive team to have very detailed discussions with them under non-disclosure agreements, many of them ongoing at this time.”

By enabling increased speed, density, reliability, power efficiency, and much lower bill-of-materials and assembly costs, the POET semiconductor platform is expected to provide disruptive performance with an industry-compatible transition framework, and positions the company as a player in the new generation of companies defining the growth paradigm in the post-Moore’s Law world.

SEMI-GAS expands mini gas enclosure line

The custom gas system performs automatic gas cylinder switchover and is suited to low flow applications or reactors operating in a limited space

SEMI-GAS Systems, a provider of ultra-high purity gas delivery equipment used in MOCVD growth, has launched the new model MGE-XS to its Mini Gas Enclosure product line.

MGE-XS Mini Gas Enclosure

Created to store and deliver ultra-high purity process gases from small gas cylinders, this new Xturion custom gas system also incorporates automatic cylinder switchover capabilities to help minimise manufacturing down-time and operator interaction.

With the addition of the new MGE-XS, SEMI-GAS’ MGE line now comes in two process models, each with two separate compartments housing two individual manifolds with separate purge inlets and vent outlets. The MGE-XS houses four process cylinders, providing two independent automatic switchover systems, in one compact package. While the original MGE-X houses two process cylinders and two dedicated purge cylinders.

Ideal for customers who have low flow applications or are operating in limited space, the MGE-XS is small, measuring 69” high by 32” wide by 27” deep.

The new mini gas enclosure line features an ergonomically bottom-mounted SEMI-GAS GigaGuard GSM Controller with 4.3” colour touchscreen, making cylinder changes and system status monitoring easy.

The GSM oversees all of the system’s operations, including the monitor and control of all process and purge gas electrical components and pneumatically actuated valves. The controller can function independently or with an optional kit that can

communicate via an Ethernet network, enabling centralised, facility-wide equipment monitoring and data collection.

In the event of excess gas flow, fire detection or facility shut down input, pneumatically actuated Emergency Shut Off (ESO) valves will interrupt the process gas supply to the manifold lines, initiating an automatic shutdown. A pneumatic ESO button is mounted on the front of the enclosure to manually trigger a system shutdown. In either event, an audible horn and blinking LED status lights notify operators that a risk has been detected.

The exhaustible MGE-XS enclosure accommodates hazardous and non-hazardous gases and is constructed of welded 11 gauge cold-rolled steel. It also includes reinforced rear mounting holes for wall installations or an optional welded steel rack for free standing applications. To further customise on-site fit-up of the MGE-XS, each unit features adjustable steel shelves, adjustable cylinder straps and adjustable back or top mounted exhaust ducts.

All MGE-X systems meet SEMI S2 and Uniform Fire Code requirements and are equipped with UL-approved fire sprinklers and ¼" safety glass windows. Self closing and lockable doors and windows, as well as a steel cylinder divider plate, and gas identification safety labels come standard, further meeting the specifications for the safe handling of hazardous production materials.

Internal panel components are orbitally welded, helium leak tested and certified to the highest purity standards. All valves, regulators, transducers, tubing and fitting bodies are 316L stainless steel to prevent corrosion from hazardous gas applications.

Jim Murphy, Division Manager of SEMI-GAS Systems says, "SEMI-GAS created a defining way to deliver low volume gases with the compact MGE-X, and the XS model is another advance. Even with low volume applications, customers want to minimise human-system interaction and maximise process tool up-time. MGE-XS accomplishes both these industry demands with automatic switchover capabilities, while also meeting the same expectations for safety, reliability, quality and minimal footprint found in the original ground-breaking model."

Aixtron makes strategic changes to executive board

The mutual decision sees CFO Wolfgang Breme leaving the group

Aixtron SE, a provider of deposition equipment to the semiconductor industry, has announced that that CFO Wolfgang Breme is leaving the group as of May 31st, 2014 by mutual agreement.

He will pursue new career opportunities outside the company.

"The Supervisory Board approved the termination of his service agreement with effect as of May 31st, 2014 and regrets Mr. Breme's departure," says Kim Schindelhauer, chairman of the Supervisory Board of Aixtron, and thanks Breme for his commitment.

"Over the past nine years, Mr. Breme has contributed decisively to the successful development and financial stability with his high personal commitment. Supervisory Board, Executive Board and the Aixtron team wish him all the very best for his future endeavours," adds Schindelhauer.

A new CFO will not be appointed.

The chairman of the Executive Board, Martin Goetzeler, will take over the tasks previously performed by Breme. The service agreement of the current Chief Operating Officer, Bernd Schulte, will be renewed for a term of three years until March 31st, 2018.

Brewer Science commercialises megasonic developer for compound semiconductor applications

Megasonic developer applies uniform acoustic energy to spinning substrates to gently dissolve and remove films and residues without damaging fragile device structures

Brewer Science, a supplier of advanced materials, processes, and equipment to the microelectronics industry, has announced the first commercial placement of a Cee 300MXD megasonic developer. This innovative developer was commissioned by MicroChem Corp.

The Brewer Science Cee 300MXD megasonic developer applies uniform acoustic energy to spinning substrates to gently dissolve and remove films and residues without damaging fragile device structures. This precision handling results in stable dimensional control of vertical profiles uniformly across the wafer surface, enabling fabrication of high-aspect-ratio structures for the MEMS, display, compound semiconductor, and advanced packaging markets. Applications include radio-frequency (RF) power, MEMS, sensors, and acoustic wave devices used for wireless communication.

"MicroChem is very pleased to team with Brewer Science on what we believe could be an enabling technology for the future," said Michael Stan, Applications Engineering Manager for MicroChem Corp. "As the MEMS industry and integrated packaging technology continue to demand higher-aspect-ratio structures for TSV and RDL layers, enhanced development techniques will likely become mainstream. The cost-effective approach being pioneered by Brewer Science gives a supplier such as MicroChem Corp. the advantage of being able to rapidly prototype formulations and processes to meet these demands," he added.

"The Cee 300MXD developer features state-of-the-art technology that creates a viable pathway for our customers to decrease process cycle times, reduce cost of ownership, and accelerate time to market," said Justin Furse, Brewer Science

Equipment Technology Strategist.

The Cee 300MXD megasonic developer gives customers a bridge from the lab to production by allowing them to avoid significant capital investment and is suitable for low-volume prototyping with a seamless transition to high-volume manufacturing.

Brewer Science announce Apogee temporary wafer bonder

New bonder completes Brewer Science tool suite for low-volume production or R&D lab environments

Brewer Science, Inc., a supplier of thin-wafer handling technology, materials, and equipment to the microelectronics industry, has unveiled the Brewer Science Apogee bonder for temporary wafer bonding applications.

The Apogee bonder supports multiple temporary bonding/debonding technologies including thermal slide, mechanical peel, and laser release debonding. The Apogee bonder completes the Brewer Science thin wafer handling tool suite for low-volume compound semiconductor production of RF filters, analog power devices, LEDs, and solar devices.

Brewer Science says this collection of tools provides reduced time to market for ultrathin wafer technologies using integrated material and process solutions.

The Brewer Science Apogee features include:

Substrate size range of 50-300 mm
Dual rigid platens heat wafer stack from both sides, minimizing thermal defects
Ultraflat self-leveling platens minimize total thickness variation (TTV)
Evacuated bond chamber eliminates voids
Carrier and device are separated during pre-bond evacuation
Total thickness variation:

Semiconductor veteran joins Veeco as CFO

Maheshwari brings more than twenty years of experience in engineering and finance to Veeco

Veeco Instruments has appointed Shubham Maheshwari, 42, as its new Executive Vice President, Finance and Chief Financial Officer (CFO). Maheshwari replaces David D. Glass, who announced his retirement from Veeco last December.

Shubham Maheshwari, Executive Vice President, Finance and Chief Financial Officer, Veeco

Maheshwari most recently served as Chief Financial Officer of OnCore, a global manufacturer of electronic products in the medical, aerospace, defence and industrial markets.

Prior to this role, he held various finance roles including Senior Vice President Finance, Treasury, Tax and Investor Relations at Spansion, a global developer of Flash memory based embedded system solutions. Maheshwari helped lead Spansion's emergence from bankruptcy to become a successful public company.

Prior to Spansion, he spent over ten years at KLA-Tencor, a global semiconductor capital equipment manufacturing company, in various senior level corporate development and finance roles, including Vice President of Corporate Development and Corporate Controller. During his tenure at KLA-Tencor, he worked on over $1 billion in acquisition transactions.

He holds a B.S. in Chemical Engineering from the Indian Institute of Technology in Delhi, India, an M.S. in Chemical Engineering from Kansas State University, and an MBA from the Wharton Business School, University of Pennsylvania.

John Peeler, Veeco's Chairman and Chief Executive Officer, comments, "Shubham brings an ideal mix of highly relevant financial leadership experience to Veeco. I am confident he will hit the ground running to help take Veeco to the next level of performance. I'm extremely pleased that Shubham has joined our leadership team."

"Veeco is a great match for me and I'm excited to come on board," comments Maheshwari. "Veeco has done an impressive job managing through an extended downturn, but I think the best is still in front of the Company. I look forward

to helping to strengthen the business and capitalising on the significant growth opportunities ahead."

NALCO interested in sourcing technology supplier for gallium extraction plant

The plant is to be set up at the firm's Alumina Refinery located at Damanjodi, Odisha, India through a JV or standalone

National Aluminium Company Ltd (NALCO) is interested in sourcing a suitable and low cost technology supplier for setting up a gallium extraction unit/plant in the company's Alumina Refinery located at Damanjodi, Odisha through a Joint Venture or standalone having gallium metal purity of ≥ 99.99 % (4N+).

The capacity of the plant will be of around ten tonnes per annum, low cost and economically viable with state of the art environment friendly technology environment standard.

For this purpose NALCO invites Expression of Interest (EOI) from interested and competent manufacturers, and technology suppliers interested in providing technology for extraction of gallium from Nalco Bayer liquor (intermediate process liquor generated from Digestion of bauxite by the "Bayer" process) and having expertise in production and marketing of metallic gallium or gallium compounds.

On receiving proposals from the parties again, a fresh tender will be floated to the shortlisted parties for selection of the suitable technology provider on gallium extraction from Bauxitic resources.

NALCO was incorporated in 1981 following a major investment decision by the Government of India to exploit a part of the Bauxite deposit discovered in the East Coast of India.

The company says it has charted an excellent track record in both physical and financial performance, and has been listed in the LME (London Metal exchange).Recently, the company was conferred the "Nav Ratna"(literally Nine Jewels} by the Government of India, in recognition of its consistent performance over the years, hereby incorporating higher investment and operational autonomy.

NALCO is operating a multi-location Bauxite Mines-Alumina-Aluminium complex along with a Captive Power Plant, in the State of Odisha, India. A major expansion programme (1st phase) was completed in 2001. The Phase-2 expansion was finished in July, 2012 and upgrading activity of the Refinery after Phase 2 expansion been completed.

Mines up-gradation is currently ongoing.

The company is listed on National Stock Exchange of India and Mumbai stock exchange

The process of extraction of Alumina from its mineral bauxite in caustic liquor solution is commonly known as the "Bayer" process. Bauxite received from Mines is either stacked in stock pile or fed directly to secondary crusher for size reduction. Secondary crushed bauxite from Silo is fed to Ball Mill along with caustic liquor for grinding.

Ground bauxite slurry after Pre-desilication is digested at atmospheric pressure (temperature 105 - 106 degree C) for extraction of alumina.

Undigested bauxite is separated as Red mud. Aluminate liquor is cooled to precipitate ATH (alumina trihydrate) which is calcined to produce alumina.

Gallium dissolves in liquid phase and get enriched with time as NALCO is not extracting gallium metal or any compound till now. But some amount of gallium is escaping from the plant liquor during discharge of red mud as well as with product alumina.

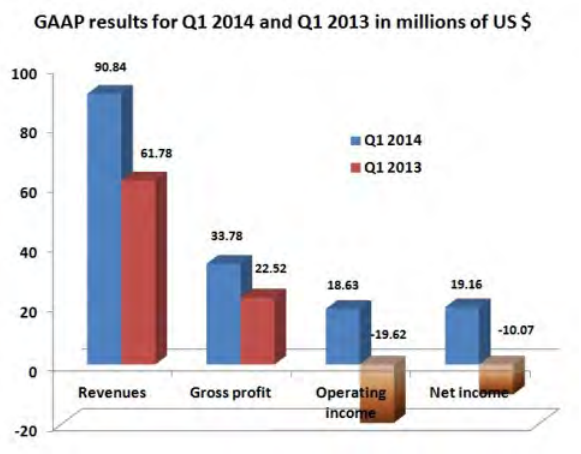
Veeco Q1 2014 results blossom

An increase in LED & Solar revenue increased to $71 million, with $64 million in MOCVD

Veeco Instruments Inc. has announced its financial results for the first quarter ended March 31st, 2014.

The semiconductor reactor manufacturer has reported its results on a U.S. GAAP basis, and has also provided results excluding certain items.

Veeco's first quarter GAAP results include a one-time gain of $29 million from the reversal of Synos acquisition related contingency accruals since it determined that the post-closing milestones necessary to trigger such contingency payments were not expected to be achieved.



«Veeco's first quarter top and bottom line performance improved meaningfully from the fourth quarter of last year," commented John R. Peeler, Chairman and Chief Executive Officer. "We delivered $91 million in revenue, up 24 percent from the fourth quarter of 2013, driven primarily by an increase in LED & Solar revenue to $71 million ($64 million in MOCVD).

First quarter 2014 Data Storage revenues were $20 million, up from $17 million in the fourth quarter of 2013. EBITA loss was $3 million, significantly improved from last quarter's loss, benefiting from higher volume, an improvement in gross margins to 37 percent, and lower operating spending. As forecasted, our investments in next generation products and in our growth businesses caused cash to decline modestly during the quarter. Yet our cash and investments balance remains strong at $483 million."

Peeler continued, "Veeco's first quarter 2014 orders improved by 21 percent from the fourth quarter of 2013 to $103 million, the highest level we have reported in nearly two years. This increase was driven by a 59 percent sequential improvement in MOCVD orders to $83 million, which represents the highest amount booked since the third quarter of 2011. Orders were received from top LED customers throughout Asia and elsewhere."

First quarter 2014 Data Storage and MBE orders each declined from the fourth quarter of 2013, to $15 million and $5 million, respectively.

Second Quarter 2014 Guidance and Outlook

Veeco's second quarter 2014 revenue is currently forecasted to be between $87 million and $97 million. Earnings per share are currently forecasted to be between ($0.46) to ($0.36) on a GAAP basis.

Peeler commented, "After a long downturn in our MOCVD business, LED fab utilisation rates have improved to high levels at most key accounts and LED adoption is happening faster than many had expected. Our customers are also reporting better market demand for LED backlighting products. It is encouraging to see that our leading customers are beginning to place orders for capacity expansions.»

« We currently anticipate that Veeco's second quarter 2014 orders will be similar to or better than first quarter orders. Yet, the timing and magnitude of key customer expansions could cause MOCVD orders to be lumpy and somewhat unpredictable on a quarterly basis, and we lack the visibility to see into the second half of the year. We continue to invest in MOCVD product and technology development to further improve our customers' cost of ownership and manufacturing capability."

Peeler concluded, "We are pleased to have made progress improving Veeco's profitability and remain focused on our strategy to turn around our performance: 1) developing and launching game-changing new products that enable cost effective LED lighting, flexible OLED encapsulation and other emerging technologies; 2) improving customer cost of ownership as well as our gross margins; 3) driving process improvement initiatives to make us more efficient; and 4) lowering expenses."

Aixtron orders and revenues up year-on-year

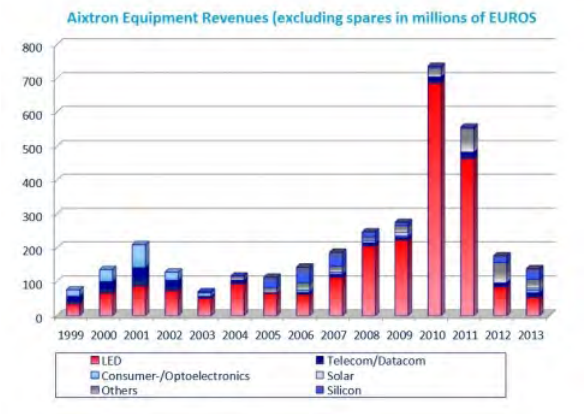
The boost in revenues was mainly due to inventory write-downs and restructuring charges included in the previous years' figures, However, the company is not expected to be profitable on an EBIT basis over the course of this year

Aixtron SE has announced revenues of EUR (€) 43.9 million for the first quarter of 2014, representing a year-on-year improvement of 9 percent.

Q1/2014 EBIT at €10.9 million and net result at €11.8 million were both up year-on-year by 86 percent and 84 percent respectively.

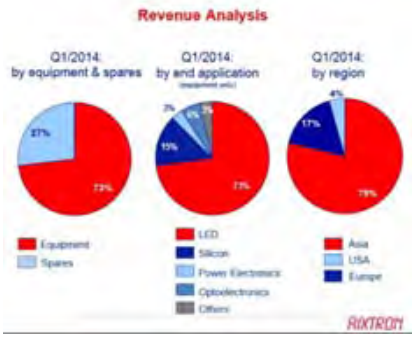
This development was mainly due to inventory write-downs and restructuring charges included in the previous years' figures, but also reflects a reduction in operating costs.

Aixtron's order intake in Q1 2014 improved by 26 percent year-on-year to €37.7 million



Financial Highlights

Capacity utilisation rates at LED manufacturers remain at relatively high levels and demand for LEDs continues to be on the rise. Despite this, there was still no noticeable increase in investments in LED manufacturing capacity expansions in Q1/2014 as depicted in the graph below.



Thus, Aixtron generated total revenues of €43.9 million for the quarter. This is a 9 percent increase from the €40.2 million in

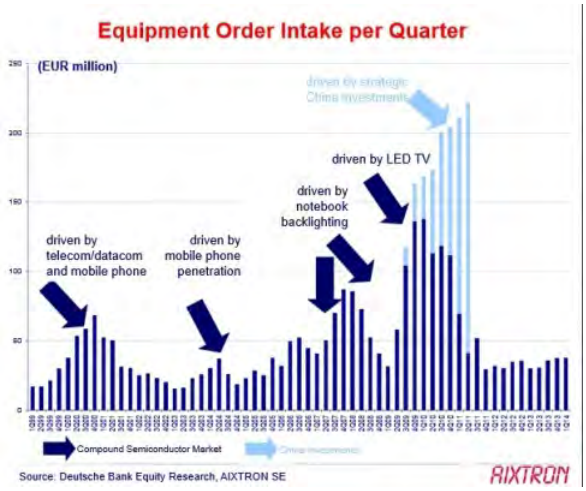
the same period last year and 14 percent down on the previous quarter (Q4/2013: €51.1 million).

The company's gross profit increased significantly year-on-year from €-47.7 million to €10.8 million, as no significant unusual items occurred in Q1/2014 (Q1/2013: €43.0 million inventory write-downs). Sequentially, gross profit was 38 percent lower than in the previous quarter, mainly due to a less favourable product mix (Q4/2013: €17.4 million).

Operating expenses reduced significantly both sequentially and year-on-year to €21.7 million (Q1/2013: €28.6 million; Q4/2013: €30.0 million). This reduction was partially due to restructuring charges included in the previous years' figure and reflects the company's ongoing focus on cost management.

Consequently, EBIT for Q1/2013 also improved both year-on-year and sequentially and came in at €10.9 million (Q1/2013: €76.3 million). The net result for Q1/2014 amounted to €11.8 million compared to the same €76.0 million quarter last year.

Aixtron's equipment order intake, still at low levels, was up year-on-year and at €37.7 million showed an increase of €7.8 million from the €29.9 million in Q1/2013.



The total equipment order backlog of €64.2 million as at March 31st, 2014 was 10 percent higher than the 2014 opening backlog of €58.1m, revalued as of January 1st, 2014, at the US-Dollar exchange rate of 1.35 USD/EUR valid at that time. Compared to the same time in the previous year, it was 18 percent lower (March 31st, 2013: €78.4 million).

Research and development costs in Q1/2014 decreased year-on-year by 17 percent to €13.7 million (Q1/2013: €16.6 million ; Q4/2013: €15.8 million) but at 31 percent of revenues still remained at a relatively high level. This underlines the important strategic significance of Aixtron's internal R&D capabilities.

Incurred losses and tax payments meant that free cash flow dropped to €13.8 million in Q1/2014 (Q1/2013: €9.3 million). Cash and cash equivalents (including bank deposits with a maturity of more than three months) as of March 31st, 2014 amounted to €292.0 million (December 31st, 2013: €306.3 million).

Management Review

Martin Goetzeler, President & Chief Executive Officer of Aixtron SE said, "We do sense that sentiment among customers is improving as the growth in the LED market drives the customers' profitability. According to leading market research firms, the LED market demand will continue to grow. This positive outlook in combination with our new MOCVD tool to be launched in the second half of this year underlines our confidence in our future development."

Goetzeler continued, by reiterating the importance of consistent R&D investments. He says, "Independent of current market developments, we continue to maintain a strong focus on R&D, providing for a competitive technology portfolio and supporting future business development. We will continue to monitor these investments very closely - in line with our ongoing focus on cost management and the improvement of processes which are amongst others central elements of our 5-Point-Program."

Guidance

Management reiterates its guidance made at the end of February for 2014, for this year's revenues to be in line with those of last year. Concurrently, the company is not expected to be profitable on an EBIT basis over the course of this year. Nevertheless, Management expects a year-on-year improvement in earnings due to progress made in cost savings and restructuring.

Emcore launches two-channel portable terahertz spectrometer

The new tool expands tetrahertz systems capabilities to include two-channels enabling simultaneous transmission and reflection measurements

Emcore Corporation has announced its latest breakthrough in terahertz technology with the release of the new PB7220-2000-T/R two-channel portable frequency domain Terahertz (THz) spectrometer.

PB7220-2000-T/R

The PB7220-2000-T/R is capable of simultaneous phase coherent measurements of both the transmission and the reflection properties of a sample. The second channel allows a single system to collect sample information at various angles of reflection or scattering from the sample while continuously monitoring the transmission.

The PB7220-2000-T/R expands Emcore's terahertz spectrometer line which also includes the PB7220-2000-T single channel system.

The company's PB7220 series THz spectrometers are designed for THz researchers and application developers who need to study the properties of materials at THz frequencies with high resolution, but don't have the resources or personnel skilled in the complexities of optical measurements.

Emcore says they are economical and portable THz systems that can sweep from 100 GHz to over 1.8 THz in a single rapid scan with high-frequency resolution.

The PB7220 series employs precisely tuned, fibre-coupled, semiconductor distributed feedback lasers along with a highly advanced photo-mixing source that puts all the THz power at the frequency of interest, yielding excellent signal-to-noise ratios of up to 70 dB Hz across the scan range.

In addition, the PB7220 series features sophisticated digital control hardware and software to provide a fully turnkey, portable THz spectrometer system.

"The PB7220 two-channel system is the most significant advancement in our THz technology since the introduction of PB7100 THz spectrometer in 2006," says Joseph Demers, Director of Advanced Photonics for Emcore.

"The industry has been seeking an economical two-channel system that can allow the simultaneous measurement of both the transmission and reflection properties of a sample. This added versatility in our THz platform makes it an even more valuable and flexible tool for a wider range of research, defence and homeland security related applications," adds Demers.

All PB7220 series models feature fibre-optically-coupled source and detector heads that are mounted on a rail system. The PB7220-2000-T single-channel system utilises a single rail while the PB7220-2000-R/T two-channel system employs an adaptable optical bench.

For both systems the source and detector heads may be detached from the processor unit and used with extended fibre optic cables to provide maximum measurement flexibility in a wide range of applications.

Agilent unveils analyser for power circuit design

The firm's tool characterises power device parameters, such as RDSon, Leakage, Ciss, Coss, Crss and gate charge

Agilent Technologies says it has introduced the industry's first power device analyser for circuit design.

The Agilent B1506A is a single-box solution that automatically characterises all power device parameters across a wide range of operating conditions and temperatures (-50°C to +250°C), at up to 1500 amps and 3 kV.

Circuit designers employ power devices in a wide range of products, therefore requiring an accurate, thorough understanding of their performance over a wide range of conditions.

However, power device data sheets typically show behaviour across only a limited range of operating conditions, and obtaining key datasheet parameters is not a straightforward process.

By providing an automated, easy-to-use way to extract power device parameters, Agilent's B1506A power device analyser for circuit design is equipped to overcome these challenges.

The B1506A measures and evaluates all kinds of parameters, including IV parameters (e.g., breakdown voltage and on-resistance); three terminal capacitances (Ciss, Coss and Crss) with high-voltage bias; gate charge; switching time; and power losses.

It also provides a fully automated measurement of temperature dependency for all parameters, from -50°C to +250°C, and seamlessly integrates with Thermal Plate or Thermostream from in Test Corp.

The GUI makes it easy for a user to extract critical device parameters across a wide range of current, voltage and temperature conditions. Such capabilities make the B1506A ideal for helping designers select the right power devices for their power electronic circuits, and for power electronics manufacturers conducting incoming device inspection and failure analysis.

"While the power devices used in power electronics circuits

are key to meeting industry requirements for low power loss and high switching frequency, until now no suitable solution has existed for evaluating all of the characteristics of those devices," says Masaki Yamamoto, general manager of Agilent's Hachioji Semiconductor Test Division. "The B1506A promises to fill this gap by providing complete characterisation for those key power devices in an automated fashion."

U.S. Pricing and Availability

The Agilent B1506A Power Device Analyzer may be ordered starting July 1. Three models are available - Opt. H21 (20 A), Opt. H51 (500 A) and Opt. H71 (1500 A) - with pricing from $120,000 to $160,000.

GTAT and EVG sign MOU to advance bonding technology

The firms will work together to develop high volume production processes and equipment necessary to bond the ultra-thin sapphire and SiC lamina to engineered substrates such as glass, silicon, and plastics

GT Advanced Technologies (GTAT) has announced several new initiatives aimed at expanding its portfolio of sapphire and SiC solutions for next generation consumer and industrial products.

The company has entered into a memorandum of understanding (MOU) with European-based EV Group (EVG), which specialises in bonding and material handling equipment.

The firms will work together in various collaborative arrangements including jointly developing high volume production processes and equipment necessary to bond the ultra-thin sapphire and SiC lamina, produced by GT's Hyperion technology, to engineered substrates such as glass, silicon, and plastics.

In addition, GT announced it will begin working with a leading glass substrate producer to develop specially engineered substrate materials that can be bonded to ultra-thin sapphire lamina to create unique composite solutions that expand the reach of sapphire into a broader set of applications.

The company also announced that it has acquired patent-pending technology for producing low-cost, scratch-resistant aluminium oxide coatings for various substrates including glass and plastics.

These coatings are expected to provide some of the durability and scratch-resistant properties of crystalline sapphire at a lower price point to address market opportunities where cost is paramount and not all of the properties of sapphire are required.

GT's business model will be focused on selling the bonding and coating equipment developed through these initiatives.

"Our sapphire composite material development program is focused on leveraging the combined expertise of GT and our technology partners in order to build a new market for low-cost and highly-durable substrate solutions for next generation consumer and industrial products," says Tom Gutierrez, GT's president and CEO. "These programs enhance our technology portfolio and leverage our significant investment in our Hyperion technology."

Novel Devices

Beyond graphene: Boron nitride could advance electronics

cientists have demonstrated that layers in 2D stacks can interact strongly and enlighten researchers on how to control the properties of such heterostructures

Researchers at The University of Manchester have shown how they can control the properties of stacks of two-dimensional materials, opening up opportunities for new, previously-unimagined electronic devices.

The isolation of graphene at the University in 2004 led to the discovery of many other 2D crystals.

While graphene has an unrivalled set of superlatives, these crystals cover a large range of properties: from the most conductive to isolating, from transparent to optically active.

The next step is to combine several of these crystals in a 3D stack. This way, one can create 'heterostructures' with novel functionalities - capable of delivering applications as yet beyond the imagination of scientists and commercial partners.

The first examples of such heterostructures already exist. These include tunnelling transistors, resonant tunnelling diodes, and solar cells.

Writing in *Nature Physics*, the scientists, led by Nobel Laureate Sir Kostya Novoselov, demonstrate that layers in such stacks can interact strongly, which helps the researchers learn how to control the properties of such heterostructures.

By controlling the relative orientation between graphene and underlying boron nitride (BN) - one of the 2D materials and an excellent insulator - the team can reconstruct the crystal structure of graphene.

Both hexagonal and cubic BN are wide-gap semiconductors with a band gap energy corresponding to the UV region. If voltage is applied to h-BN or c-BN, then it emits UV light in the range 215 - 250 nm and therefore can potentially be used as LEDs or lasers.in graphene and even opening of a band-gap, which might be useful for the functionality of many electronic devices.

Novoselov says, "Research on heterostructures is gaining momentum, and such possibilities for controlling the properties

of heterostructures might become very useful for future applications."

PhD student Colin Woods, the researcher who carried out the vast majority of the work, explains, "It was extremely exciting to see that the properties of graphene can change so dramatically by simply twisting the two crystals only a fraction of a degree. Generally, the previous model used to describe the sort of interaction which has been observed in our experiments describes only the 1-dimensional case, but even there it produces very nontrivial solutions. We hope that our system will push the mathematical development of the model to two-dimensions, where even more exciting mathematics is to be expected."

The work has been described in the paper, "Commensurate-incommensurate transition in graphene on hexagonal boron nitride," by C. R. Woods *et al* in *Nature Physics* (2014). doi:10.1038/nphys2954