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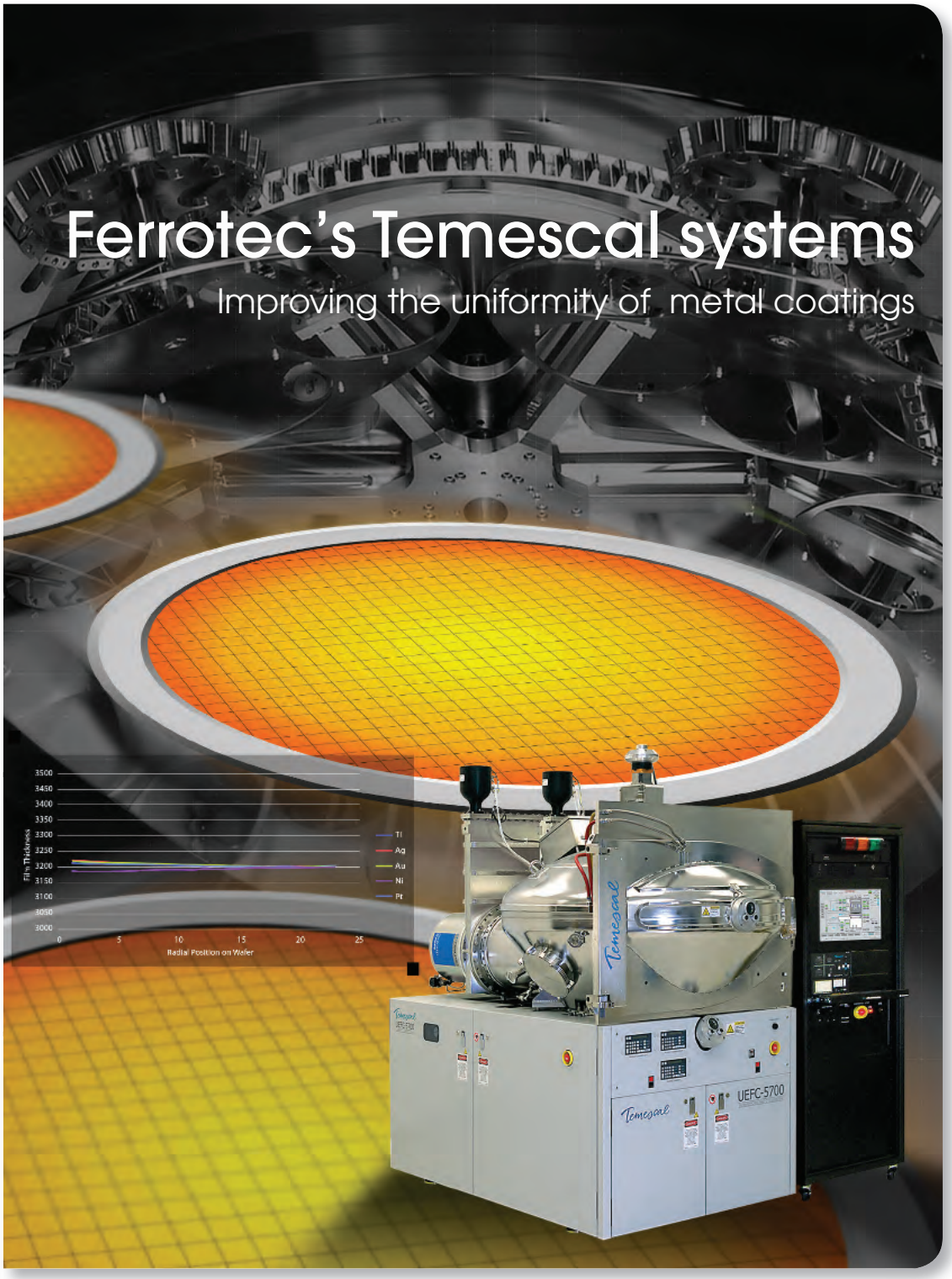
GaN LEDs go from green to red

SiC diodes reach ultra-high voltages

Battle for MOCVD sales intensifies

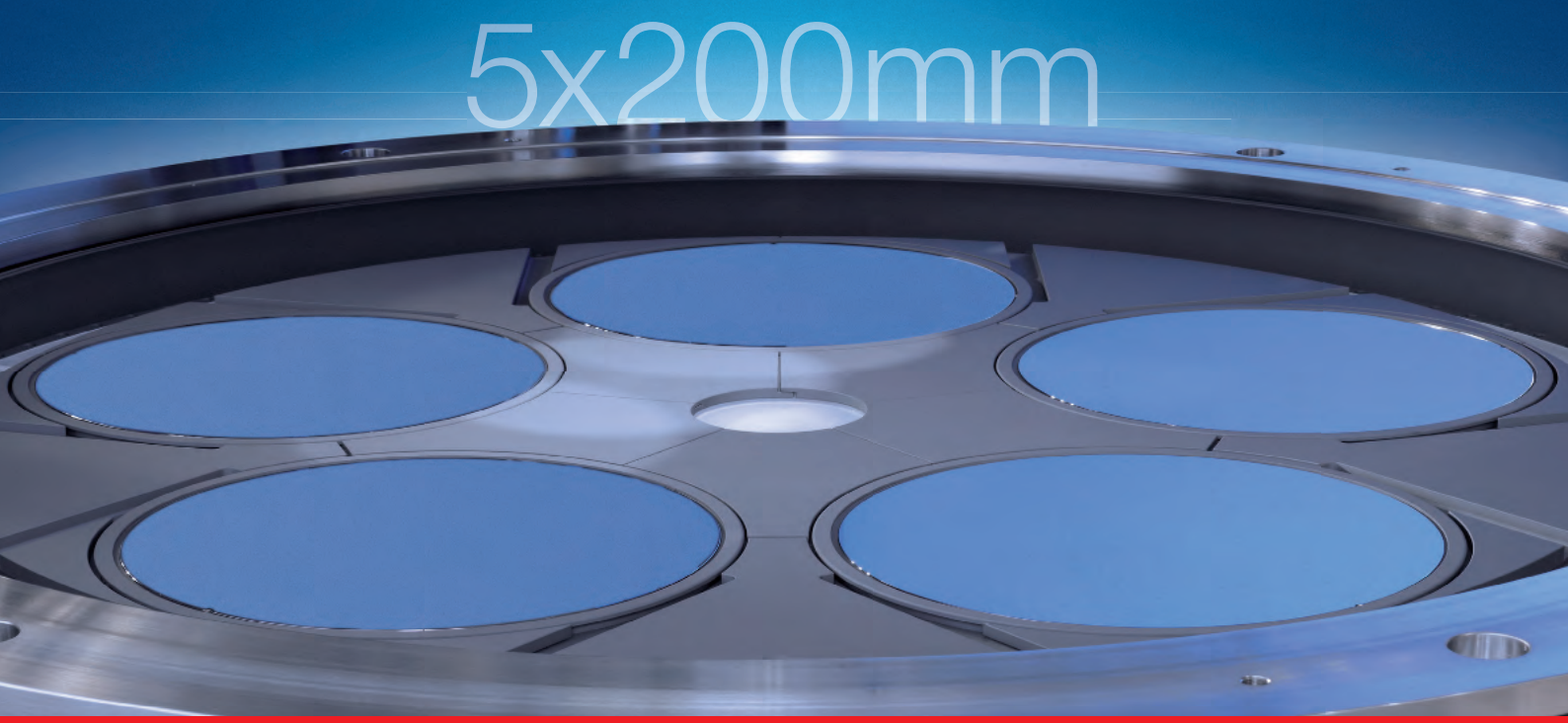
Cutting costs for semi-polar GaN

New boss' plans for MOCVD firm



AIXTRON

200mm GaN-on-Si Batch Reactor



AIX G5+

AIX G5+ for GaN-on-Si

- Dedicated technology package
- Compatible with the AIX G5 HT platform
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ALWAYS ONE STEP AHEAD

editorial view

by Dr Richard Stevenson, Editor

Growing together

When you're at a party, you may dread being asked what you do. Often, saying that you work in the compound semiconductor industry will kill the conversation dead, because the person that you are talking to will have little idea of what you do. All they will grasp is that it is very technical.

What they will fail to appreciate, but you as an insider know, is that the CS industry is certainly not a niche, but a rather large collection of them: power electronics, RF devices, lasers, long-wavelength detectors and so on.

What holds all of these disparate sectors together is the way we make our devices: nearly every chip that we produce involves the growth of crystalline layers, either by MOCVD or MBE.

One of the leading manufacturers of MOCVD tools is Aixtron. This German outfit has traditionally taken the largest share of reactor sales, but in recent times Veeco has pulled ahead, thanks to greater success in China. Aixtron's new boss, Martin Goetzeler, is planning to take the company back to its leadership position, while improving the balance sheet, and on page 33 you can read his interview with this magazine.

In this issue, you can also learn about the development of reactors at the Japanese firm Taiyo Nippon Sanso. This company has traditionally focused on its domestic market, but now seems to be striving for a more global presence. Another of this firm's aims is to promote its tools for the growth of power electronic devices and ultraviolet LEDs. Both markets are still in their infancy, but have the potential to drive an increase in reactor sales, which should also get a boost from the uptake of solid-state lighting.

At present, MOCVD manufacturers are still suffering from overcapacity in the LED market, which followed the boom years of 2010 and 2011. But hopefully order visibility will soon improve, with sales taking a steady, maintainable upward path that will enable a healthy business for tool makers, which is ultimately good for all of us.

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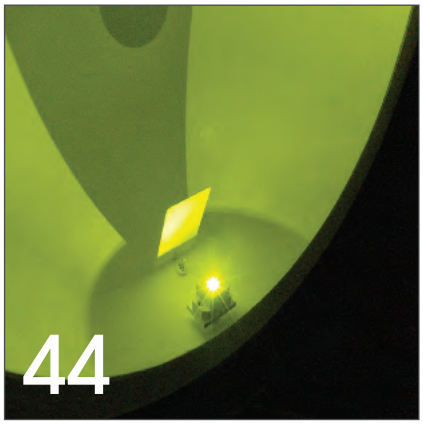

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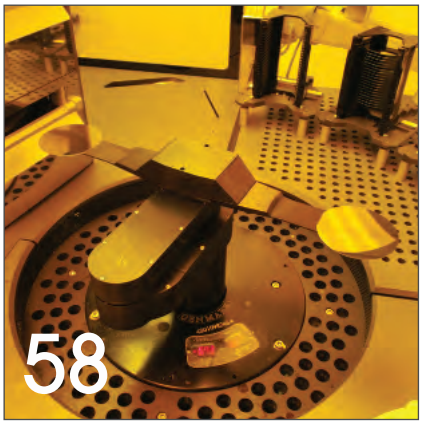

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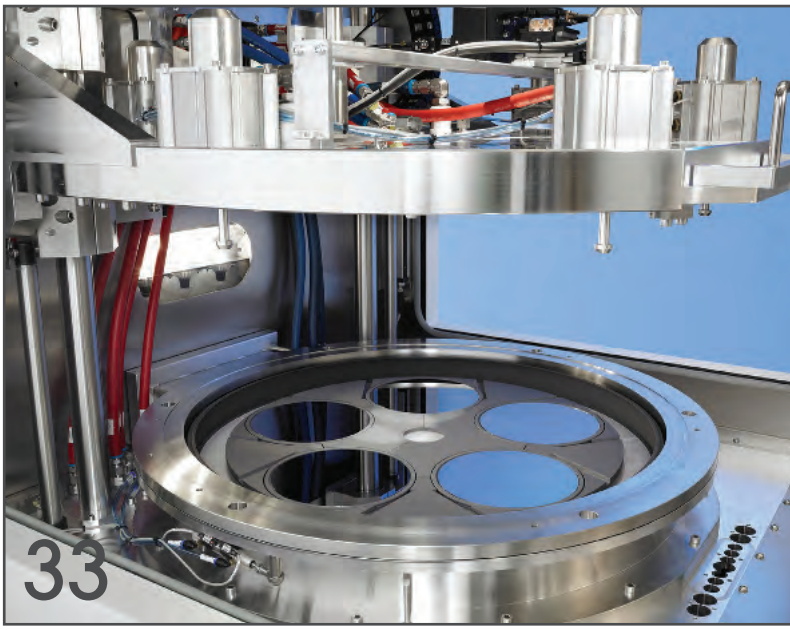

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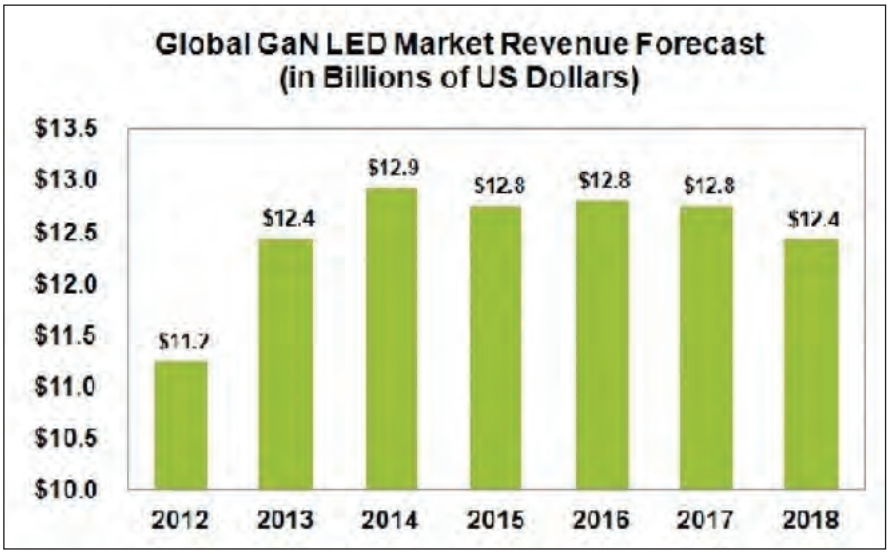
Magazine & Front Cover designed by Mitch Gaynor

GaN LED revenue lifts 10.6 percent in 2013

DRIVEN BY SURGING DEMAND from the lighting, tablet and mobile phone backlighting segments, global revenue for GaN LEDs climbed 10.6 percent in 2013, but this could mark the last hurrah for the era of double-digit dollar growth for the market.

Worldwide revenue for GaN LEDs rose to $12.4 billion in 2013, up from $11.2 billion in 2012, according to IHS Technology. Revenue growth this year is forecast at 4 percent, with sales totalling $12.9 billion. Although unit shipments will continue to rise, the market will enter a sustained period of flatness starting in 2015, based on data from the new IHS report, *Quarterly GaN LED Supply and Demand Market Tracker: Q4 '13.*



"The GaN LED market has experienced strong revenue growth in recent years, propelled by the combination of growing demand from the lighting and display backlighting segments," says Jamie Fox, principal analyst for LEDs at IHS. "However, LED backlighting market revenue has begun to decline – although lighting will continue to expand. The combination of the contraction in backlighting and rise in lighting will result in flat revenue for the GaN LED market in the coming years."

While revenue growth will stall, GaN LED unit shipments will continue to rise in the coming years, but at a more moderate pace than before. Following increases of 17.3 percent in 2013 and 7.3 percent in 2014, unit shipments will rise in the 3 to 4 percent range from 2015 through 2018. LEDs are used extensively as backlights for liquid-crystal display (LCD) panels. But backlighting applications including televisions and monitors will soon reach 100 percent LED saturation. What's more, the value of the LEDs in each television and PC monitor shipped has begun to decline.

Meanwhile, the fast growth of LEDs in tablets is slowing. The backlighting market in this area is starting to mature in terms of LED technology, and shipment levels of the tablet devices also are not growing as rapidly as before.

Overall, the GaN LED backlighting segment is projected to decline to $3.7 billion in 2018, down from $4.3 billion in 2013. In contrast, the GaN LED lighting segment will rise to $5.9 billion in 2018, up from $4.2 billion in 2013.

All the GaN LED backlighting applications combined still exceeded the lighting segment in 2013, at $5.5 billion compared with $4.2 billion. Lighting and backlighting revenue will be on a par with 2014 and 2015, but lighting will take a decisive lead in 2016.

Osram InGaN LED opens up new design options for cars

OSRAM has launched the yellow Oslon Compact LED, an emitter with package dimensions of 1.5 mm x 1.9 mm x 0.7 mm that is claimed to be is powerful and suited for use in light guide applications.

This high-power LED, based on InGaN, offers an output of more than 120 lumens at high currents and application temperatures of 100° C (T j in the chip). The yellow Oslon Compact is an addition to the two white versions and is ideal for front turn indicators.

Thanks to its compact design it can be used in particular to create light guide solutions. The light guides themselves measure less than 10 mm in diameter so the LEDs have to make full use of the available area by being packed very close together.

Andreas Geistreiter, Marketing LED Automotive at Osram Opto Semiconductors says, "For turn indicators or daytime running lights, the new Oslon Compact is suitable especially for light guide solutions, just like the other members of the product family".

"Thanks in particular to its high luminous efficacy and compact size it represents a further step in the direction of miniaturisation and greater freedom of design, opening up such possibilities as quasi-3D effects. This special

design element is of huge interest in the premium automotive segment, and thanks to the new Oslon Compact it is now easier for set makers to achieve," continues Geistreiter.

InGaAs / SiGe SRAM cell project launched

EUROPEAN SCIENTISTS from academia and industry have begun a new research project focused on an alternative approach to extend Moore's Law.

The goal is to reduce costs and improve the energy efficiency of electronic devices ranging from mobile phones to supercomputers. The research project, called COMPOSE3, is based on the use of new materials to replace today's silicon, and on taking an innovative design approach where transistors are stacked vertically, known as 3D stacking.

Coordinated by IBM Research, COMPOSE3 is a scientific collaboration among industry, research organisations and small- and medium-size enterprises from six European countries: CEA-Leti STMicroelectronics, and the Centre National de la Recherché Scientifique in France; University of Glasgow in the UK; Tyndall National Institute at University College Cork in Ireland; DTF Technology GmbH in Germany; and Fundación IMDEA Materiales in Spain.

Moore's Law predicted that the number of transistors that can be placed on an integrated circuit will double every eighteen months, leading to a reduction in the cost per digital function. This law has reached its limit due to shrinking chip geometries. For example a processor's clock speed has barely increased in the past five years, with typical operating frequencies at 2 to 3 GHz. In addition, energy consumption of electronic devices is growing at a staggering rate with estimates that it accounts for up to 10 percent of the total electrical energy generated in industrialized countries. To address these challenges, scientists will develop a static random-access memory (SRAM) cell based on two novel materials, InGaAs and SiGe, which replace silicon in the heart of the transistor.

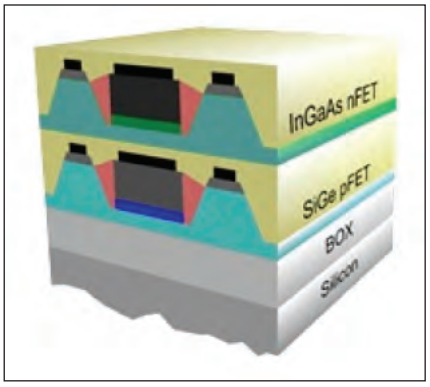
SRAM is an essential circuit component found in processors in a wide range of applications from smartphones to high-performance computers, and is usually built of two different types of transistors, called nFET and pFET. In COMPOSE3, the nFET will use InGaAs, whereas the pFET will use SiGe. An SRAM cell has therefore been selected as the ideal test vehicle to demonstrate this kind of hybrid technology. As charge carriers can move faster in InGaAs and SiGe than in silicon alone, the transistors can also be operated at a lower voltage, greatly reducing the power consumption of digital circuits.

The chemical properties of InGaAs and SiGe offer the possibility to stack transistors vertically at the nanometre scale, opening avenues to increase the number of devices per unit area, while reducing the manufacturing costs.

"This technology will provide a new paradigm shift in density scaling combined with a dramatic increase in the power efficiency of CMOS circuits. Our synergistic approach is based on replacing silicon with high-mobility channel materials such as SiGe and InGaAs," says Jean Fompeyrine, manager of the Advanced Functional Materials group at IBM Research.

"Using these materials in a technology that delivers performance at low power and at the same time provides a density increase at reduced costs is a fantastic challenge that requires the collective knowledge of industry and academia," continues Fompeyrine.

The challenges are significant, particularly with minimisation of electrically active defects in the vicinity of InGaAs and SiGe,



the fabrication of transistors with low-resistance contact, and thermal management during 3D stacking.

Within three years the team expects to unveil a proof of concept for building the world's first 14nm 3D-stacked SRAM cell based on InGaAs and SiGe materials.

Glasgow orders Oxford cluster system

Oxford Instruments has recently received a multi-million pound order for a complex deposition and analysis cluster system from the James Watt Nanofabrication Centre at the University of Glasgow. The system will enable development to improve the energy efficiency performance of electronic and optoelectronic devices for a large range of applications.

Through its Plasma Technology and Omicron Nanoscience businesses, the Oxford Instruments Nanotechnology Tools business sector was able to provide the broad range of technologies necessary for this 'Powerhouse' multi-chamber and multi-function system.

This Oxford Instruments four chamber cluster system combines the following: Plasma Technology's FlexAL Atomic Layer Deposition tool used for depositing very thin films of metals, oxides and nitrides using both thermal and inductively coupled plasma (ICP) ALD processes, a PlasmaPro System100 ICP for etching of compound semiconductor materials and a PlasmaPro System 100 ICP for High-Density PECVD deposition system providing for low damage, low temperature thin films; plus the Omicron Nanoscience NanoSAM LAB, for surface sensitive chemical analysis and high resolution imaging of small (micro and nano) structures by Scanning Auger Microscopy) and Scanning Electron Microscopy.

These systems will be combined in a unique configuration, and under

vacuum, allowing device manufacturing and characterisation measurements to be performed on device interfaces and surfaces without exposure to atmosphere. This is a very exciting development for Oxford Instruments.

They will be used in projects that will develop applications and improve the efficiencies of electronic and optoelectronic devices, and aid in the reduction of ICT energy consumption and carbon emissions.

Projects include ''Silicon compatible GaN power electronics'' developing energy efficient power electronics, and ''Scalable solar thermoelectrics and photovoltaics'' where the objective is to dramatically reduce the cost of large scale exploitation of solar energy and in so-doing massively decrease the carbon dioxide emissions associated with electrical and thermal power generation.

MIT awards Cree for innovative technology

CREE has been recognised as one of 2014's 50 Smartest Companies in *MIT Technology Review's* annual list of the world's most innovative technology companies.

The honourees are nominated by MIT Technology Review's editors, who look for companies that have demonstrated original and valuable technology over the last year, are bringing that technology to market at significant scale and are clearly influencing their competitors. The companies on the list represent the disruptive innovations most likely to change our lives.

Jason Pontin, publisher and editor in chief of MIT Technology Review, states, "At times it seems impossible to keep pace with important emerging technologies. This issue celebrates organisations at the forefront, displaying 'disruptive innovation' that will prove to surpass the competition, transform an industry and change our lives."

Guided by a culture that thrives on relentless innovation, Cree launched several products during the past year that have significantly contributed to the changing LED lighting landscape. The Cree LED Bulb works as good as or better than traditional incandescent bulbs at a price that has given consumers a reason to switch to LED.

At $99, the Cree XSPR LED street light delivered all the benefits of LED lighting at up-front cost parity to outdated and uninspiring traditional street lights.

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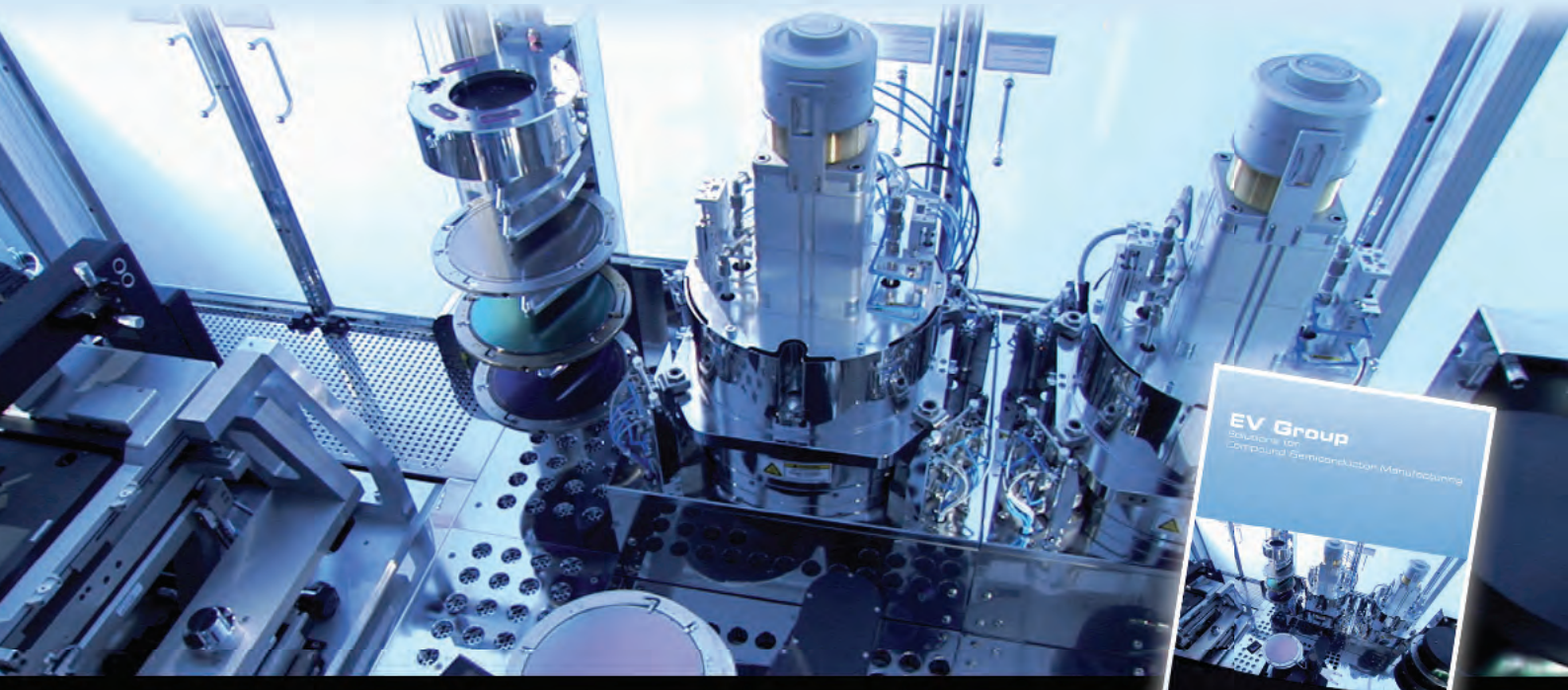

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TriQuint combines GaAs and silicon to accelerate global mobile growth

TRIQUINT has unveiled three new highly integrated multi-mode, multi-band power amplifier modules (MMPAs) that are claimed to deliver longer battery life for LTE smartphones and mobile devices while simplifying increasingly complex RF design.

The firm's MMPAs use both silicon and GaAs technology. The combination of the technologies is more efficient in terms of design and infrastructure than its current silicon competitor, silicon CMOS.

While silicon CMOS is gaining traction at the lower end of the market in 2G and lower 3G mobile devices, the technology does not provide adequate support across all radio frequency bands. These versatile new products – which are already capturing design wins in leading LTE smartphones support envelope tracking for higher power efficiency, 0MIPI interface for design flexibility.

"Building on the success of TriQuint's highly integrated TRIUM MMPAs, our three newest products add more LTE bands to cover more regional markets, as well as support for power-saving envelope tracking and a versatile new MIPI interface," explains Sean Riley, Vice President of Mobile Products.
Device manufacturers are adopting envelope tracking (ET) in next-generation smartphones to maximise energy efficiency. ET extends battery life by dynamically adjusting the supply voltage to the power amplifier (PA), in contrast to PAs with conventional constant-supply voltage.

TriQuint's new MMPAs also feature a new mobile chip interface - based on an open "MIPI" standard - used by several chipset providers to increase interoperability among vendors and reduce development time and effort.

In addition to designing more sophisticated devices, manufacturers serving the global market must produce several regional variants of each model to operate in carriers' specific assigned spectrum. This is more challenging as numerous new LTE bands are allocated.

The design of TriQuint's new MMPAs gives manufacturers a common platform to release new products at a faster pace, while controlling design and manufacturing costs. They support a growing number of popular 3G/4G bands for specific regions as well as quad-band GSM/EDGE. By integrating more functionality into smaller form factors, they simplify PCB routing, reduce BOM count and speed time to market.

Seoul Semi breaks the one trillion Korean won sales mark in 2013

LED chipmaker Seoul Semiconductor has achieved the company's greatest sales revenue,1.0321 trillion Korean won (US $973 million) and an operating profit of 965 hundred million Korean won in 2013.

In comparison to 2012, sales increased by 20 percent and the operating profit by 190 percent. Seoul Semiconductor has increased sales by focusing on Acrich2 LED modules which the company says is the world's first Alternating Current drive, and steady selling products such as mid-power and high-power packaged LEDs.

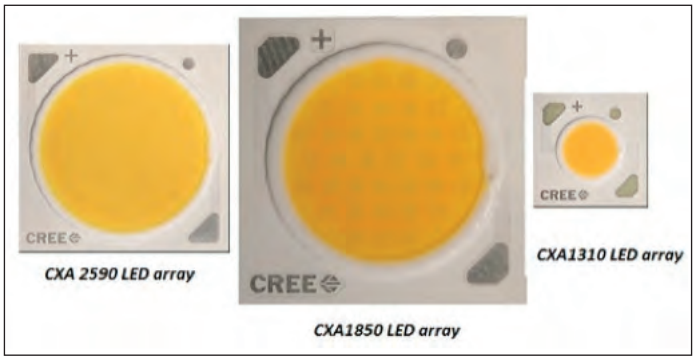
Applying the patented Black Hole Lens technology to direct-type LED for TV in the IT sector, Seoul Semiconductor has increased IT related sales. In addition, the sales of tablet PC related products are also the tangible results of its rise in the market.

After being listed on the Korea Stock Market (KOSDAQ) in 2002, another contributing factor to reach one trillion Korean won in sales after 12 years was the establishment of its patent portfolio that consists of more than 11,000 patents. Investing approximately 10 percent of its sales revenue each year in LED product research, development and registering over 600 patents in a year, the company holds world-class competitive patents.

Cree launches three new high density LED arrays to redefine LED lighting

CREE says that with three new LED arrays, it has redefined what is possible for LED lighting in high-intensity applications.

The Cree XLamp CXA2590, CXA1850 and CXA1310 LED arrays double the light output of existing standard-density CXA LED arrays without increasing the size.



This increase in lumen density delivers new levels of light intensity, which enables the complete replacement of ceramic metal halide (CMH) light sources, expands the possibilities of LED spotlights and enables applications that could not be addressed by previous LED technologies.

"The beauty of these new high-density LED arrays from Cree is that they are helping us bring products to the market that currently don't exist," said Mike Wang, vice president, lighting engineering, Edison Price Lighting, Inc. "Never before have we been able to harness such a large amount of light in such a small package, which can help us improve our lighting designs and address a number of applications that we previously could not."

By emitting more than 15,500 lumens from a 19 mm light source, the CXA2590 LED array enables luminaires with the same centre beam candlepower (CBCP) and light quality of a 150-watt CMH light source at lower power, longer lifetime and with better control.

Delivering more than 9,000 lumens from a 12 mm light source, the CXA1850 LED array enables lighting solutions with the same CBCP and light quality as 70-watt CMH while using half the power.

The CXA1310 LED Array provides more than 2,000 lumens in a 6 mm light source, which allows lighting manufacturers to design smaller, more efficient track lights, reduce the size of halogen replacements by half and deliver twice the CBCP of CMH at 30 percent less power.

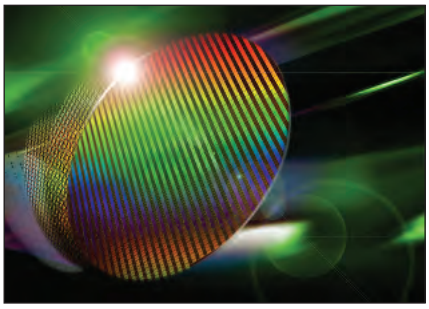
"The high-density LED arrays from Cree are extremely impressive," says Kenny Eidsvold, president, Intense Lighting.

"We are looking forward to using these products in applications requiring very high centre beam candlepower that previously could not be achieved with LED-based solutions."

IQE 850nm VCSELs achieve record power efficiencies

IQE's laser epiwafer technology has been employed to develop ultra-high efficiency optical interconnects reported in two papers presented at Photonics West by Technische Universität (TU) Berlin.

VCSEL wafers, manufactured at IQE's Cardiff facility were used by researchers at TU-Berlin to produce high-performance communications lasers that achieved error-free operation at speeds up to 40Gb/s with record low energy consumption. The VCSELs demonstrated extreme temperature stability during high-speed operation up to 85°C. Expanding growth in data communications is creating a bottleneck as demand for higher performance battles with the need to reduce power consumption. This is driving the move from copper cables to optical fibre communications, which is essential in enabling the transmission of the high data volumes demanded from cloud computing, big data and the internet



of thing. The efficiencies achieved with VCSELs are a critical factor in reducing the overall energy consumption of optical interconnects used in data centres.

IQE President and CEO, Drew Nelson, comments, "Today's energy hungry data centres are increasingly co-located alongside major industrial power plants. Data volumes are forecast to continue growing and with more than twenty billion devices being interconnected by 2020, the energy demand is rapidly becoming unsustainable. Data centres are already early adopters of VCSEL technology to help reduce energy demand and are likely to continue to drive the trend for optical communications for industrial and commercial applications."

Dieter Bimberg, a professor and head of the Solid State Physics Institute adds, "Error-free operation of 850 nm VCSELs at 25Gb/s was achieved with record-low dissipated energy of 56fJ/bit. This is the lowest reported value of dissipated energy at error-free operation for any semiconductor laser diode at any wavelength or bit rate."

"This result is achieved at a low current density of 10kA/cm^2, demonstrating the suitability of our devices for application in reliable and sustainable commercial optical interconnects. At 40Gb/s the IQE/TU-Berlin VCSELs dissipate only 108fJ per transmitted bit which is at least four times less than any other published result for semiconductor laser diodes."

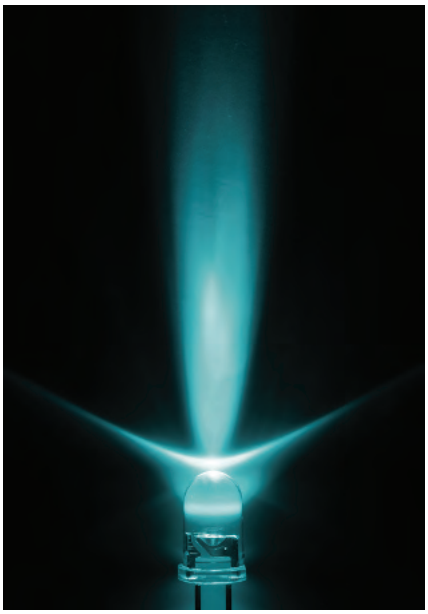
GTAT licensed to use Kyma's III-nitride technology

KYMA says its PVDNC technology creates a cost-effective nanocolumnar crystalline AlN nucleation layer on flat sapphire and silicon substrates as well as on patterned sapphire substrates. The technology will be used in the production of LEDs and power devices

Kyma Technologies has licensed its nitride semiconductor plasma vapour deposition of nanocolumns (PVDNC) technology to GT Advanced Technologies (GTAT).

The nanocolumnar AlN presents an excellent surface for subsequent nucleation and growth of GaN buffer layers which are important for GaN LEDs and power electronics.

Kyma has offered PVDNC AlN templates to the market for many years and also employs such templates as a starting material for growing bulk and thin film crystalline GaN by hydride vapour phase epitaxy (HVPE).



"After many years of advancing our patented PVDNC technology, we are excited to partner with GT Advanced Technologies who we believe is well positioned to broadly disseminate this technology not only into the rapidly growing market for nitride based LEDs but also into the nascent market for nitride based power electronics," says Keith Evans, Kyma's President and CEO.

The PVDNC technology complements GT's recently announced move into HVPE equipment. The combination of PVDNC AlN nucleation layers and HVPE GaN buffer layers has the potential to double the throughput of today's MOCVD tools and to improve the performance and yield of devices. The result is higher throughput of improved devices made at lower fabrication cost, a triple win for the customer.

"Kyma's innovative "nano-columnar" PVDNC technology adds an important component to our expanding LED product base," concludes Tom Gutierrez, GT's president and CEO. "Our goal is to offer a range of solutions that improve the quality and lower the cost of LED manufacturing. The combination of GT's PVD AlN tool coupled with the HVPE system we are developing is expected to offer LED manufacturers a significant cost reduction to producing epi-ready wafers compared with today's current manufacturing techniques."

GaN device market to reach over $2.2 billion

ACCORDING to a new market report published by Transparency Market Research *GaN Semiconductor Devices (Power semiconductors, Opto semiconductors) Market – Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013 - 2019,* the market was valued at US $380 million in 2012. This, says the firm, is expected to reach $ 2.2 billion by 2019, growing at a CAGR of 24.6 percent from 2013 to 2019.

North America was the largest contributor to global GaN semiconductor devices market accounting for 32.1 percent of the overall GaN semiconductors devices market in 2012. Asia Pacific is expected to be the fastest growing market for GaN semiconductor devices during the forecast period, growing at a CAGR of 27.7 percent from 2013 to 2019. This is mainly due to the rapid growth in the electronic industry in Asia Pacific.

The growing demand for high speed, high temperature and power handling capabilities have made the semiconductor industry rethink upon the designs and materials used in semiconductors. As various faster and smaller computing devices are coming forth, the use of silicon in semiconductors is making it difficult to sustain Moore's Law.

Owing to the unique characteristics of GaN such as superior noise factor, high maximum current, high breakdown voltage, and high oscillation frequency, GaN is a unique material of choice for numerous applications such as military, aerospace and defence sector, automotive sector and high power applications such as industrial, solar, power and wind. GaN is power efficient as it requires less heat sink compared to silicon.

Growing application areas as well as increased demand from military is the major driving force for the growth of GaN semiconductor devices market. The increase in demand is mainly due to significant reduction in weight and size of devices obtained by usage of GaN. What's more, developments in improving the breakdown voltage of GaN are expected to boost the usage of GaN in the field of electro-mobility. In 2012, opto semiconductor was the major product

type and accounted for 96.6 percent of the global GaN semiconductor device market. This was mainly due to adoption of GaN opto semiconductors in military, aerospace, defence and consumer electronics sector. However power semiconductor segment is expected to grow at the fastest rate during the forecast period. This is mainly due to growing need of high power devices for industrial applications.

Among the different applications, the military defence and aerospace sector held the highest market share and was valued at USD 82 million in 2012. Consumer electronics was the second largest application segment followed by ICT and automotive sector. With the introduction of 4G network, the demand for high power transistors and base stations is expected to rise. Hence the demand for GaN power semiconductors in ICT is expected to grow at the fastest pace. North America was the market leader in 2012, followed by Europe, Asia Pacific and RoW.

The global Photonic IC market is highly fragmented and competitive. Major industry participants include Fujitsu Limited (Japan), GaN Systems Inc (Canada), Freescale Semiconductors Incorporated (U.S.), International Rectifier Corporation (U.S.), Cree Inc (U.S.), Nichia Corporation (Japan) and RF Micro Devices Inc. (U.S.) among others. The power semiconductors reviewed in the report are Schottky diodes, Metal Oxide Semiconductor Field Effect Transistor (MOSFETs), High Electron Mobility Transistors (HEMTs) and rectifiers and other advanced transistor types.

The opto semiconductors described include LEDs and laser diodes.

MA-COM acquires Nitronex

M/A-COM Technology Solutions Inc. has acquired Nitronex, LLC, a specialist in the design and manufacture of GaN based RF solutions for $26 million.

The acquisition is expected to provide MACOM with fundamental GaN-on-silicon epitaxial and pendeoepitaxial semiconductor process technology and materials for use in RF applications, establishing MACOM's growing GaN technology portfolio as one of the broadest in the industry.

Nitronex previously leveraged this technology to offer the industry's first GaN-on-silicon RF discrete devices and MMICs, providing a combination of GaN-based performance, ease of integration and a cost structure that can support high volume, mainstream markets. The high device linearity, high output power and efficiency characteristics of GaN devices make GaN-on-silicon technology ideal for demanding high bandwidth communications such as CATV, broadband radio, wireless infrastructure, radar and ISM applications.

"GaN technology has been long viewed as the driver of the next generation of RF and Microwave applications," says John Croteau, President and CEO, MACOM. "With today's announcement, MACOM now provides, what we believe to be the industry's largest portfolio of GaN devices. MACOM's broadened portfolio of GaN-on-silicon and GaN-on-SiC technologies offers customers the flexibility to utilise the best solution to solve their RF and Microwave design challenges."

"Nitronex is excited to join MACOM, a leader in high performance RF and microwave technology," says Greg Baker, President and CEO of Nitronex. "Today's announcement accelerates the deployment of GaN as a dislocating technology and furthers Nitronex's vision of bringing GaN-on-silicon to the fullest breadth of commercial and aerospace and defence applications possible."

Cree: From hope to hit?

As investors applaud Cree's latest financial results, LED lighting market conditions look set to promote more of the same

WITH SECOND QUARTER TARGETS beating analysts' expectations and shares spiking more than 6 percent in after-hours trading, the future looked bright for Cree within hours of its latest financial results. Then, only days later, the US LED and power electronics developer released a concept 200 Lumen per Watt LED luminaire, shattering efficiency targets that the US Department of Energy predicted wouldn't be reached until 2020. The company is on a winning streak: Can we expect more of the same?

"Cree has positioned itself well to capture a lamping secular trend here, and for the first time ever the industry is going through, in effect, an analogue to digital transition," says Jed Dorsheimer, managing director of display and lighting equity research at Canaccord Genuity. "Market share is shifting and we have pricing and policy converging at the same time, thrusting forward solid-state bulb adoption."

"Cree is well positioned in components, lighting systems and replacement bulbs; this is driving their results," he adds.

Indeed, US government has been pushing stringent measures to phase out the incandescent and ease in the LED. January 1st brought a ban to the manufacture of 40 W and 60 W incandescent bulbs, while 75 W and 100 W bulbs were snuffed out last year.

This strict regulation will fuel Cree's ambition to achieve mass LED adoption, and predicted LED market growth will only help. While surplus LEDs dragged down prices in 2012, the market picked up in 2013 thanks to product innovation and falling LED prices. Cree's past disappointing financial results reflect the dip, but its latest success surely mirrors the eagerly anticipated growth. LED market share in the global lighting market

'Looks like a light bulb, lights like a light bulb and works better than a light bulb,' says Cree

is now expected to mushroom in the next decade and Cree intends to capture this.

Road to success

Product innovation, from bulbs to luminaires, has been fundamental to Cree's dominant market presence. In March last year, the company launched a $10 incandescent look-alike, one of a series of bulbs intended to kick-start the sluggish US domestic market. Meanwhile, the last fiscal year has seen, for example, a new 75 W replacement LED bulb and the industry's first $99 LED street light.

This relentless delivery of products would not be possible if the company hadn't set out, from word go, to be vertically integrated. "It's always difficult to vertically integrate and if Cree was to vertically integrate now, instead of years ago, it would be a recipe for disaster," says Dorsheimer. "But the fact the company saw these trends several years ago and had the focus and wherewithal to make some very difficult decisions, is now starting to yield these good results."

Dorsheimer names Cree, Philips, TCP and Feit Electric as some of the leading lights amongst the LED lighting pack, highlighting how other industry heavyweights are playing catch up.

"We see larger companies such as GE missing out on as they are not already well positioned for this [LED lighting] opportunity," he says. "So there is market share that is going to be lost to the more nimble companies well positioned in [sales] channels to take advantage of this."

Indeed, an important piece of Cree's success has been its partnership with US-based The Home Depot. The home improvement retailer has more than 2000 stores across the nation, and without a doubt has helped to thrust Cree's LED products into the marketplace.

What is clear from CEO Chuck Swoboda's recent earnings call is that Cree will now push more products through this sales channel and others.

"[We will now] build the Cree brand and selling the Cree bulb is the foundation to our brand strategy," he says. "[This] and our marketing investment is unlike anything that has been done in lighting over the last several decades... Bulb sales to consumers doubled in Q2 and the product has been more successful that either Cree or The Home Depot would have predicted ten months ago."

And a strong branding could help the company win even more market share from its competitors.

"I'm not so sure people are going into Home Depot and looking for a Cree-branded bulb, but they are going in and the sales rep is telling them about it," says Dorsheimer. "Consumers are beginning to hear more and more about Cree and this will pay dividends as the market goes forward."

IGBT inventor crusades

wide bandgap semiconductors

As academic Jay Baliga from North Carolina State University steps up to lead the $140 million 'Next Generation Power Electronics National Manufacturing Innovation Institute', Compound Semiconductor asks about his past, plans and relentless pursuit of the power semiconductor.

Q You invented the silicon IGBT, have pioneered wide bandgap semiconductor devices, and you've just received the IEEE Medal of Honor. Where did this all start?

A I invented the IGBT in 1980, the same year that I derived an equation that, for the first time, related resistance in power devices to material properties. I called it Baliga's figure of merit. So when I discovered this, I also started looking for alternative semiconductor materials to silicon, and the first promising material I found was gallium arsenide. Working at GE at the time, we put together a group and developed the first wideband gap power device based on GaAs in 1985. We commercialised this and these devices are still available across the industry today.

Q At any point did you feel torn between the two competing technologies; silicon and wide bandgap semiconductors?

A It was actually a pretty tough time for me as I was trying to develop the IGBT as quickly as possible and then I had to do the GaAs programme as well. But I had always seen wide bandgap semiconductors as the future, although I had not appreciated how long it would take for wide bandgap semiconductor devices to become commercial. With the IGBT I commercialised it in a remarkable ten months, which was why it became so widely used in so many diverse applications from air cooling systems to drives and lighting. Thirty years has been a very long time, but wide bandgap semiconductors are now cannibalising on the IGBT, and this is how I always believed it would happen.

Q The first wider bandgap semiconductor you worked on was GaAs, what came next?

A My equation predicted that with SiC, which has an even wider bandgap, I could get a 1000 fold improvement [in performance]. I'd predicted a 13.7 times improvement with GaAs, so this was another two orders of magnitude. When I found this one thousand fold opportunity, I started to look at how to make devices. But this was the early 1980s, and there was no SiC technology at the time. So we went to see Professor Robert Davis in the materials science and engineering department at North Carolina State University. He developed some growth processes for SiC wafers, and his students later spun off the company, Cree. Cree started to produce SiC wafers and this, as well as my interest in collaborating with Dr Davis, brought me to North Carolina from GE.

Q So what power devices followed?

A In 1991, I set up a power semiconductor research centre at the university. This was, and is, an industrial consortium. With the funding that came from that consortium we made the first high performance SiC electronic devices. In 1992, we announced a very high performance Schottky rectifier and by 1995 we had developed a very high performance power MOSFET.

I do think these devices helped the industry appreciate this technology; these systems had proven the theory, so many programmes to develop more devices followed. By 2000 to 2005 we started to see a lot of products, particularly Schottky rectifiers and junction barrier Schottky (JBS) rectifiers based on an idea I proposed for silicon in the 1980s. These rectifiers were the first products and then we had power MOSFETs. Today, Infineon, Cree, Rohm and a whole bunch of companies now manufacture these SiC products.

Q It's no secret that the cost of SiC devices is hampering adoption; do you see a solution?

A Yes, the problem for the industry right now is the cost of these products. It is much much greater than silicon, making the devices too expensive for mainstream applications, despite the advantages. In the 1980s, silicon carbide was thought of as a material for, say, high temperature, radiation-hard applications but my belief has always been that the material can be used in mainstream power electronics and this is what I have been championing since then. But to make that happen you have to have low enough costs to be competitive with silicon – this is the goal of the new manufacturing innovation hub at North Carolina State University.

Q How will the new hub achieve cheap silicon carbide devices?

A We will bring together the materials suppliers of SiC as well as GaN, and align the materials with the foundry that will make the chips. We will then develop high volume manufacturing technology and also bring in companies that package these devices so they can operate at higher temperatures than silicon.

Q The entire supply chain is involved; how do you organise the research and intellectual property issues for example?

A These details are being worked out and the US Department of Energy is involved in the process. We plan to collaborate very strongly with the [hub partners]. My focus is on SiC devices and processing so I will work with the foundry that is going to build SiC chips. We will share whatever IP comes out of this as part of the consortium. I'm used to developing IP, I have 120 patents.

Q Will the hub focus more on SiC devices than GaN devices?

A No, GaN is now coming along very strongly. We have 600 V devices and these are getting very competitive. GaN can be grown on silicon so the cost structure is very different to SiC. We will have to see how this pans out, but I would say we have equal emphasis on SiC and GaN.

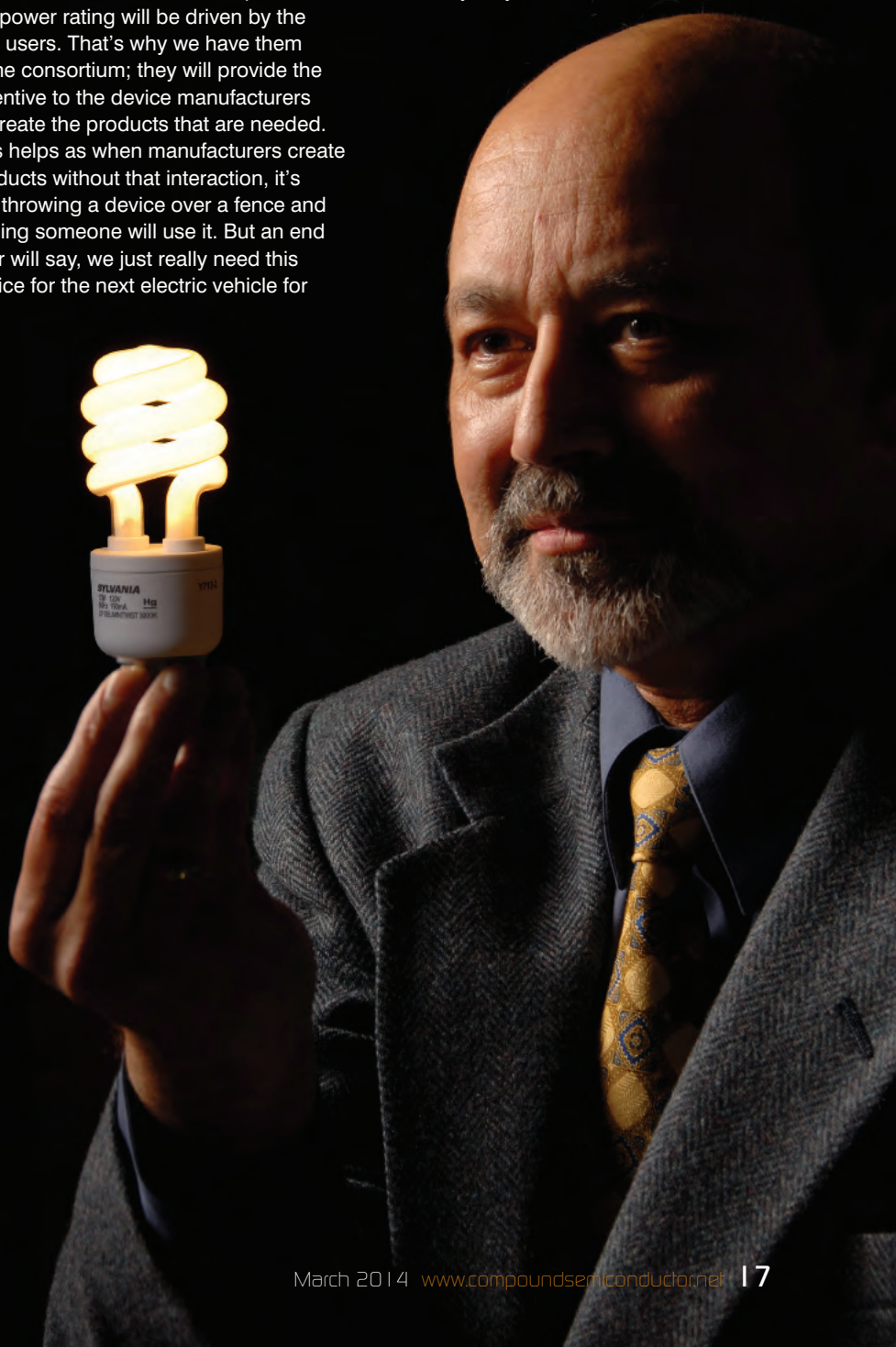
Q What devices can industry expect when the project finishes in five years?

A For GaN, 600 V seems to be the sweet spot and for SiC I have been saying all the way from 600 V to 5000 V for MOSFETs. Essentially, industry needs two devices; the rectifier and the switch. Both will be developed and the power rating will be driven by the end users. That's why we have them in the consortium; they will provide the incentive to the device manufacturers to create the products that are needed. This helps as when manufacturers create products without that interaction, it's like throwing a device over a fence and hoping someone will use it. But an end user will say, we just really need this device for the next electric vehicle for example. I had this benefit at GE when I was developing the IGBT; I knew exactly what the applications were so I could design my device to meet the needs and get it commercialised very quickly.

This consortium will enable that. We want to bring as many applications as we can to this consortium, to proliferate the technology, expand volume and drive the costs down. This is the goal of the hub, to bring all of this together

Q That's quite a goal?

A Yes it is, but it is a goal that will make my 30 year old vision come true.



Kyma reveals ammonothermal-HVPE GaN growth plans

Kyma teams up with Ammono and Avogy to advance novel bulk GaN growth.

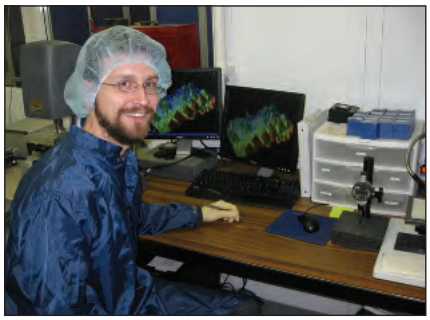
LATE LAST YEAR, US-based wide bandgap materials supplier, Kyma Technologies, won $3.2 million from DoE agency, Advanced Research Projects Agency-Energy (ARPA-E), to develop high quality GaN substrates. Joining forces with Poland-based bulk GaN pioneer, Ammono, as well as US power electronics developer, Avogy, Kyma intends to pioneer a novel growth process to deliver the low cost, high performing GaN boules that power electronics manufacturers crave.

The project is ambitious but with Kyma chief executive, Keith Evans, describing the industry line-up as "the dream team", those involved expect success. So what lies in store?

The Kyma team will first combine Ammono's ammonothermal growth process with its HVPE-growth process to grow high quality boules quickly. Without a doubt, ammonothermal growth creates higher structural quality wafers than HVPE growth alone, but takes time. And as Kyma's chief science officer, Jacob Leach, puts it: "We want to get the structural quality of the ammonothermal process with the high growth rate of HVPE."

To date, most manufacturers of GaN substrates, including Kyma, grow GaN wafers by HVPE on a non-native seed such as sapphire. But while the process is quick, it is not simply extendable to boule growth due to lattice and thermal expansion mismatch between the GaN and the non-native seed.

So with this in mind, Leach and colleagues will take a high structural quality seed GaN wafer, grown by Ammono, and rapidly grow GaN layers on it by HVPE. Their initial aim is to replicate the structural quality of the ammonothermal seed using HVPE, and then create GaN overlayers with lower impurity concentrations and point defect densities than in the original seed.



Kyma's chief science officer, Jacob Leach, beside a Veeco Wyko optical surface profilometer that is used for investigating surface morphology and defects in as-grown plus post polished materials.

"We aim to have two inch thick boules that we've not only grown, but also demonstrated the ability to slice and polish; we want to make real substrates," says Leach. "We will deliver these to our device partner, Avogy, who will make vertical diodes using their processes, to demonstrate the utility of these substrates."

Close collaboration between the key GaN industry players offers clear appeal, but why is Kyma growing its GaN layers on an Ammono-grown wafer; why not use an HVPE-grown free-standing GaN wafer as the seed? As Leach explains, GaN seed wafers produced by HVPE on sapphire suffer from lattice lensing. Here, the crystalline lattice is curved across the wafer, which changes the local mis-cut across the wafer.

"If you measure the radius of curvature in the lattice of Ammono's ammonothermal seeds it's of the order of around a kilometre, while the radius of curvature in our HVPE seeds is about 2 m to 10 m," he says. "It would be tough to take an HVPE seed and grow very thick boules by HVPE, so we want to marry these two processes."

If successful, the team intends to launch a two-inch commercially viable product by the end of the project, some four years away. Not a modest task, but Kyma chief executive, Evans, believes this is achievable. As he highlights, Kyma is not starting from scratch, but has carried out GaN-on-GaN growth in the past. And, what's more, he is very excited about combining the ammonothermal and HVPE growth processes.

"There have been academic studies about this and Kyma has been talking about it for years," he says. "But to the best of my knowledge, this is the first time that two commercial entities have done this."

Evans firmly believes that high structural quality boules are crucial to driving down GaN wafer costs and provide the only route to manufacturing economies of scale. Indeed, silicon, GaAs, InP, germanium and most sapphire substrates are made by slicing from a boule.

And now he hopes the Ammono-Kyma-Avogy combo will provide the winning formula."We've picked the best structural quality GaN maker, plus our HVPE process and the best vertical GaN power electronics developer to make a great team," he says "You know Robert Dwiliński [Ammono] and I have been thinking about this for half a decade, and as I have said; 'they have the seed and we have the speed'."

Rubicon
reveals sapphire plans

Rubicon Technology plans to ease LED manufacture by ramping patterned sapphire substrate production.

While industry players debate whether silicon or sapphire is the best foundation for the GaN LED, US sapphire substrate manufacturer, Rubicon Technology, has sold $28.2 million of common stock to fund expansion.

Developing sapphire substrate fabrication for LEDs is high on the company's investment list, chief financial officer, Bill Weissman, tells *Compound Semiconductor*. And plans are underway to do this soon.

The company will first extend sapphire substrate patterning facilities. Etching a nano-pattern onto the sapphire wafer eases epitaxial growth and reduces the light reflected back into the LED from the polished surface, boosting light output. But according to Weissman, LED chip manufacturers are becoming more and more interested in outsourcing this production step. "We're seeing a real trend here," he says. "So a lot of the money we are raising is going into the expansion of our LED patterning operation."

The company started supplying 4- and 6-inch patterned sapphire substrates last year – Weissman reckons only Rubicon offers 6-inch wafers – and will now triple capacity in its existing cleanroom at its fabrication facility in Penang, Malaysia. Then, if demand for patterned sapphire substrates continues, construction of additional polishing and patterning facilities to this plant could follow by the end of the year.

"We don't think chip manufacturers are going to shut down their internal patterning operations, but we do think they will stop investing and expanding those capabilities, and so will outsource more and more," he says.

At the same time, Rubicon is eyeing other LED opportunities, including aluminium nitride on sapphire templates. Here the company would deposit an AlN layer onto its patterned 4- and 6-inch sapphire substrates, onto which chip manufacturers could then directly grow GaN layers. Kyma, for one, has demonstrated 10-inch diameter AlN on sapphire templates for LED growth and alongside the likes of Azzuro Semiconductors and Translucent, is also working on 300 mm (12-inch) AlN on silicon templates.

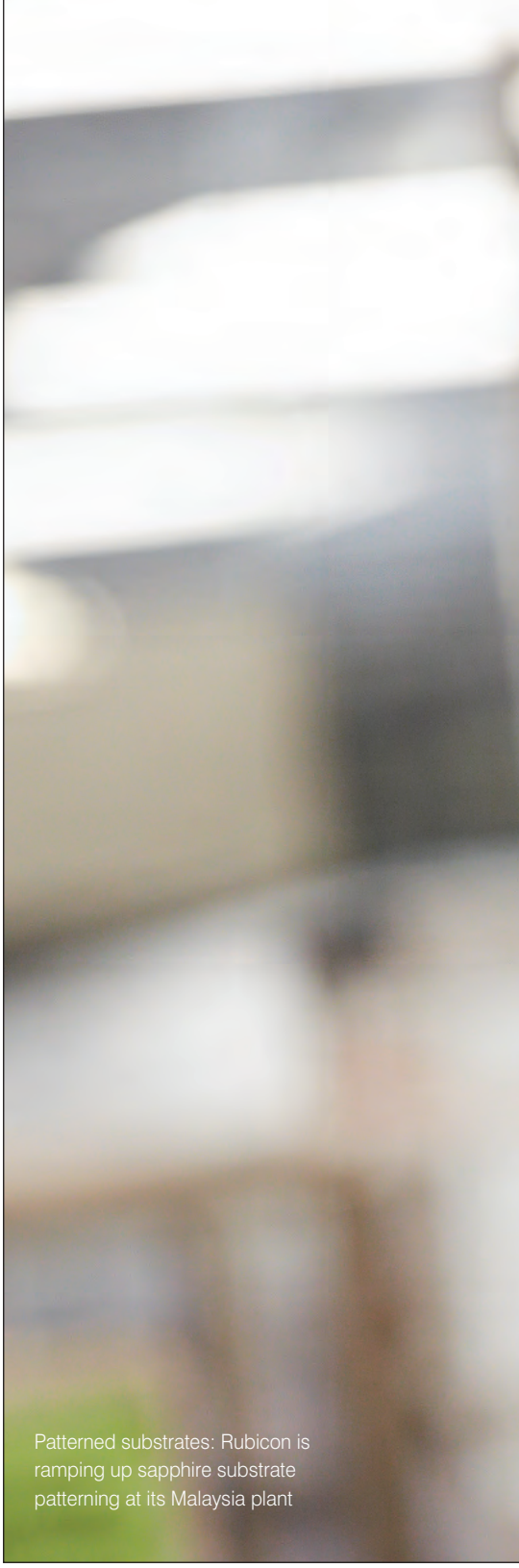
"Templates could be a next potential step downstream for us," says Weissman. "The jury is still out on whether chip manufacturers are interested in this product – issues include contamination for example – but this is something we're looking at as an additional product within the LED market."

Silicon rivals

But while Rubicon executives grow their LED materials empire aren't they concerned about a potential industry transition from sapphire to silicon substrates?

Only late last year, business analyst IHS forecast that come 2020, GaN-on-silicon LEDs will increase market share from today's 1 percent to 40 percent, mostly at the expense of GaN-on-sapphire devices. This forecast lies at the extreme end of the predictions for silicon success, but nonetheless indicates a rising interest in processing LED structures in depreciated CMOS facilities.

But Weissman says the company isn't worried and he doesn't expect GaN-on-sapphire LEDs to lose market share to silicon-based alternatives in the near future. Many organisations have been developing methods to circumvent the



Patterned substrates: Rubicon is ramping up sapphire substrate patterning at its Malaysia plant

dramatically different GaN and silicon coefficients of thermal expansion, but he asserts: "No-one has really demonstrated a solution that works well in the production of high brightness LEDs."

"Toshiba recently bought Bridgelux but to my knowledge is not selling any meaningful volumes into the high brightness LED market," he adds. "I think in time we may see some of the LED market convert to silicon substrates, but this is years away and will probably only be for a limited market."

In the meantime, Rubicon will continue to build its product base. Since its inception in 2001, the company has focused on developing a highly vertically integrated business for a range of markets. From processing of alumina to wafer polishing, and now patterning, Rubicon claims to have the most vertically integrated business model in the sapphire industry.

But it's not all about LEDs. Right now, the company is developing large rectangular optical sapphire windows for defence and medical applications and exploring how to cut the costs of sapphire cover glass for smartphone camera lenses and other applications. Still, LEDs remains its number one market. "MOCVD tool utilisation rates are now very high and LED manufacturers want to find ways to extend throughput without extending footprint; moving to larger substrates is a great way to do this," says Weissman.

"We believe strongly that LED manufacturers are going to move to 6-inch substrates soon," he adds. "We've always had a strong leadership in larger diameters and I think we're going to reap the benefits of this in the next few years."

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Chaired by

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IQE

LEDs

LEDs are the dominant source for backlighting screens of all sizes. To penetrate new markets and grow revenues, can chipmakers now trim the cost-per-lumen of the LED or equip the device with additional features?

Keynote presentation: Young Soo Park
Slashing LED costs with 200 mm silicon substrates

SAMSUNG

William Henry
Applications and opportunities for MicroLED emitters

INFINILED

Pallavi Madakasira
LED light bulbs: When and how will the lighting of tomorrow become the lighting of today

luxresearch

Ulrich Steegmueller
Success factors in the increasingly competitive LED ecosystem

OSRAM Opto Semiconductors

David Kepniss
Sub part-per-billion analysis of high purity hydrogen - process improvement applications with the HEMS™ analyzer

Power+Energy

Silvia Schwyn-Thoeny
Increasing LED performance and reducing production costs to accelerate the growth of LED lighting

evatec process systems

Wolfram Drescher
"Cold split" – A simple thinning and wafering process technique

SILTECTRA

Ann Hughes
Innovation to maximise production productivity

SAFC Hitech™ Enabling Technology

* All speakers and presentations are subject to change.

Integration of CMOS and III-Vs

Silicon is running out of steam, and the future is widely tipped to be high-mobility channels made from germanium and III-Vs. But how will these materials be introduced in the world's leading silicon foundries?

Keynote presentation: Jean Fompeyrine
Co-integration of III-V and Ge CMOS

IBM

Thorsten Matthias
Direct wafer bonding: Enabling technology for future photonic and electronic integration

EVG

Shinichi Takagi
III-V and germanium FET technologies on Si platform

The University of Tokyo

Aaron Thean
Beyond silicon CMOS: Transforming transistors with heterogeneous material integration

imec

Power Electronics

Silicon has dominated the power electronic market for decades, but wide bandgap semiconductors will soon replace this material. What's the primary role for SiC, and where will GaN feature?

Keynote presentation: Ming Su
Can SiC or GaN power the next-generation hybrid electric vehicle drive systems?

Ford

Keynote presentation: Mike Briere
Pioneering GaN on Si power devices on large diameter substrates

International IOR Rectifier
THE POWER MANAGEMENT LEADER

Philippe Roussel
Vertical integration vs outsourcing in the wide bandgap sector

YOLE Développement

Marcus Behet
SiC and GaN/Si for power electronics – niche forever?

DOW CORNING

Denis Marcon
200mm GaN-on-Si CMOS compatible platform

imec

Kolja Haberland
Advanced in-situ growth monitoring for GaN based power electronics on silicon

LAYTEC
Knowledge is key

Roman Sappey
Defect inspection and monitoring in SiC and GaN power device processes

KLA-Tencor

Chris Hodson
Low damage plasma processes for compound semiconductor applications

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Continues on next page

Front Ends for Mobile Devices

Handset front-ends are becoming more complex, due to an ever-increasing number of bands used for mobile communication. Will this trend play into the hands of GaAs chipmakers? Or is silicon CMOS technology going to grab market share?

Keynote presentation: Jeremy Hendy
Envelope tracking - transforming the performance of CMOS and GaAs PAs

Eric Higham
Coming full circle - will Si CMOS burst the GaAs bubble?

Thomas Meier
GaAs & Silicon: Co-existence in a wireless world

Brendan Timmins
Minimizing the cost of precious metals used in compound semiconductors

Dirk Schumann
Waterbased stripping innovation for wafer stripping and metal lift-off

Cris Kroneberger
Non contact magnetic drive assembly for improved reliability and reduced particulates

Lasers, PICs and PV

Rocketing levels of internet traffic are putting greater and greater strain on optical networks and data centres. Can this be addressed by advancing the performance of conventional lasers, or does the market need to turn to greater use of PICs?

Keynote presentation: Michael Lebby
Photonic integration in InP: A regrowth-free platform for the fabless manufacturing model

Michael Vyvoda
Using proton induced exfoliation to manufacture low-cost, device quality single crystal substrates

Gregory Fish
III-V heterogeneous photonic and electronic integration on silicon

Petteri Uusimaa
RGB laser solutions to display and projection application

Hong Lin
Bulk and free-standing GaN substrate technologies and industry status in the LED, laser diode and power applications

Rainer Krause - Soitec
Wafer bonded 4-junction GaInP/GaAs//GaInAsP/ GaInAs high performing concentrator solar cells

Wide Bandgap RF Devices

GaN and SiC have a great set of attributes that make them very promising materials for producing RF devices. But are they now fulfilling their potential and netting substantial sales?

Keynote presentation: Andrew Barnes
Overview of GaN reliability improvement activities at the European Space Agency

Chris Horton
Enabling material solutions for GaN in the RF arena

Marc Rocchi
100nm GaN/Si mmW foundry service and MMICs

Marianne Germain
Industrial manufacturing of GaN epiwafers for high voltage and RF markets

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BY PHILIP GREENE FROM FERROTEC, TEMESCAL DIVISION

IN VERY GENERAL TERMS, compound semiconductor devices are all fabricated in the same way. Whether it is LEDs, lasers, solar cells or electronics, production always begins with deposition of epitaxial layers onto a substrate, followed by processes that add metal films and contact wires to construct a chip that is housed in a suitable package.

A standard technique for depositing a metal on a compound semiconductor is electron beam evaporation. It may be performed as part of a lift-off process, which involves deposition on a patterned sacrificial layer that is then removed to leave a metallic film on part of the surface.

Strengths of electron-beam evaporation include a high effective deposition rate, which enables acceptable deposition times, and a highly directional source

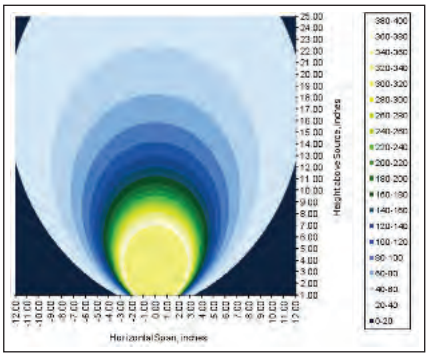


Figure 1. Growth rates of metals in an electron-beam evaporator decrease with distance from the source to the substrate, and vary with angle

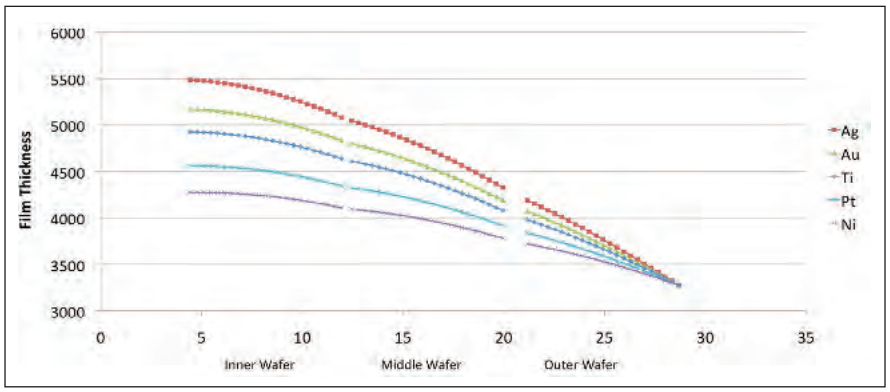


Figure 2. In a single-axis rotating dome, deposition without a mask produces variations in metal film thickness of +/-12.8 percent to +/-24 percent, depending on material

that limits detrimental sidewall coverage. Very high-quality films are possible by carrying out electron beam evaporation under a high vacuum: This leads to very low levels of incorporation of background gas contaminants, while scattering of the evaporated materials is minimised, thereby maintaining the highly directional nature of the evaporated species.

The directional nature limits photoresist via sidewall coverage when the substrate is oriented perpedicularly to the evaporant flux. However, a substrate oriented perpendicularly to the evaporant flux only receives truly normal incident flux at its centre, with some angular variation of the incident flux across the width of the substrate. This can be kept within a desired range by placing it at an appropriate distance from the source. The greater the distance, the smaller the deviation from normal incidence, with a lower deposition rate as one price to pay. Although the rate can be cranked up by increasing the source power density, there are material-based limits to what is practical. Unfortunately, the nature of the process is such that when an array of perpendicularly oriented substrates are placed at a fixed distance from the source, the deposition thickness will not be inherently uniform, but have some variation in thickness across and between substrates at different locations.

At Temescal, a division of Ferrotec based in Livermore, California, we have devoted much effort to exploring the critical interrelationships between electron beam system architecture, material behaviour and process methodology in order to devise approaches that lead to higher uniformities for electron beam

evaporation. Our success includes the development of a process methodology that could reduce losses from uniformity masks and offer significant improvements to collection efficiency (see *Compound Semiconductor* March 2013, p. 29). We have also explored the more general issue of attainable film uniformity, and here we consider what can be achieved with the historical techniques and the newest methodologies available.

Realising a highly uniform film is not just an end in itself – it is critical to several processes, including the formation of eutectic films used for bonding. In these films, small variations in the ratio of materials can lead to a rise in melting temperature, and ultimately be the source of bonding issues across the substrate. That's because composition variations have to be addressed by turning to a higher temperature to ensure melting across the entire film. The composition variation also has the unwanted side effect of possible changes in film morphology upon cooling.

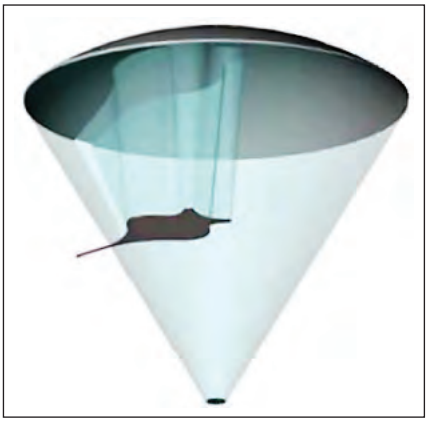


Figure 3. Inserting a shadow mask can improve thickness uniformity in an electron-beam evaporator

Users of electron-beam evaporators face many potential sources of non-uniformity, and it is not possible to cover all of them here. So we will focus on the main factors influencing uniformity, and assume that film deposition is carried out using a well-controlled evaporation source, housed in a tool with tight mechanical tolerances relating to its geometry.

One factor having a big influence on film uniformity is the shape of the vapour cloud. Its impact on the uniformity of films deposited on 150 mm wafers is quite different in two of our tools designed for high-volume production: the Temescal FC-4400, which features a wafer carrier with a single axis of rotation that holds up to 30 wafers in three radial tiers; and the Temescal UEFC-5700, a tool with dual axes of rotation that either accommodates: 36 wafers in six domes, each holding six wafers; or 42 wafers in three domes, each holding 14 wafers. Both tools have similar distances between the electron-beam source and the substrates of about 42 inches.

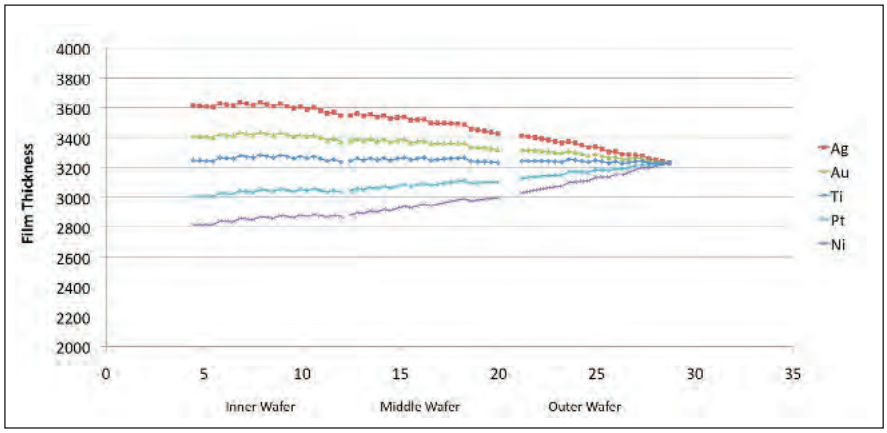


Figure 4. In a single-axis rotating dome, adding a shadow mask improves thickness uniformity. Note that the deposition conditions used to generate the plot shown in figure 2 are repeated, but with the addition of an optimised shadow mask. The vertical axis has been changed in order to better display the data

Vapour clouds

Many factors influence the distribution of the evaporant flux, including the inclination angle and azimuthal angle, the power provided to the source material and its evaporation rate, beam cross section and density (size) and the height and shape of the source.

We have worked hard to minimise the influence of all these parameters by designing the hardware and refining the process so that it provides the most stable, consistent conditions. One of our insights is that it is critical to get high levels of uniformity at the source, because any variation here can carry over into non-uniformities for the vapour cloud. Manufacturers of electron-beam deposition tools often mount the substrates on a rotating dome-shaped carrier to minimize the influence of asymmetries in the azimuthal angle. By taking this approach, substrates experience an average of the deposition

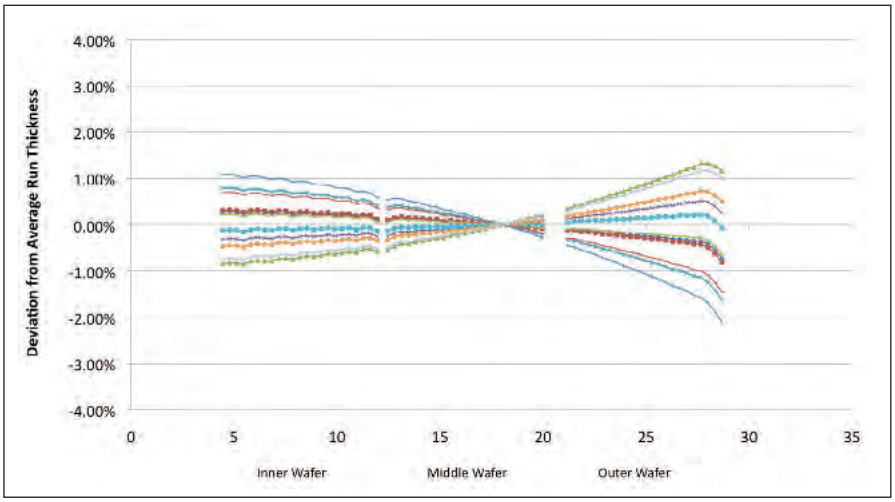


Figure 5. Deposition conditions vary from run to run and evaporator to evaporator. These variations, which impact the thickness profile, are considered in this plot that shows deviations in thickness profiles over multiple runs from six evaporators. Note that to remove the slope across the dome – an inherent feature from a mask that was designed to balance the results from two materials – data were normalized to remove that slope from the average profile

rate across all azimuthal angles, and thus have a smooth film thickness profile, with high values in the centre and lower ones towards the outer edges of the dome.

Engineers will often curve-fit the shape of the thickness profile observed across the wafers and carrier to better predict and understand the influence of measurement errors and small random fluctuations in conditions. One curve function offering a close fit to the observed thickness variation is the cosine power law – using this, one can predict thickness resulting from changes to the hardware, not including measurement error. Here we report the results of the application of that methodology to predict the best uniformity that can be achieved under realistic conditions.

The shape of an azimuthally symmetric cloud of gold vapour emanating from a 6 kW source is shown in Figure 1. This plot reveals the effective deposition rate across a substrate carrier placed normal to the flux. Regardless of source-substrate distance, the deposition rate varies with angle and is highest directly above the source. Given this, one could say that evaporation from the source is 'directed upwards', with a degree that changes significantly with different evaporants – and may even change significantly via modifications to the evaporation rate of a material.

Rotation about one axis…

Over the years, we have expended considerable effort in documenting vapour cloud profiles for numerous materials over a range of process conditions. In this article, we draw on a small fraction of this database to highlight the sensitivity of the system. For example, the choice of material has a big impact on film thickness variation across all substrates: it can range from +/-12.8 percent to +/-24.0 percent in a tool employing a standard single rotation axis, and featuring a lift-off dome configuration (see Figure 2).

Adding one or more 'shadow masks' to block some of the evaporant flux is a conventional approach for increasing the uniformity along the radius of the dome (see Figure 3 for an illustration of this approach). The evaporant flux is greatest towards the centre of the rotating dome, so shadow masks are carefully shaped to block more of the flux heading towards the inner portion of the dome, compared to that travelling to the outer regions.

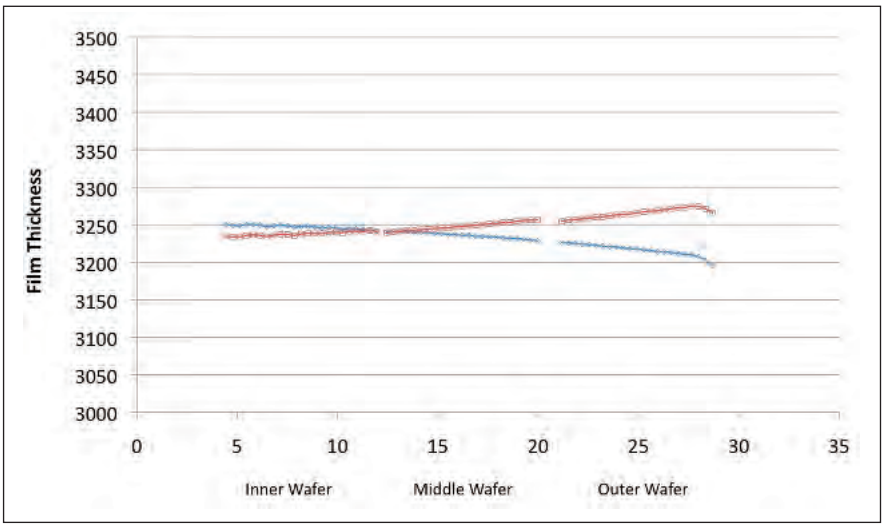


Figure 6. Even variations in the height of the source produce differences in film thickness. This plot show the variations in a single axis rotating dome with a mask, with source heights of + 0.5 inch (blue line) and -0.5 inch (red line)

With a fixed-position shadow mask, each and every material, regardless of deposition conditions, gets the same correction for relative thickness. The improvement can be far from modest – see Figure 4 to gauge the benefit wrought by the addition of a shadow mask designed for the average thickness profiles from the data in Figure 2. The improved thickness uniformity with the addition of one shadow mask varies from material to material, from a low of +/-0.9 percent to a high of +/-6.9 percent. These results highlight that a well designed mask can tune the uniformity for a given process condition to exceedingly tight standards. However, although these gains are significant, there is a limit to what a single mask can produce, in terms of tuning the uniformity for multiple processes. The obvious solution – and one that has been applied when there is a select set of processes with critical uniformity tolerances – is to work with multiple shadow masks, which are moved into and out of the evaporant cloud at appropriate times. However, it is often impractical to do this for every

Figure 7. Higher levels of film thickness uniformity are possible by switching from a single-axis tool to one that provides dual axes of rotation. An example of the latter is the Temescal UEFC-5700, which accommodates 36 wafers in six domes, each holding six wafers

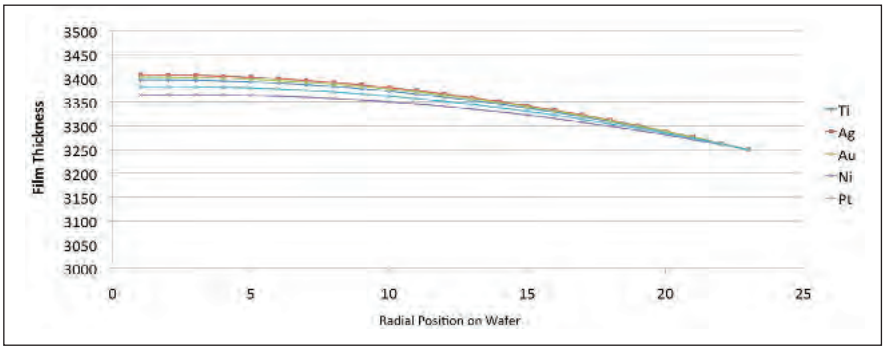


Figure 8. With the high uniformity lift-off apparatus (HULA), which incorporates a second axis of rotation, unmasked thickness profiles are just +/-1.74 percent to +/-2.36 percent. Note that this plot displays the uniformity across the wafers in the radial direction for the same set of material conditions as shown in Figure 2. The scale of the vertical axis has been reduced to better display the range in thickness. Since the wafers in this design are held in a single tier, the uniformity is representative of the shape for all of the wafers

material, so process engineers only select mask designs for the most critical materials.

Complicating matters, associated with every process is a normal variation in the shape of the evaporant cloud. The shadow mask is a fixed component in the system, designed for a particular process (material and rate), and so its correction cannot always match actively changing conditions. The degree of variation strongly depends on the material, although it can be restrained by employing identical source conditions.

So far, we have only presented plots of film uniformity based on representative deposition conditions for each material. When these deposition conditions vary, thickness profiles change. An example of the extent of this change is illustrated in the variations in growth of titanium films deposited in six identically configured evaporation systems (see Figure 5 for changes in radial thickness profile.) By repeating the same deposition process across six tools we explore the influence that variations in deposition conditions have on the uniformity. These results demonstrate that repeatability of the deposition profile can be kept in the +/-1.5 percent range for this practical range of deposition conditions. The range includes some variation caused by source depletion from within the crucible over the course of multiple runs, as well as other small, unintended differences.

Changes to the height of the evaporant surface also produce variations in the system, but in this case they are independent of material type. To some extent these changes are unavoidable, because as material evaporates from a source, the height of the evaporant will fall. The impact on uniformity can be significant when uniformity tolerances are tight. For example, changes in uniformity of +/-1 percent and a change in the outer position thickness of nearly 2 percent can occur when the source height shifts from 0.5-inch above to 0.5 inch below the nominal evaporant surface (see Figure 6). This is a realistic scenario for several common sources. Processes that require a tighter range on uniformity cannot allow that large a change in source height, so must break more frequently for source replenishment to maintain an even height.

While repeatability in the +/-1.5 percent range is representative of the exceptional performance capabilities of a well-tuned precision system like the FC-4400, it serves as a noteworthy benchmark for conventional methodologies when compared to the levels of uniformity achievable in the UEFC-5700.

... and two axes

To minimize the inclination angle non-uniformity, we have developed the high uniformity lift-off apparatus (HULA).

These patent-pending tools feature a second axis of rotation, which greatly reduces the range in non-uniformity prior to the addition of a shadow mask.

A tool that we have already mentioned in this article, the UEFC-5700, has a HULA configuration (see Figure 7). This tool features six small domes, which each spin about their own axes while rotating about the tool's central axis. Rotating the substrates in this manner has several major benefits: it increases collection efficiency by reducing the need to turn to a shadow mask to increase uniformity; and it greatly reduces sensitivity to material type and process conditions, thereby enhancing uniformity.

With the addition of the HULA motion, calculations indicate that the ranges for unmasked thickness profiles of different metals plummet to just +/-1.74 percent to +/-2.36 percent (see Figure 8). The tremendous reduction in overall range for each material and the differences in ranges between material types go hand-in-hand with similar reductions in sensitivity of the uniformity profile to run-to-run variation and source height variation. Those variations that caused shifts in uniformity in a single-axis tool of +/-1.5 percent are reduced in their influence to under 0.2 percent. The upshot of all of this is a system that delivers very robust uniformity characteristics across a wide range of materials.

Further improvements to thickness variation are possible with the addition of a very small shadow mask (see Figure 9). Using one designed for platinum film deposition, thickness variations are of the order of +/-0.5 percent – values so small that the metrology used to measure film thickness becomes very challenging, and the variations in film thickness may exceed the practical measurement accuracy commonly available.

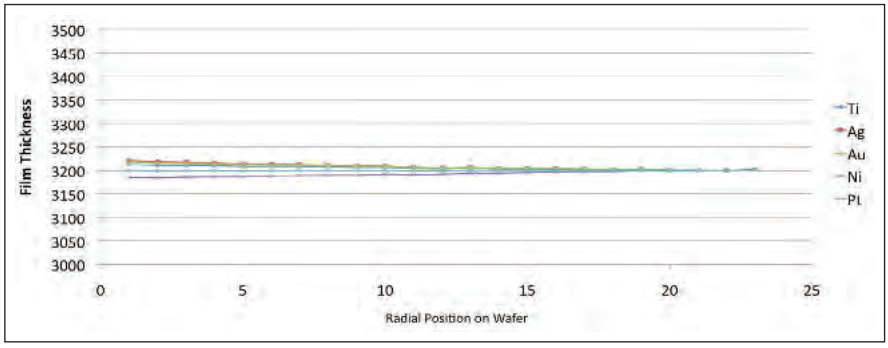


Figure 9. Adding a mask for platinum deposition to a HULA apparatus trims the thickness variations to around +/-0.5 percent

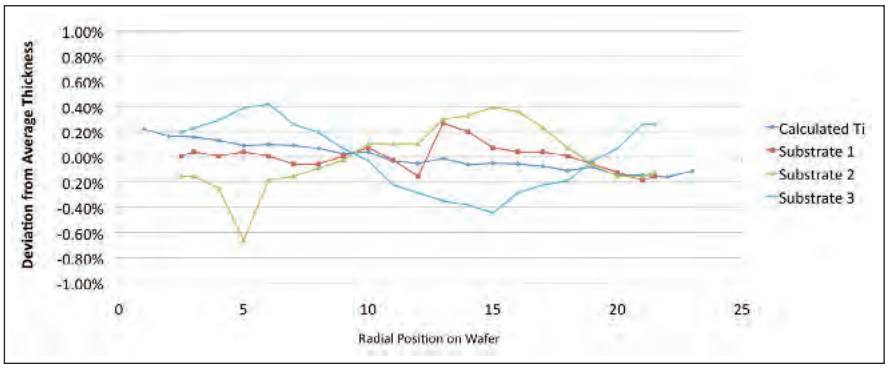


Figure 10. The calculated values can be compared to experimental values

We have also compared the calculated results for titanium (shown in Figure 8) with measurements on 20 nm-thick titanium films. Comparisons were made by plotting deviations from the average thickness for each substrate, and measuring the titanium film thickness with an optical technique that is sensitive to tiny variations in average thickness over the measurement area. There is good agreement between calculated and measured values, but some discrepancy at levels near +/-0.2 percent (see Figure 10). In this thickness range a 1 percent variation in thickness is comparable to the diameter of an atom, and this level of uniformity indicates a remarkably uniform distribution of atoms across the substrate.

Some of these measurements reveal a small decline in thickness between the inner and outer portions of the wafer. However, there is also other structure apparent, which varies from substrate to substrate. Although these features will partly be caused by measurement uncertainty, it is not possible to rule out substrate mechanical positioning as a contributing factor behind the thickness variation. When films are this uniform, variations in thickness that result from an angular tilt to the substrate or a radial displacement of just 0.04" become apparent.

Wafer-related limitations

Another impediment to realising a perfectly uniform film is the flatness of the substrate. For lift-off, the substrate is oriented in such a manner that at its centre, the direction of the impinging incidence flux is normal. Consequently, deposition at the edges of the substrate occurs at a small angle from normal. Making matters worse, the distance to the source is larger at the edges of the substrate than its centre. This difference is magnified as wafer diameter increases, but can be reduced by increasing the distance between the electron-beam source and the substrate – although this action has downsides, such as reduced deposition rates.

Inserting a shadow mask into the electron-beam evaporator can address variations in film thickness in the radial direction. However, in the direction perpendicular to this – the cross-wafer direction – the mask has a limited influence on reductions in film thickness.

Variation in film thickness due to flat wafers is also influenced by the number of axes of rotation in the system: the HULA motion without a shadow mask gives some slight improvement over the single axis motion without a mask, but the single axis and HULA results are effectively identical after the addition of a shadow mask (see Figure 11).

These uniformities, and those revealed in other plots presented in this feature, indicate that users of electron-beam evaporators have entered a new era for process tolerances and expectations in a production tool. When a single-axis tool is built to tight mechanical tolerances and runs a well-controlled and stable process, select processes can produce a thickness uniformity within a range of +/-1.5 percent on 150 mm wafers. The range of processes capable of delivering this level of uniformity expands with the addition of a second axis of rotation, which is found in the HULA tools.

For the deposition of eutectic films, this level of uniformity can mean the difference between an experimental process and a production wafer. But that's not all, as this level of uniformity can also drive further manufacturing efficiencies, thanks to reduced product binning – the sorting of finished devices based on variations in performance characteristics, such as voltage output, operational frequency and thermal tolerance. Such variations result from process variables and the inherent limits of each process, with a wider spectrum of product binning increasing parametric yield loss, which is the cost-per-wafer after sorting.

To increase uniformity to inside the +/-1 percent range requires the addressing of additional impairments to perfect film growth. This is hampered by wafer flatness, with success demanding even tighter tolerances on the mechanical systems that support and move the substrates. Programmes directed at uniformities of better than +/-1 percent must also consider whether the metrology is capable of accurately and consistently reporting the correct thickness. This is particularly challenging when the goal is to achieve differences in thickness that are smaller than that of the typical substrate surface roughness, or in the case of thin films, where the difference can be less than the width of an atom.

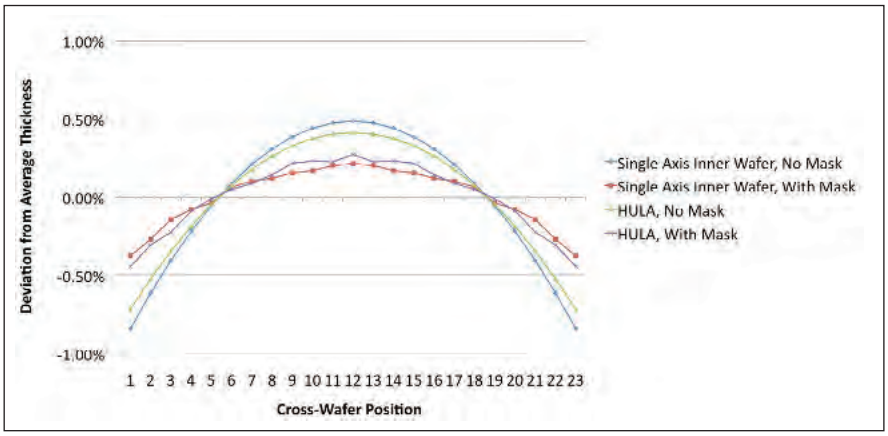
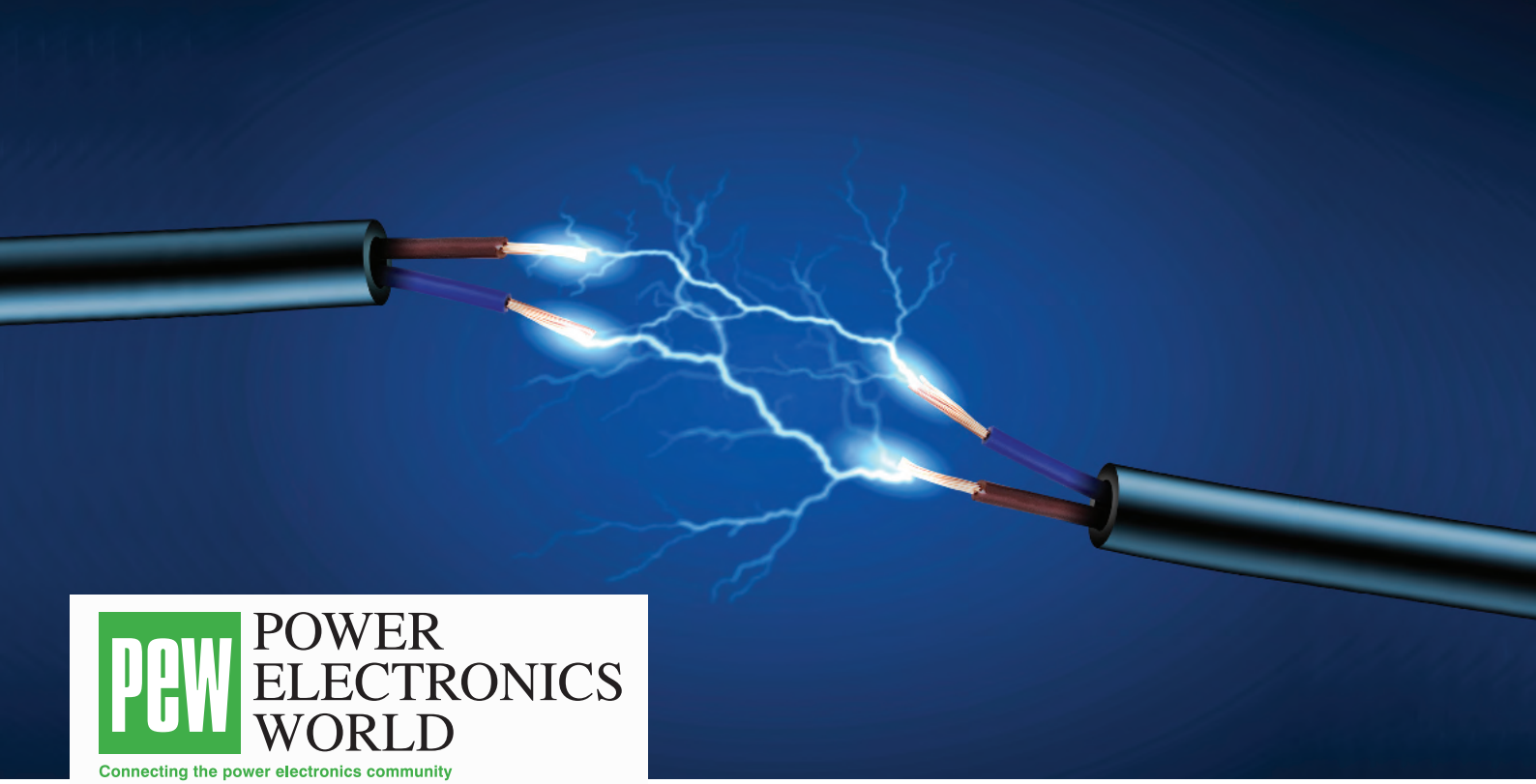


Figure 11. Without a mask, the addition of a second axes of rotation leads to a significant improvement in cross-wafer uniformity. But when the mask is added, this difference is minimal



POWER ELECTRONICS WORLD

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Power electronics is a global market and found in almost every electronic device – from energy networks, trains, aeroplanes and of course, mobile phones, PCs and cars. With diversified applications and voltage ranging from a few volts to several thousands volts, power electronics touches on many industry supply chains (production, distribution, consumption).

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Aixtron's new CEO takes holistic approach

Profitability, greater customer focus and technological innovation top the agenda of Aixtron's new boss Martin Goetzeler.

Interview by RICHARD STEVENSON.

Q Why did you decide to take on the role of CEO of Aixtron?

A I have followed Aixtron over many years as president of Photonics 21, as CEO and COO of Osram and most recently at the EU, where I was I heading a review of nano-electronic projects. For me, Aixtron is an exciting tech company, with a leading portfolio in many semiconductor manufacturing technologies that address applications such as LEDs, OLEDs, power electronics, silicon, graphene and CNTs. It is also great for me to serve various megatrends, like mobility and energy efficiency.

Also important to me is Aixtron's global presence, and the capable, proven team that has a track record of withstanding difficult times.

Last but not least, it's fair to mention that customers - as well as shareholders and other stake holders – believe in the capability of Aixtron to deliver future innovative technologies, and so do I.

Q What previous positions have you held, and how will that help you to lead the company?

A After 17 years with Siemens, I began my career at the Siemens subsidiary Osram in 1999, working for several years in Italy, in the UK and the US, and as CEO and COO. Right from the beginning as chairman of the board of the former Osram GmbH in 2005 I focused on expanding the LED and also the Asia business.

The largest share of investments went to innovative products, for example LEDs and energy efficient products.

This allowed Osram to successfully lead through troubled times during the 2008-2009 economic crisis. And on that basis I also feel very well prepared to successfully lead Aixtron through these challenging times.

Q How would you describe the state of Aixtron when you arrived?

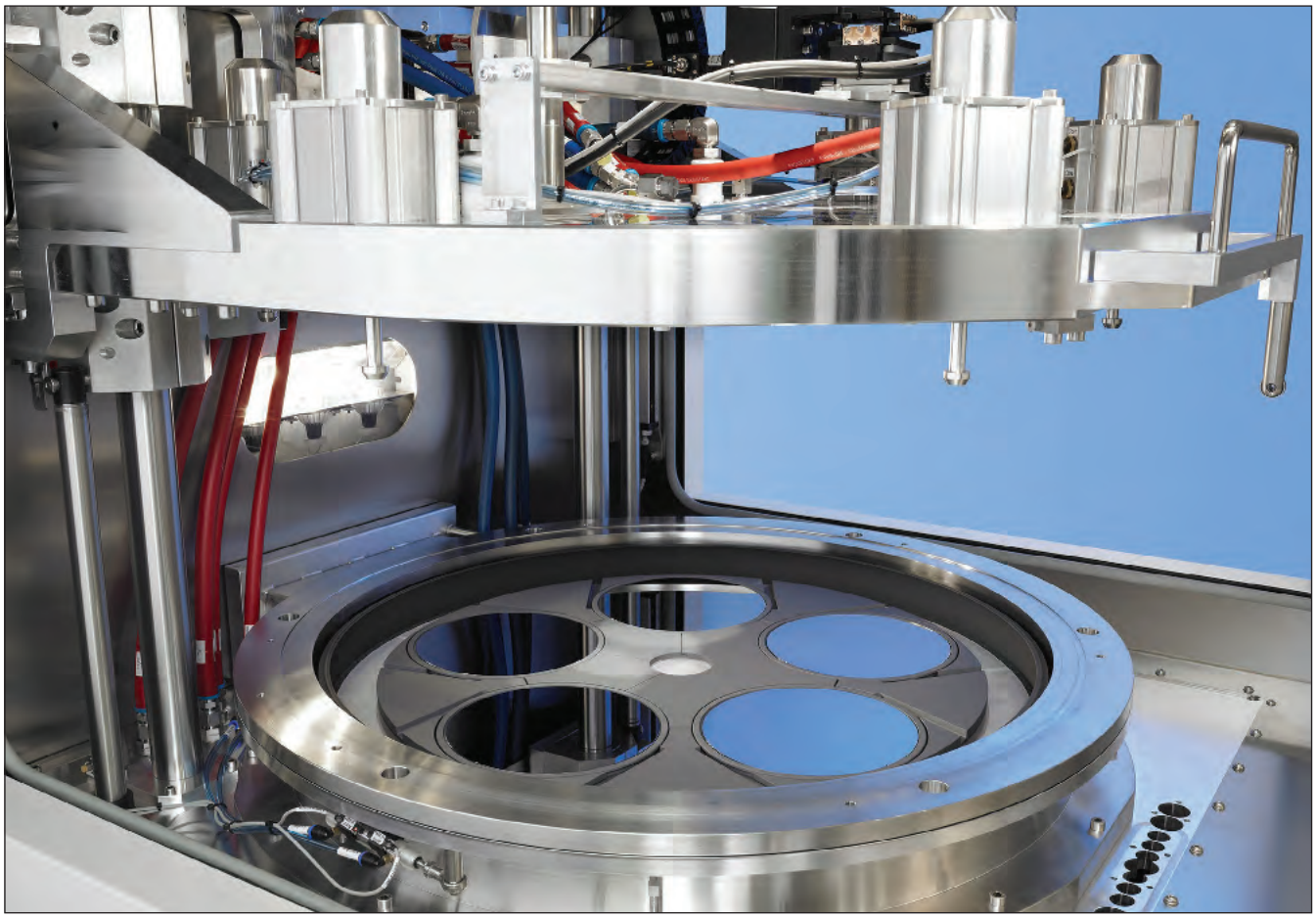
A Aixtron has a comprehensive technological expertise and a core competency in the deposition of complex materials, which the company turned over many years into business success by providing enabling technologies for emerging and also growing semiconductor markets.

When I joined the company in March 2013, the supervisory board asked me to return the company to the success path, which means to the position as a technology and market leader and back to financial solidity.

Against this background we diligently analysed and addressed the current situation. We quickly introduced our five-point program in order to re-focus the company and to increase the efficiencies within our organisation.

We set out a clear direction for the company, focusing on our customers, the utilisation of our technology portfolio, process optimisation, sustainable profitability and a focus on leadership.

Based on our strategy review, we continue to invest into our diversified product portfolio, including OLEDs and power electronics, to develop a broader



The AIX G5+ 5 x 200 mm Planetary Reactor: high throughput of homogeneous 200 mm GaN-on-silicon wafers for production of low-cost and efficient LEDs and power devices

revenue base. We also had to cut costs, which included a staff reduction. Ever since, we have seen good progress on our operational actions.

Q MOCVD sales are now very weak, following a massive rise in sales several years' ago. Do you think that the future will be cyclical, with tremendous ramps in shipments, followed by very lean times?

A I communicate regularly to our investor base that the majority of MOCVD demand will be driven by the LED lighting cycle. We believe that this cycle will be less cyclical than the previous cycle. The reason for that is that the LED lighting market has a three-dimensional demand pattern.

Firstly, different applications require different products, and have different return-on-investment propositions. Residential has different light sources. Street lighting, office lighting, shop lighting, architectural lighting, hospitality – each of these has different return-on-investment propositions. Secondly, different regions have different competitive dynamics and product preferences. You see that when you travel to Asia, or you to travel to the US – you have different products in offices and residential areas.

The third dimension is that you have a large number of players involved in the LED lighting space. This complex dynamic pattern makes it very difficult to anticipate the exact timing and shape of market demand going forward for LED manufacturing equipment. We currently see the lighting demand cycle as not a boom-and-bust cycle, but more in the shape of a gradual demand growth. It is more sustainable and lasting longer.

Q What does Aixtron need to do to become the dominant player in the market once more?

A First we have to continue to execute on our five-point programme. This is focusing on the customers, so we strengthen the customer support and the responsiveness, for example through our technical key account managers; stronger local teams, including regular personal contact. I'm meeting with customers regularly, to understand our relationship and how things are going with our products.

Our second point is to drive our product and technology portfolio. Our aims are to use our unique product portfolio more effectively and to further strengthen our various technologies.

Thirdly, we have to improve our processes – we must systematically optimise and accelerate our processes and project structures, for example in the areas of product development and supply chain management. The fourth point is managing financial targets. The special focus is on costs, cash and return-on-capital-employed.
And the last point is to strengthen Aixtron's leadership and corporate

culture. If I summarise where we are, we see major progress on cost-saving and cash management, on strengthening our customer relationships, on newly introduced processes, and on our technology roadmap. We are confident that our next generation of MOCVD reactors will meet the requirements of our customers, and therefore I am convinced that we will regain market share.

Q How close is the LED market to capacity?

A Referring to the last and biggest cycle, it was a cycle driven by the fast switch to LED TV and by the strategic demand from China supported by their subsidy programme for LED manufacturing equipment.

This was followed by a period of low equipment demand, characterised by the absorption of overcapacities, combined with uncertainties due to strongly declining end-product pricing and margin pressures. And hence, what we see is that players running with high utilisation rates decided to invest in smaller volumes step by step. At the peak of the cycle you had huge volumes, and now we see that the players continually invest, but they don't invest in 50 tools, but maybe in 4 or 12.

Q Why has Aixtron lost market share to Veeco?

A At the time when China issued its subsidy programme for MOCVD we had our new showerhead system targeting that market in the development pipeline. At that point in time our competitor had a suitable product available.

Subsequently, we brought our tool to market earlier than we had planned, which led to issues in terms of cost, reputation and also quality, regarding some start-up problems.
We have learnt our lessons with these challenges, with clearly defined measures benefitting our existing and new product generations.

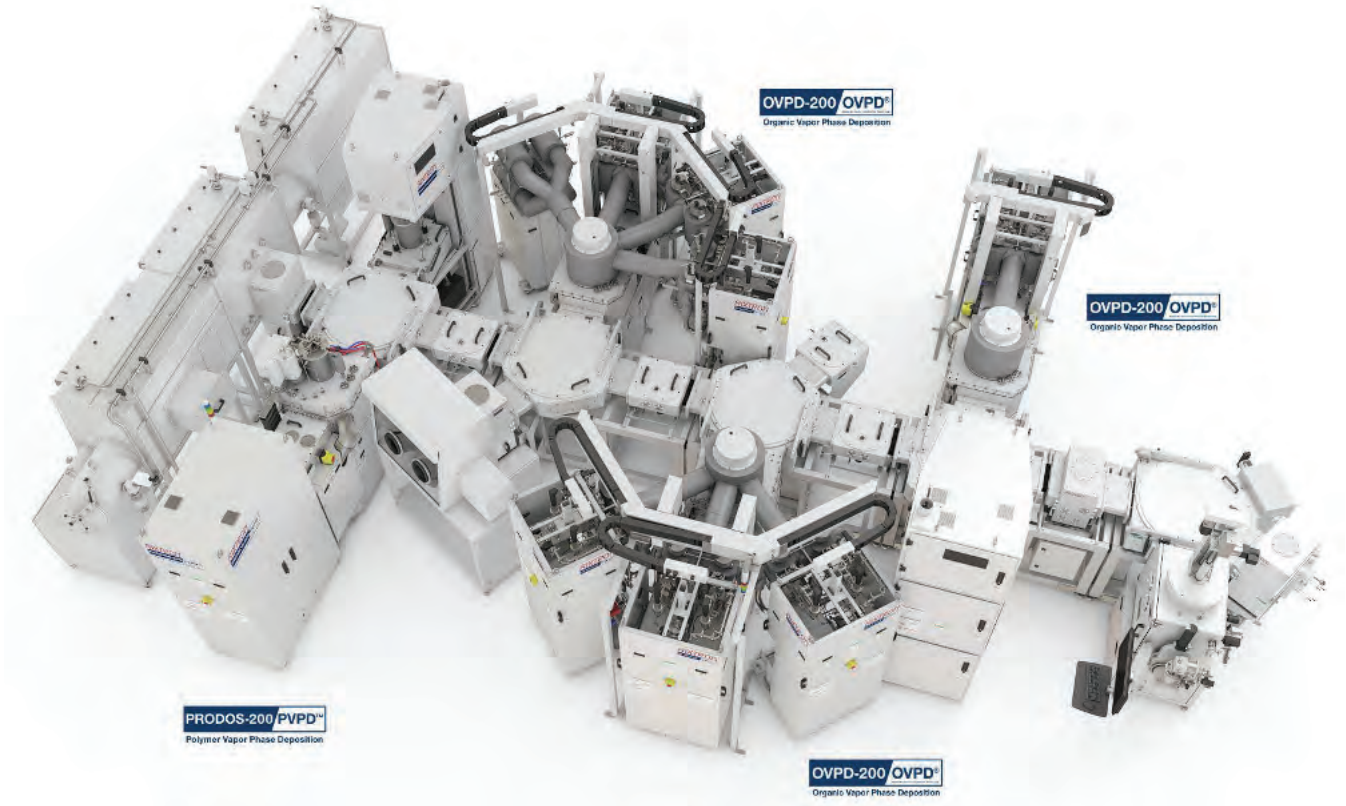
Furthermore, we have strengthened our team in China with local management, and actively support our customers with a demonstration and training laboratory, as well as installing technical key account managers as direct customer support.

Q Will MOCVD reactor sales continue to be a two-horse race, or could the likes of Taiyo Nippon Sanso and Valence Process Equipment become major players?

A We have great respect for all existing competitors and new entrants into the market. For new entrants, we see the barriers for entry remaining high. Nevertheless, we will continue to focus on our strengths: We continue to build on our thirty years of experience and our strong R&D commitment, in order to drive innovations, resulting in higher quality and lower cost of ownership for our customers.

Q How much interest is there in the production of GaN LEDs on silicon?

A We see an interest in the LED industry regarding the production of GaN LEDs on silicon in order to bring down the overall manufacturing costs, including substrate costs and using existing infrastructure. Most of the players are still in the R&D phase. The device design and



A new, cost-effective production technology for use in organic electronics: Aixtron's new organic cluster system for 200 mm x 200 mm substrates to be put into operation in the first quarter of 2014

manufacturing process are technically demanding. Market researchers, like IHS, forecast that the penetration of GaN-on-silicon wafers into the LED market will rise from just 1 percent today to 40 percent by 2020, and we feel we are very well positioned for that trend with our diversified MOCVD portfolio.

Q Do you believe that Aixtron has the best MOCVD tools on the market, or do you need new products?

A Overall, due to our broad and innovative portfolio, we see ourselves very well positioned in all the market segments we address. Moreover, the new MOCVD products we have in the pipeline have the potential to lower the total cost of ownership of our customers, helping them to be successful in this competitive environment. We are confident that these tools will strengthen our position in MOCVD and we will continue to make significant investments. This is not only important in the new technologies aiming to the future markets, such as power electronics and OLEDs, but also in silicon semiconductors.

Q Researchers at Sandia National Labs and the University of California, Santa Barbara, are arguing that lasers, rather than LEDs, are the optimum source for solid-state lighting. Does this concern you, given that laser chips deliver more intense light, and volumes of epitaxial material would diminish?

A We are monitoring various technology developments and we continue to see the LED becoming the dominant lighting technology in the near future.

However, if the laser would replace it at some point in the future, we wouldn't complain, since lasers also require MOCVD technology. As the manufacturing process for lasers requires longer deposition times and is more complex, it would require enhanced deposition systems, something we are able to offer. Overall, I would say that lasers could open the path to a broad range of new applications, which would then result in new opportunities for our company.

Aixtron's R&D Center in Herzogenrath reflects the company's strong focus on research and development

Q Could the power electronics market provide significant sales of MOCVD tools by the end of this decade?

A We expect that the end markets for power electronics will grow strongly, due to the requirement for energy-efficient devices. With the increasing demand for higher-voltage applications, for hybrid electric vehicles, renewable energy, smart grids, and power management, compound materials like gallium nitride or silicon carbide provide higher efficiency. We know that many customers are developing compound-based devices and production processes on MOCVD equipment and when they move to mass-production we anticipate the demand to increase significantly.

Q Will OLEDs, carbon nanotubes and graphene ever represent significant markets for Aixtron?

A We are optimistic about the commercial perspective of OLEDs, CNTs and graphene, and we have technological answers. We are investing extensively in these areas. Our deposition technology for manufacturing OLEDs has proven that it is more efficient, in terms of throughput and material consumption, than existing methods. This is why industry has shown great interest in our technologies that specifically target the production of large-area displays for TVs and lighting. This is a patented technology. On the carbon-based applications, it's clearly still in an early phase. However, we have already delivered our systems to renowned universities, research institutes and research centres in companies. Aixtron also plays a leading role in the EU project, the graphene flagship programme. We are heading the production work package.

Q Aixtron has laid-off about 20 percent of its staff. Are you confident that following this restructuring there will be no need for further cuts?

A Due to the prevailing uncertainties and low visibility, particularly in the MOCVD market, we cannot give any detailed guidance when we can see any rebound of the market demand. Nevertheless, and I would like to emphasize this, we believe that we are on track to further strengthen the company. We continue to improve our key processes as well as our cost structure – at the same time – we are maintaining our investments into future technologies that offer significant market opportunities.

Q What do investors feel about the company's current performance?

A I know from various discussions with investors that they have acknowledged the subdued situation of the global MOCVD market. My impression is that they trust in our ability to reposition our company in the MOCVD market, to return to profitability, and to develop a strong position in future markets, such as OLEDs and power electronics. Moreover – I don't know if you've heard about it – we have recently closed a capital raise that was over-subscribed by investors. I value this as a sign of confidence in our long-term strategy.

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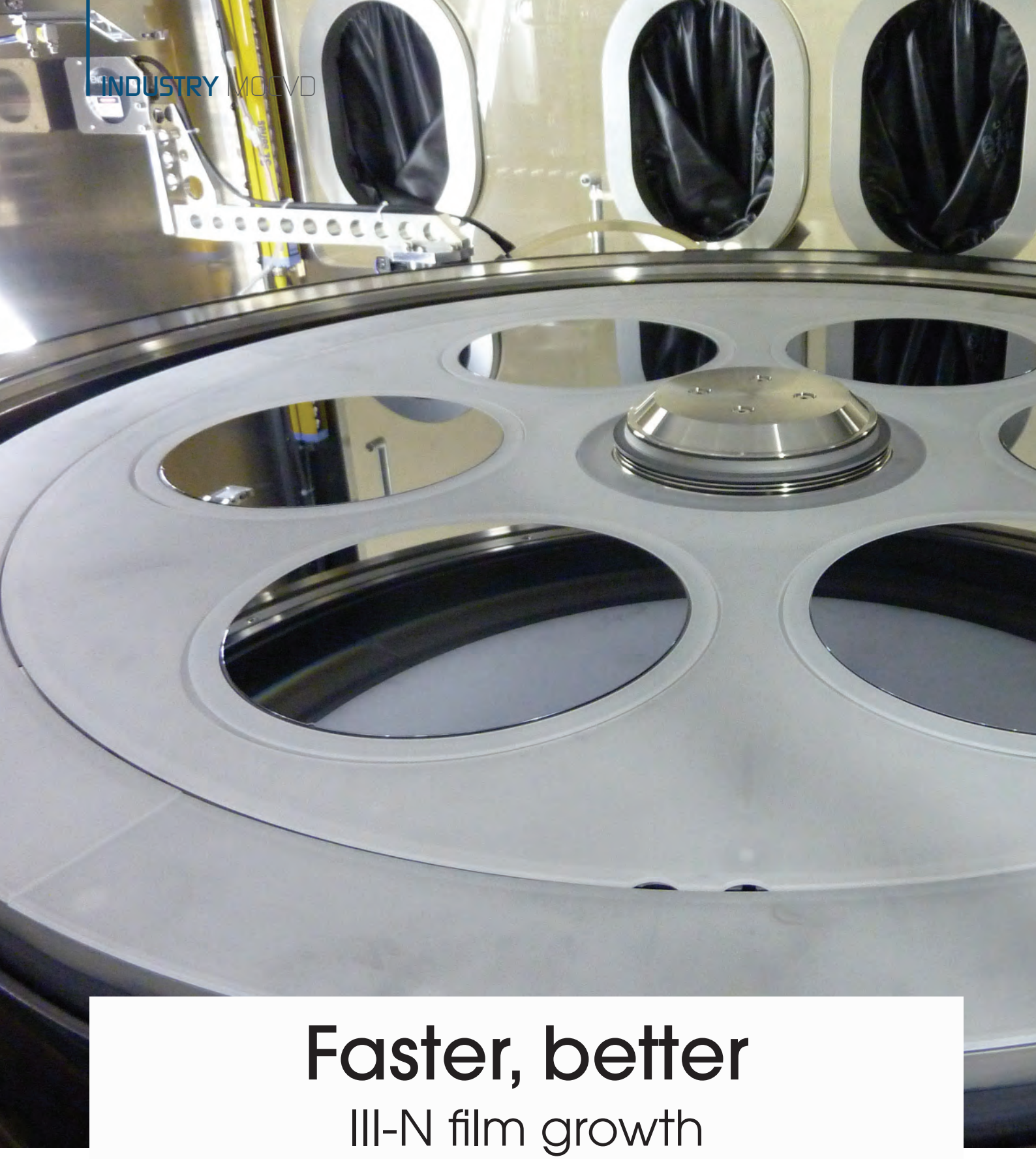
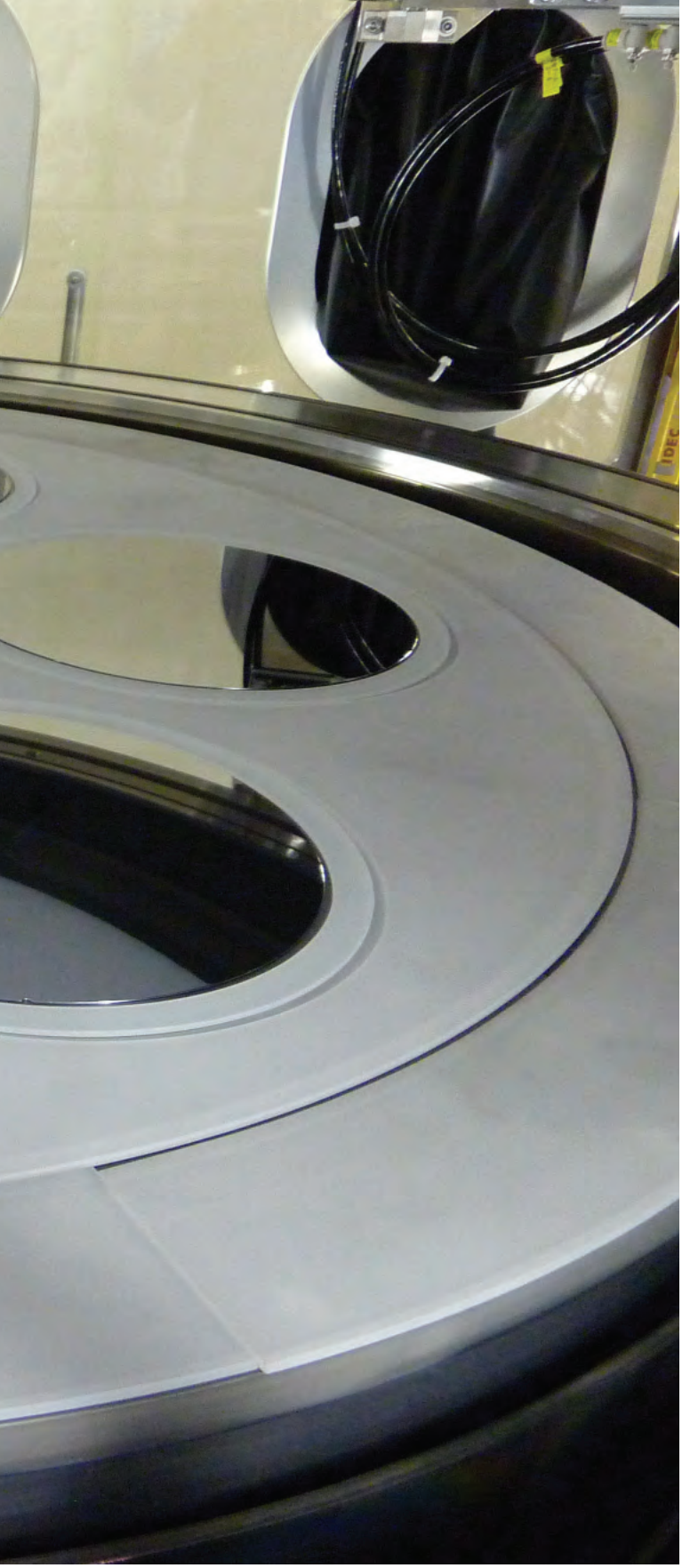


Faster, better

III-N film growth

MOCVD reactors equipped with three-layer nozzles and operating at atmospheric pressure can produce growth rates and doping ranges that manufacturers of GaN power electronics and ultraviolet LEDs are looking for.

By KOH MATSUMOTO FROM TAIYO NIPPON SANSO



Left: The UR26K can accommodate ten 6-inch wafers or six 8-inch wafers

THE III-N CHIP generates billions of dollars every year, with revenues continuing to grow. Sales in this sector are currently dominated by InGaN-based LEDs, which are backlighting many screens and driving a revolution in LED lighting. But other significant markets are emerging: ultraviolet LEDs, which are attractive replacements for mercury lamps, thanks to superior robustness, longer lifetime and portability; and power electronics based on GaN that offers a step up in efficiency compared to silicon incumbents.

Developers and manufacturers of all of these devices are working with different types of substrate for chip production. Sapphire is the most common platform for the LED, but savings are promised by switching to large area silicon substrates that enable chip processing in under-utilised, depreciated silicon fabs. Silicon substrates are also popular within the III-N power electronics industry, but in both this sector and in that of the LED, if native, low-cost substrate were available, they would be widely used. In fact, a small proportion of the world's LEDs are already being manufactured on GaN, while some groups pioneering ultraviolet LEDs are using AlN substrates for device development.

However, regardless of the substrate employed for making their nitride-based devices, engineers are searching for excellence from their MOCVD tools in three areas: control of the gas-phase reaction for high aluminium concentration and high growth rate; control of carbon doping, from low to high doping densities; and deposition of high-quality layers at high growth rates.

At Taiyo Nippon Sanso of Tokyo, Japan, we satisfy all these requirements with a portfolio of MOCVD reactors featuring a 'horizontal three-layer' design and growth at atmospheric pressure. Our smaller tools have an enviable reputation with the R&D community, and our large-scale production machines share the same design philosophy, making it easy to transfer recipes from one type of machine to the other.

Although many know of us through our supply of industrial gases – this activity dates back to the founding of our company in 1910 – we have a strong track record in MOCVD, with efforts commencing in 1983. We initially launched systems for the growth of materials based on the InP and GaAs families of materials. However, by the late 1980s, we started to develop our range of GaN MOCVD systems. They now meet the needs of every customer, from those wanting to carry out research on a single-wafer 2-inch system, to those requiring a large-scale machine for volume production that is capable of accommodating up to six 8-inch wafers or ten 6-inch wafers (see Table 1).

The majority of GaN MOCVD reactors employ either a vertical or a horizontal gas flow. Our reactors adopt the latter approach, with precursors supplied from a nozzle upstream of the substrate holder, which is a part of the machine that is also referred to as the susceptor. Materials are consumed along the direction of gas flow, so rotation of the wafers is required to ensure a uniform thickness of film growth. In a single-wafer tool the wafer is rotated about its centre. Meanwhile, in multi-wafer reactor, planetary motion is used, with accurate control resulting from a carefully chosen gear and ball bearing system.
One distinctive feature of our reactors is their three-layered gas ejection nozzle. Materials are injected into the reactor via high flow speeds through this nozzle, to enable good control of organometallics and ammonia, and ultimately the deposition of high-quality GaN, AlN, and AlGaN at high growth rates.

GaAs, InP

Model	Type	Wafer	
HR-3000	Horizontal / Face up	3" x 1	R&D
HR-4000	Horizontal / Face up	2" x 3	
HR-6000	Horizontal / Face down	2" x 6 or 3" x 3	
HR-8000	Horizontal / Face down	3" x 6 or 2" x 18 or 4" x 4	Mass Production
HR-10000	Horizontal / Face down	4" x 5 or 3" x 10	

GaN

Model	Type	Wafer	
SR2000	Horizontal / Face up	2" x 1	R&D
SR4000	Horizontal / Face up	2" x 3 or 4" x 1	
SR6000	Horizontal / Face up	2" x 6 or 3" x 3 or 6" x 1	
UR25K	Planetary / Face up	4" x 11 or 6" x 7	Mass Production
UR26K	Planetary / Face up	6" x 10 or 8" x 6	

Table 1: Taiyo Nippon Sanso produces a wide range of MOCVD tools that meet the needs of R&D groups and high-volume manufacturers of compound semiconductor chips

In our small-scale machines, the nozzle is positioned in the upper-flow section of the susceptor, but in large-scale mass production systems, it is located in the centre of the susceptor, so that gas spreads out from there. A resistance heater raises the temperature of the substrates to that required for growth. The heating system is zone-controlled to realise the optimum temperature distribution on the susceptor. The number of zones varies with the size of the reactor, from just one for the smallest R&D tool to six for our biggest mass-production machine.

The Taiyo Nippon Sanso UR26K is the company's biggest MOCVD reactor

Another feature of our systems is continuously controllable pressure, which can be varied from 10 KPa to 100 KPa. Thanks to well-controlled gas phase reactions, adjustments in pressure can tune the material properties, which depend on growth pressure.

Quartz is used for the flow channel components. One merit of quartz is that it is easy to clean – and that is a big advantage for growth of GaN on silicon, because component cleanness is critical for reproducible growth. Note that mass production machines are equipped with an automated component exchange robot, making it relatively easy to carry out maintenance on the tool.

Higher growth rates

The capability of our reactors is highlighted by the high quality of various epiwafers produced by them. This includes electronic devices based on AlGaN and GaN that can be formed by high-speed growth and feature a very wide range of carbon doping levels; high-voltage GaN-on-GaN diodes with well-controlled, shallow silicon doping levels; and AlGaN films with a high aluminium content, which can be used for producing ultraviolet LEDs.

Growth of high-quality, wide-bandgap electronic structures on silicon demands a multi-layer buffer structure incorporating GaN, AlN and AlGaN. And if a HEMT is to offer high-voltage power-switching, this buffer must be thick enough to enable a high breakdown voltage.

One downside of any thick layer is that it adds to growth times and thus reduces the number of epiwafers that can be

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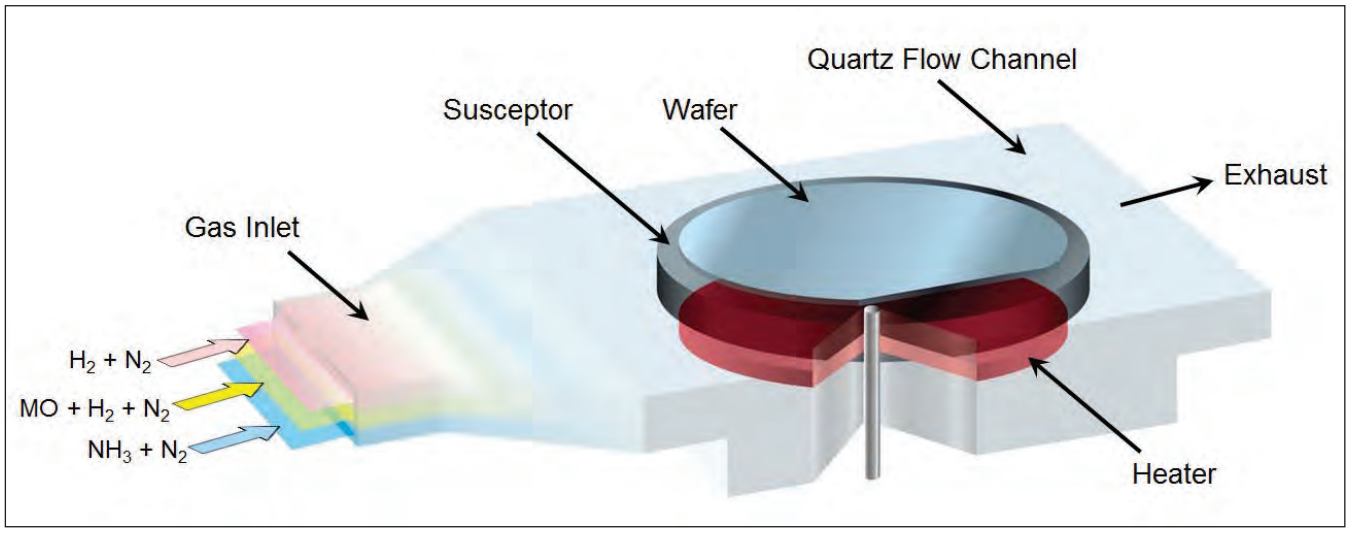

Figure 1: Process gases enter the horizontal flow reactor through a three-layered gas-injection nozzle

produced per day from an MOCVD system. With a conventional reactor, the growth rate for the buffer is limited to 1 - 3 μm/h due to parasitic reactions.

However, with our systems, far faster growth rates are possible, thanks to the combination of a laminar high flow velocity and a specially designed three-layer-flow, gas-injection nozzle. Equipped with these attributes, engineers using our tools have a better control over vapour phase reactions and can realise shorter process cycle times.

Growth rates for III-Ns depend on the constituents, with maximum values of 27 μm/h, 3.8 μm/h, and 11.4 μm/h for GaN, AlN and AlGaN, respectively (see figure 2). Employing a very high growth rate, we have deposited a 3 μm-thick HEMT test structure on 6-inch silicon, using a growth rate of 8.5 μm/h for the AlGaN/AlN strained layer superlattice and 7.5 μm/h for GaN. The net time for film growth, which excludes temperature ramping and reactor purging, is only 41 minutes, compared to 88 minutes for our standard growth time.

This trimming of the growth time by just over 50 percent did not lead to a significant deterioration in electrical properties. According to Van der Pauw measurements, in the high-growth-rate epiwafer the typical electron mobility was 1530 $cm^2 V^{-1} s^{-1}$ at a sheet carrier density of 8.9×10^{12} cm^{-2}. It is possible that further optimisation of the growth process could enable even shorter growth times, and thus deliver an additional hike in the productivity of III-N wafers for electronic applications.

Superior doping control

For a power switching device, the usual approach is to heavily dope the GaN buffer layer with carbon so that it is highly resistive, while employing a pure (undoped) GaN layer for the channel. Research groups have shown that increasing carbon concentration boosts breakdown voltage, while increasing growth pressure cuts yellow luminescence in GaN and suggests suppression of current collapse.

With conventional reactors, the range of carbon concentrations at a given growth rate is held back by the limited range of V/III ratios and growth pressure. It is possible to deposit GaN layers with very low carbon concentrations, but this requires low growth rates, and that leads to long growth times. In stark contrast, with our tools the range of V/III ratios and growth pressures that can be used is far wider, and this allows engineers to obtain the carbon concentration they wish at a high GaN growth rate. For example, it is possible to produce GaN films at carbon concentrations from 10^{16} cm^{-3} to 10^{20} cm^{-3} with growth rates in excess of 3 μm/h (see Figure 3).

An alternative, attractive architecture for GaN-based electronics is the vertical diode. This device, which offers easy wiring and packaging and high area efficiency, consists of *n*-type and *p*-type GaN layers that are grown on a conductive GaN substrate. Challenges for manufacturing this device include: a reduction in growth time, because the *n*-type GaN needs to be tens of microns thick; and uniform silicon doping of GaN from concentrations of 10^{15} cm^{-3} to 10^{19} cm^{-3}. Producing films with

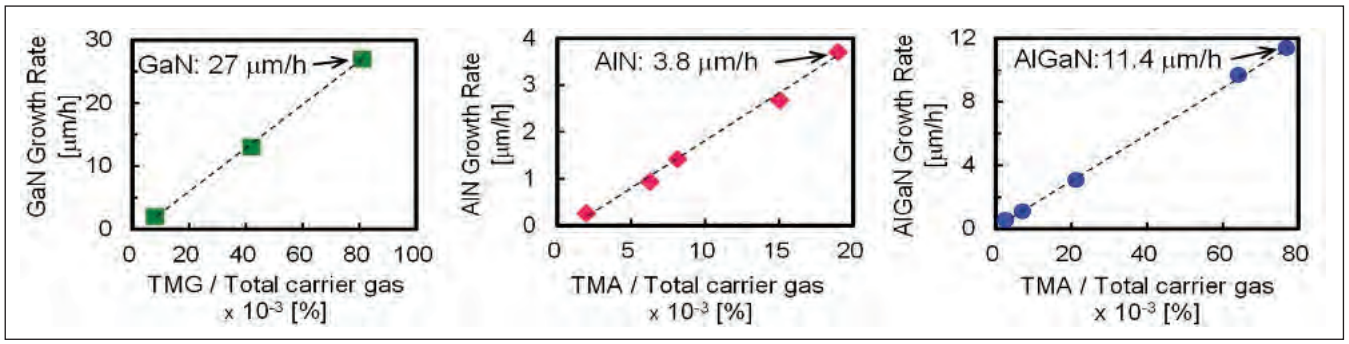

Figure 2. Growth rates for III-N binary and ternary films deposited in a Taiyo Nippon Sanso reactor

low doping concentrations is not easy, requiring control of the very diluted SiH_4 gas supply and a low level of carbon impurities, so that it is possible to produce low compensation *n*-type GaN.

Realising GaN films with these attributes requires a suitable reactor design and a good growth process. As previously stated, the growth rate of GaN in a conventional reactor leads to device deposition times that can be 10 hours or more. But with our system, because it is possible to cut carbon concentration via atmospheric pressure growth, *n*-type GaN growth rates can be very high, leading to runs of just several hours for epiwafers production.

The carrier concentration in *n*-type GaN grown on 6-inch sapphire depends on the ratio of SiH_4 to tri-methyl-gallium (see Figure 4). Uniform doping at 5×10^{15} cm^{-3} is possible under growth rates as high as 3.6 μm/h, indicating that our reactor is very suitable for growth of nitride-based vertical diodes.

Ultraviolet LED structures

Essential ingredients for the ultraviolet LED – which can be used for curing, money checking, and air purification – are the growth of AlN and high aluminium composition AlGaN. These layers are normally deposited on sapphire, and when conventional equipment is used, within-wafer uniformity and crystal quality are hampered by an excessive gas phase reaction. This impacts productivity and yield.

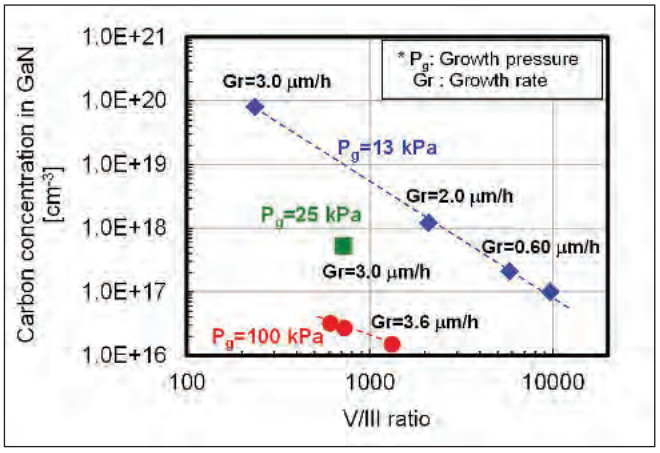

Figure 3. Increasing the growth pressure leads to faster growth rates with a low carbon concentration

However, if engineers use our tool, the parasitic reaction is controlled and high-quality, uniform AlN and AlGaN films can be grown at high growth rates. For example, it is possible to deposit AlGaN with an aluminium content of about 60 percent on 4-inch sapphire at 6.4 μm/h. Photoluminescence measurements of an InAlGaN multi-quantum well structure produce intense emission at 330 nm, and a high level of uniformity in the peak emission wavelength across the wafer (see Figure 5). These results demonstrate that our reactors have the capability to increase productivity for manufacturers of ultraviolet LEDs, just like they can do for the makers of electronic devices based on nitride materials.

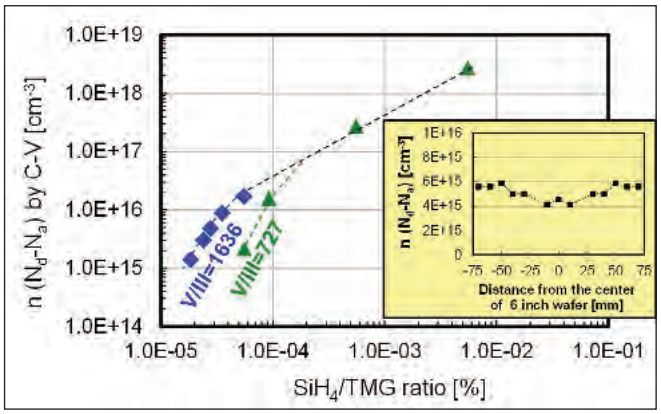

Figure 4. The carrier concentration in *n*-type GaN depends on the ratio of SiH_4 and tri-methyl-gallium and the V/III ratios. The inset reveals the uniformity of doping across a 6-inch epiwafer

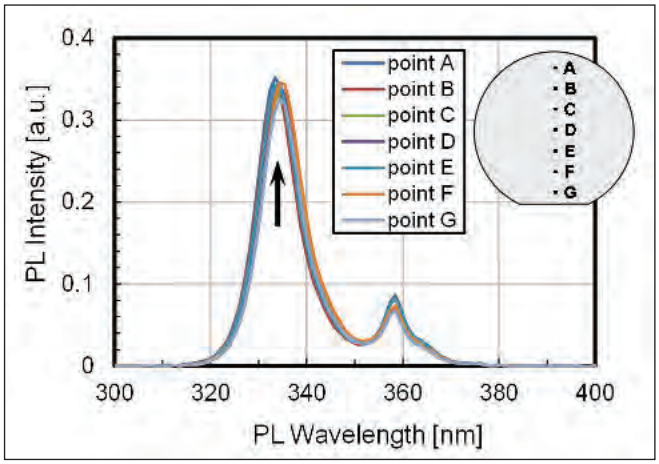

Figure 5. A high level of uniformity of peak emission wavelength indicates the potential of the Taiyo Nippon Sanso reactor for ultraviolet LED production.

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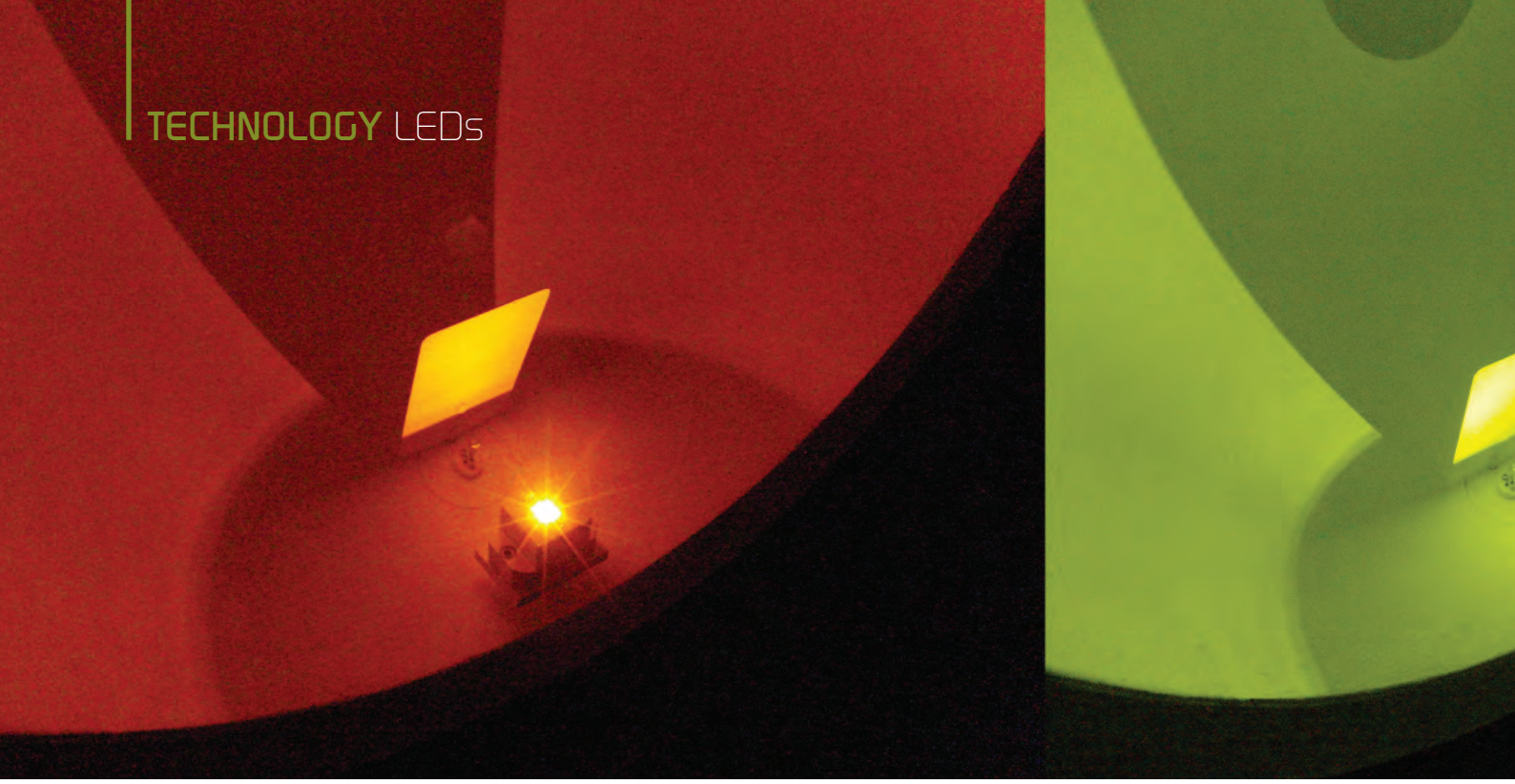


Addressing the green gap with a novel active region

Capping wells with AlGaN and turning to InGaN barriers empowers LEDs to deliver efficient emission at longer wavelengths

By REI HASHIMOTO FROM TOSHIBA

AS THE PRICE OF LED bulbs falls and they get more efficient, criticism of these solid-state sources is shifting to sub-standard colour quality. Responding to such a demand, manufacturers are making solid-state sources with a colour-rendering index (CRI) in excess of 90 today.

The near-natural light that emanates from these pricier bulbs results from a combination of phosphors emitting in the yellow, green and red. But there is an inevitable penalty to pay with these multi-phosphor sources – lower efficiency. This stems from a combination of the Stokes shift from blue light to the other emitted colours, and energy losses resulting from some phosphors absorbing light emitted by other ones.

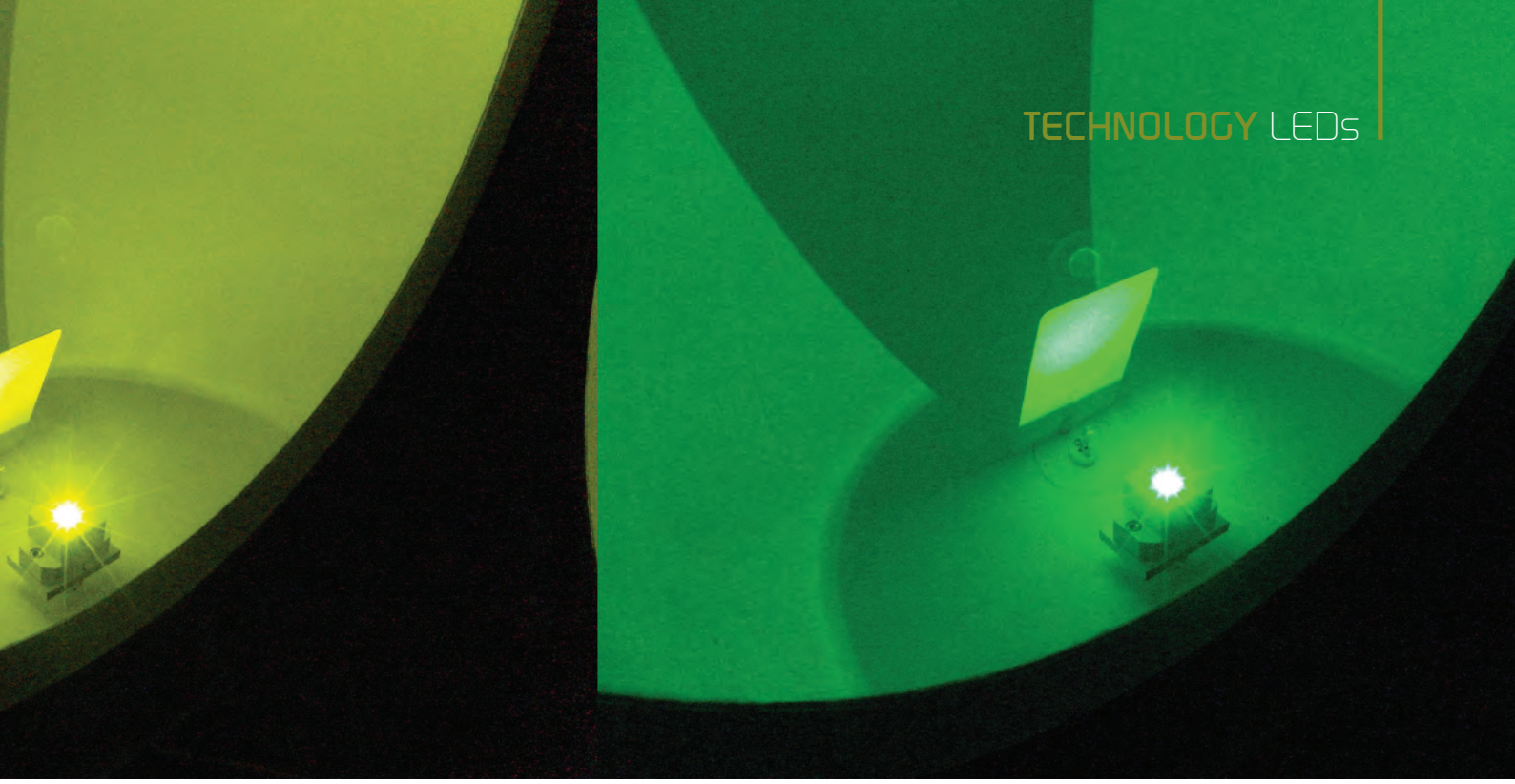
Fortunately, there is an alternative approach to high-efficacy, natural white lighting: Colour mixing three or more LEDs emitting at different wavelengths.

Simulations by Yoshi Ohno from the National Institute of Standards and Technology showed that this approach promises to deliver spectacular results [1]. By mixing four coloured LEDs (such as a red, a green, a blue and an amber), it is possible to create a white-emitting source with an efficacy of 356 lm/W, a correlated colour temperature of 5000K and a CRI of 90.

Furthermore, by eliminating the phosphor, costs can be trimmed, while control of the LEDs opens up the opportunity for colour tuning.

To turn this vision into reality, LED bulb manufacturers need to work with high efficiency LEDs emitting in the red, green, blue, yellow and amber. But this is not possible today. Efficient emitters only exist at wavelengths shorter than 540 nm and longer than 600 nm – in the spectral range between there is a severe drop in external quantum efficiency. This weakness in LED performance is referred to as the 'green gap'. A bright green LED could address this, and might also serve other applications, such as traffic lights and projection systems.

At wavelengths of 600 nm or more, the InGaAlP material system can be used to create bright LEDs with a low operating voltage and an external quantum efficiency in excess of 60 percent.



Increase the aluminium content in this quaternary and emission can reach the yellow or green, but this increase in emission wavelength comes at the expense of efficacy, which plummets due to a tremendous hike in the density of non-radiative centres.

Moving to shorter wavelengths also reduces the confinement of electrons and holes in the quantum wells, which in turn limits efficiency and increases the decline in device performance with rising temperature.

The alternative approach is to stretch the emission of a GaN-based blue LED to longer wavelengths. The starting point is very promising: A blue LED combines an external quantum efficiency of over 75 percent with excellent thermal stability, a narrow full-width half maximum and a lifetime in excess of 40,000 hours. These attributes are not just advantageous for a full-LED, white-lighting system – they are also valued for full-colour projection.

One attractive attribute of InGaN LEDs is that they can, in theory, produce all the colours needed for a high-efficiency, full-LED white-lighting system. All that is needed to reach longer wavelengths is to increase the indium content. If a white lighting system were made in that way, it would be easy to construct, because all the coloured LEDs would exhibit similar levels of reliability, thermal stability and operating voltage.

These benefits have helped to spur the development of longer-wavelength, high-efficiency LEDs, such as those emitting in the green, yellow and amber. Progress has not been easy, however, due to two obstacles: the quantum-confined Stark effect (QCSE) and crystal degradation.

The QCSE, which is induced by a strong internal piezoelectric field in highly strained InGaN quantum wells, leads to a pulling apart of electrons and holes in the quantum well. This separation of opposing charge carriers is more severe at higher indium content, and accounts for a decline in radiative efficiency with increasing wavelength.

It is possible to eliminate these internal fields by growing an LED on a non-polar substrate, while a semi-polar platform

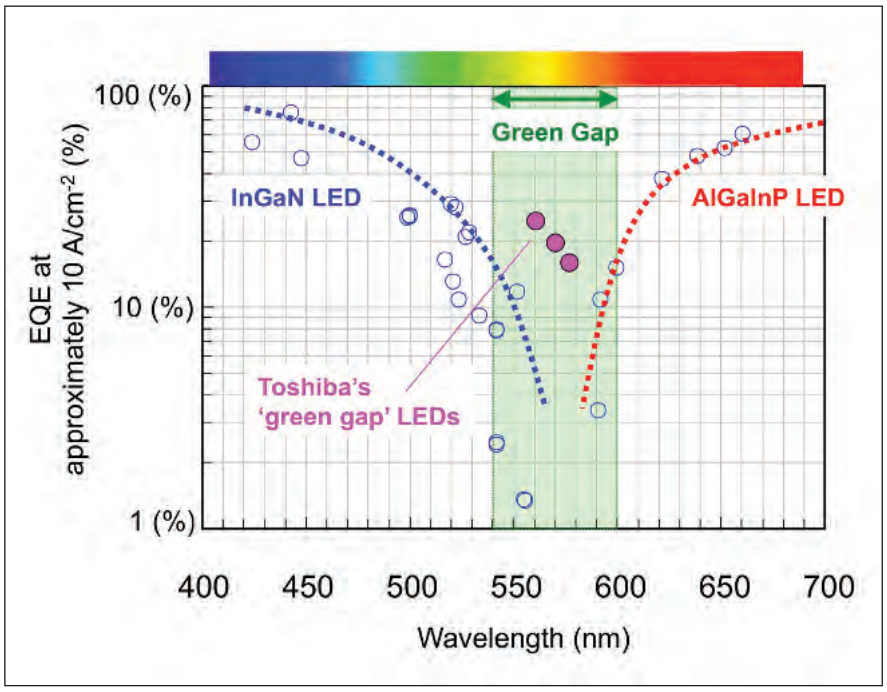


Figure 1. The 'green-gap' problem is a decline in LED efficiency towards green wavelengths. Toshiba has improved efficiency in this spectral range with a novel active region formed with a faster growth rate

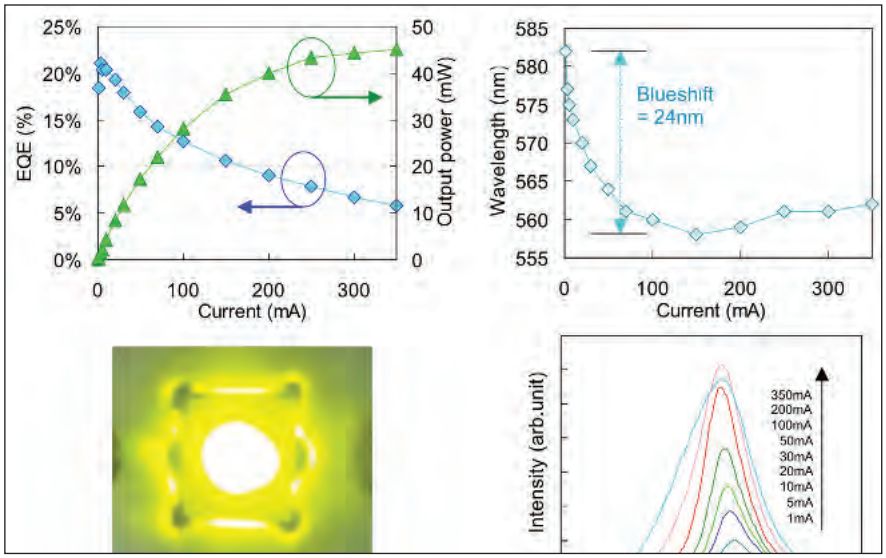


Figure 2. Toshiba's yellow LED emits a peak wavelength of around 570 nm and produces an external quantum efficiency of almost 20 percent at 20 mA

can reduce them. Escaping from the impairments resulting from of the QCSE can enhance the radiative efficiency and assist the fabrication of high-efficiency, longer-wavelength LEDs. In fact, superior optical properties of green LEDs using non-polar (11$\bar{2}$0) or semi-polar (20$\bar{2}$1) GaN substrates have already been reported. Furthermore, weakened electric fields can facilitate thickening of the quantum wells for reduction of average carrier density, achieving low droop operation which is one of the greatest concerns for GaN based LEDs [2]. However, there are challenges associated with the crystal growth of relatively high indium contents layers needed to form yellow or longer wavelength emitters on semi-polar and non-polar substrates.

Also, both of these foundations, which are formed by slicing GaN crystals, are prohibitively expensive. This means that the only practical way forward for producing longer wavelength LEDs is to build them on conventional *c*-plane sapphire (0001) substrates.

In addition to the issues associated with the QCSE, crystal degradation hampers the development of longer-wavelength, GaN-based LEDs. As indium content in the InGaN alloy increases, this layer is plagued with an increasing number of imperfections: threading dislocations, stacking faults, V-shape defects and indium-rich surface clusters. All of them act as non-radiative centres, hindering LED performance.

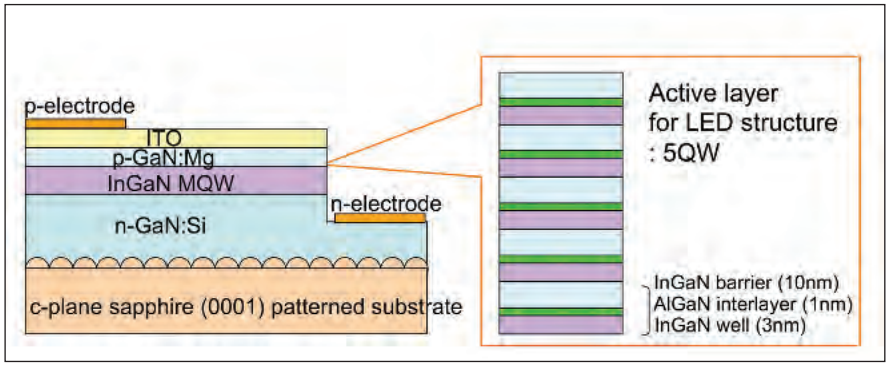


Figure 3. Toshiba's novel LED structure is formed by MOCVD

The density of these defects increases at higher indium concentrations, due to a greater lattice mismatch between GaN and InN and an increase in the miscibility gap in the InGaN crystal phase. To produce an LED emitting at 540 nm or more, the indium content must be greater than 25 percent – compared to just 14 percent for a blue LED. This increase in indium richness for the green emitter makes it very tricky to grow an active region with eight or nine quantum wells, a standard structure for a blue emitter. The higher indium content can result in high levels of accumulated strain, which can cause catastrophic crystal degradation.

To address the green gap, our team from Toshiba Corporation of Kawasaki, Japan, has developed optimised growth conditions for forming a new active region by MOCVD. This structure, which is formed on conventional *c*-plane sapphire substrates, features a 1 nm-thick AlGaN capping layer directly above each InGaN quantum well.

There are several benefits associated with the addition of this thin AlGaN capping layer [3]. Its primary purpose is to shift the wave-function of the electrons toward the inside of the well, thereby increasing electron-hole overlap and radiative recombination. However, introducing the capping layer also creates a barrier to electron overflow from each well, so we do not need to employ a thick, conventional AlGaN electron-blocking layer above the active region. What's more, the thin layer of AlGaN recovers the smoothness of the surface after the high-indium-content InGaN well, which has a very rough surface. In order to produce longer wavelength LEDs with a high external quantum efficiency, it is essential to realise a high degree of surface flatness prior to the growth of each quantum well.

We have worked hard to optimise the crystal quality of our new active region. To fabricate green, yellow and amber LEDs, we need to have an indium content in the InGaN quantum wells of 24 percent to 28 percent, which is a composition that is tricky to realise by MOCVD.

The common approach to increasing

indium richness is to lower the growth temperature, but this leads to a hike in defect density. Although a more elevated temperature reduces the defect density, thermal instability of InN makes it more challenging to form InGaN films with a higher indium composition.

To try and combine high growth temperatures with high indium-content, we investigated and optimised the growth rate of InGaN. This approach paid dividends, as we found that by increasing the growth rate by a factor of ten, the same InGaN composition could be obtained at a higher growth temperature. This allowed us to grow high-indium-content InGaN quantum wells with a high crystal quality at the desirable, higher growth temperature.

Another tweak that we made to the conventional active region was to replace the GaN barriers with those made from InGaN. This switch decreased the defect density in the active region, thanks to a reduction in lattice mismatch between the well and barrier. By improving crystal quality – while not changing the QCSE and having little, if any, impact on the internal electric field – we were able to increase photoluminescence decay time and grow an active region with five quantum wells that did not exhibit a decline in photoluminescence intensity [4].

The result of all of our refinements to the active region is a tremendous increase in the efficiency of GaN-based LEDs emitting in the green-yellow, yellow and amber.

Driven at 20 mA, our 570 nm LED that emits in the yellow delivers 8.4 mW at an external quantum efficiency of 19.3 percent [5]. Meanwhile, at the same drive current, our 560 nm green-yellow LED and 584 nm amber LED deliver 11.2 mW and 4.9 mW at external quantum efficiencies of 25.5 percent and 11.4 percent, respectively [6].

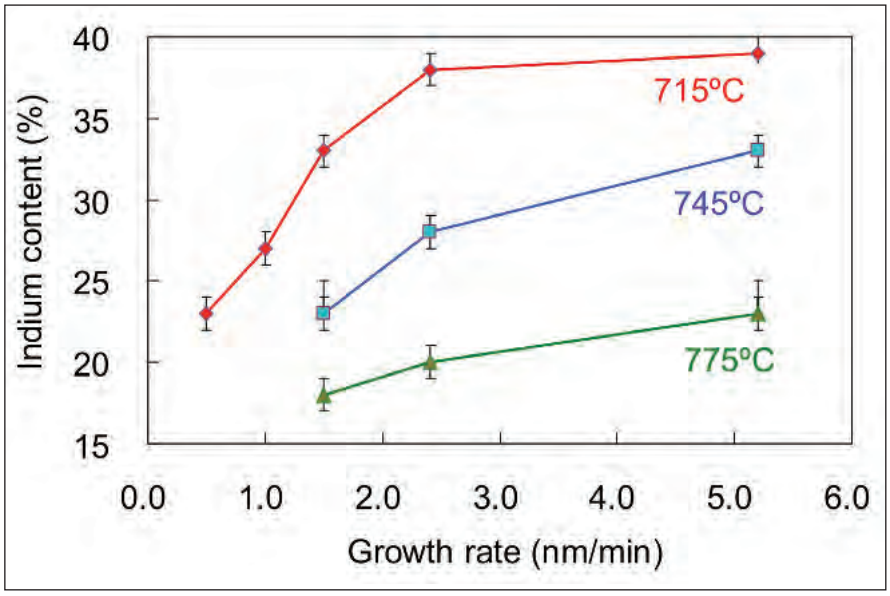


Figure 4. Increasing the growth rate holds the key to realising a higher indium composition at a high growth temperature

These results show that our approach goes a long way to addressing the 'green gap' and the issues associated with the construction of full-LED lighting systems. But we still have much more work to do.

Another of our goals is to improve the performance of our devices as the current through them is cranked up from 20 mA to the levels required in lighting systems. At present, our long-wavelength LEDs suffer from severe droop and a large blue-shift in emission wavelength with current. These weaknesses will not need to be addressed to reach an external quantum efficiency of 50 percent – that should be possible by improving InGaN crystal quality – but the QCSE and droop will have to be addressed if these long-wavelength LEDs are to catch the level of performance of their blue-emitting cousins.

If full-colour lighting systems are to appeal to the public, they will also have to be affordable. To help to trim costs, we can switch the substrate used to make our LEDs from sapphire to silicon. This move will be relatively easy to implement, because today we have replaced the sapphire substrate with 200 mm silicon for the mass-production of blue LEDs.

This switch, plus our approach to addressing the green gap, could usher in an era of solid-state lighting that is not only highly efficient and long-lasting, but capable of delivering high-quality, adjustable white-light.

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Scaling semi-polar substrates

Growth on patterned sapphire can lead to large, low-cost semi-polar substrates

By KEISUKE YAMANE FROM YAMAGUCHI UNIVERSITY, JAPAN

ONE-FIFTH OF THE WORLD'S ELECTRICITY is consumed by lighting. So, to try and trim carbon footprints, many companies and governments are funding efforts to increase the efficiency of the light bulb.

Much interest has been devoted to solid-state lighting, thanks to its potential to deliver efficacies of several hundred lumens-per-Watt, which is far higher than the best fluorescent sources of today. At the heart of this type of light source is an InGaN-based LED that typically emits in the blue and pumps one or more phosphors of longer wavelengths. White light results from colour mixing.

Most InGaN-based LEDs are fabricated on a polar {0001} (*c*-plane) GaN layer, which is grown on a *c*-plane sapphire substrate. This platform is cost-effective, and the growth technique for forming the LED epistructure on it is refined and widely used in high-volume fabs. In contract, high-performance nitride devices, such as laser diodes or very high efficiency LEDs, are fabricated on bulk GaN substrates. The reason for this is that deposition on a native substrate gives the best device performance, because it minimises interface effects and defect formation.

Regardless of the substrate, LEDs formed with *c*-plane GaN-based material have a major impediment to high performance: separation of the carriers by a piezoelectric field (see Figure 1(a)). This field pulls apart electrons and holes, reducing the likelihood for radiative recombination and thereby impairing efficiency.

To reach longer wavelengths, indium content is increased, but this also increases the strength of the unwanted electric field in the device – and is the primary reason for the low luminous efficiency of green light-emitting devices.

An attractive option for addressing these fields is to turn to a new approach for band engineering, which involves growth on different planes of GaN. Piezoelectric fields are absent on non-polar planes, while drastically cut on semi-polar planes, and in both cases this

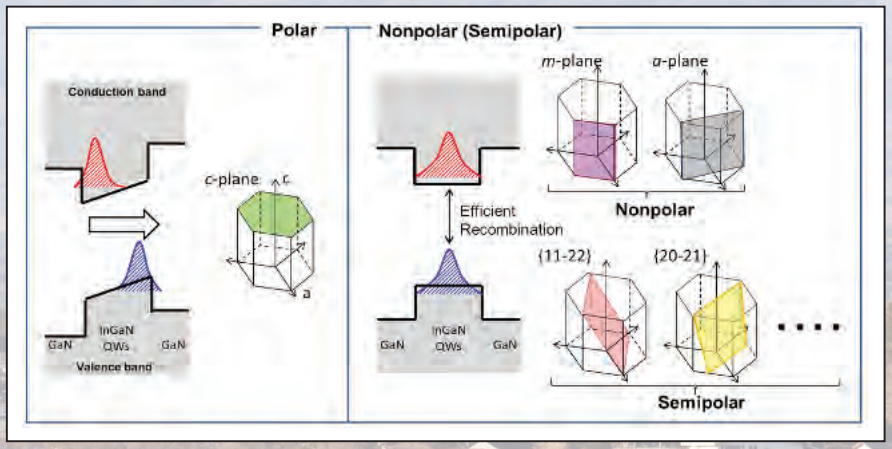


Figure 1. Band alignment of an InGaN/GaN quantum well structure for polar and nonpolar/semi-polar planes. Conventional InGaN quantum wells are grown in the *c*-direction (left). The InGaN quantum well gets compressively strained due to the different lattice constants of the two materials. This leads to an internal piezoelectric field, resulting in a tilt of the energy band. Consequently, there is a spatial separation between the electrons in the conduction band and the holes in the valence band. Moreover, the effective band gap is slightly reduced. This effect is called the quantum confined Stark effect. Removing the internal electric field allows the electron and holes to spatially overlap perfectly, resulting in efficient recombination (right)

enables greater electron-hole overlap and more efficient devices. If device developers want to turn to a non-polar plane, they have to choose between two orientations; but if they want to employ a semi-polar plane, they have a vast number of variants to consider, and it is still debatable which is the best of them.

What they are looking for is a plane that combines ease of high-quality crystal growth with straightforward device processing and favourable bandgap engineering. One orientation with much merit is the {20$\bar{2}$1} plane, which was used by a team from Sumitomo to make the world's first green laser diode.

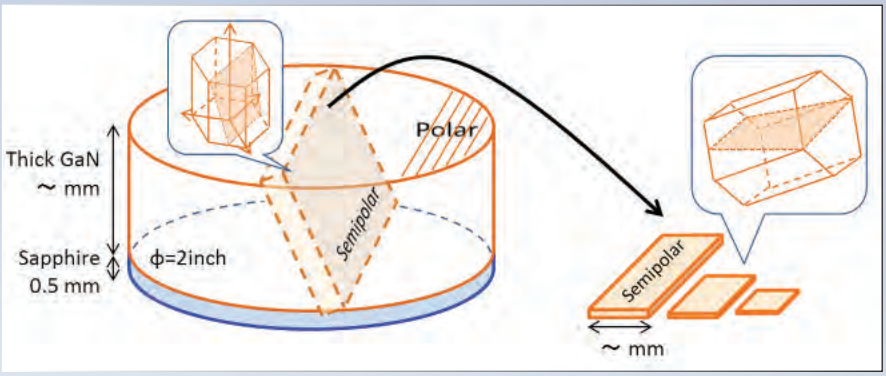


Figure 2. The conventional fabrication process for semi-polar GaN substrates: A GaN layer more than a few millimetres thick is grown, by HVPE, on c-plane GaN template and sliced in intended semi-polar directions

GaN substrates

Today, hydride vapour phase epitaxy (HVPE) is viewed as a highly practical approach to obtaining thick layers of GaN, which can serve as quasi-bulk substrates. GaN is first grown on a foreign substrate, such as GaAs or sapphire, before the two are separated. The biggest advantage of this technique is its ability to produce high-quality material at high growth rates, thanks to high surface migration of the halide species. For this reason, the vast majority of GaN substrates shipped today are produced with a HVPE process.

The thick polar GaN material produced by HVPE is also used to make semi-polar and non-polar GaN substrates, which are formed by cutting along appropriate planes (see Figure 2). However, the size of nonpolar and semi-polar GaN substrates is typically restricted to just a rectangular area of a few square millimetres, due to the dimensions of the polar GaN.

Due to the small size of semi-polar substrates produced by HVPE, there has been much interest in developing alternative approaches that could yield large-sized, semi-polar and non-polar GaN platforms. Our team at Yamaguchi University has been one of the groups attempting to pioneer new technologies to produce such orientations. Since 2004, we have been using MOCVD to develop epitaxial lateral overgrowth via selective area growth on a patterned sapphire substrate.

Our approach begins by forming trenches in sapphire with a width and depth of a few micrometres (see Figure 3). The orientation of these grooves is carefully chosen to ensure that one sidewall of the trench acts as a nucleation plane for *c*-plane GaN growth. Under optimised conditions, the epitaxial process starts on this sidewall and continues laterally over the terraces to yield a continuous semi-polar GaN layer. With this approach, we have formed a

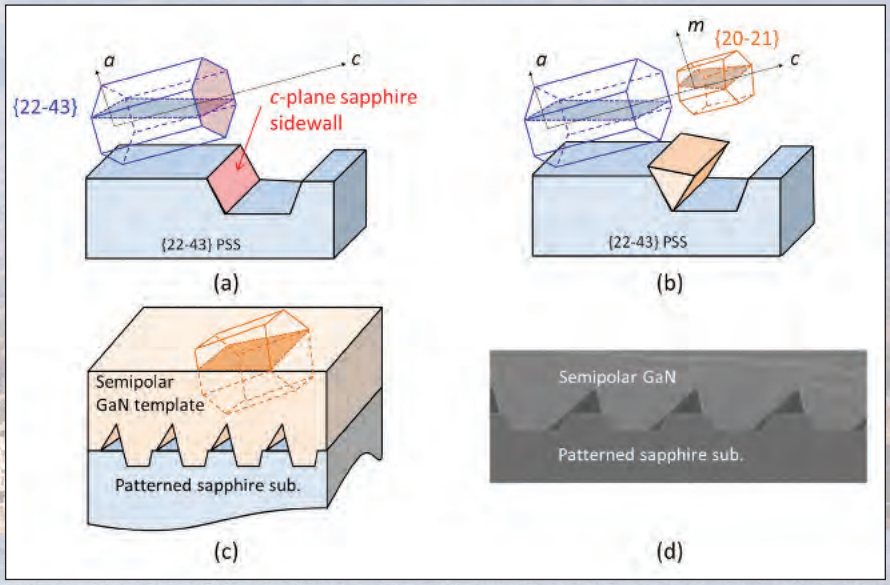


Figure 3. Growth process of a {20$\bar{2}$1} GaN layer on patterned sapphire. (a) Formation of *c*-plane sapphire sidewall by dry etching, which is 74.6° inclined from the {22$\bar{4}$3} plane of the sapphire. (b) Nucleation of GaN stripes from the *c*-plane sapphire side-walls by MOVPE. (c) Formation of the {20$\bar{2}$1} GaN film by the coalescence of neighbouring GaN stripes. (d) Cross-sectional scanning electron microscopy of a {20$\bar{2}$1} GaN layer

variety of thin films of 2-inch semi-polar material, based on orientations such as {10$\bar{1}$1}, {11$\bar{2}$2}, and {20$\bar{2}$1}.

Although producing these thin films is important, for practical applications bulk substrates are needed, and that means the deposition of thick, crack-free layers of GaN that are free from anomalous growth. We have done just that by turning to new sample structures for the fabrication of a semi-polar {20$\bar{2}$1} GaN substrate using SiO_2 stripe-masked templates (see Figure 4). Optimised SiO_2 striped masks were prepared in the direction perpendicular to the *a*-axis on a 2-inch {20$\bar{2}$1} GaN templates, prior to the of growth of a 1.4 mm-thick GaN layer at a deposition rate of 350 mm/h. The growth tool employed is a vertical-flow-type HVPE apparatus equipped with liquid gallium source, hydrogen chloride, ammonia, nitrogen and a hydrogen gas cylinder.

The SiO_2 stripes play a crucial role in this substrate formation process. Without the striped mask, GaN forms a rough and cracked surface. But when it's there, the surface is far smoother, with roughening originating from unintentional anomalous growth regions on the template – note that these regions were completely embedded during selective area growth by HVPE. What's more, the SiO_2 mask is effective on other planes, such as {10$\bar{1}$1} or {11$\bar{2}$2}, when growing GaN on patterned sapphire.

Another attractive feature of our approach is the effective self-separation of the patterned sapphire and the GaN film. In comparison, typical methods employed for separating a GaN layer grown on a foreign substrate are more involved, such as mechanical polishing, laser or chemical lift-off, or self-separation via the growth of an intentional interlayer. With these more common methods, an additional process is required before or after HVPE growth of GaN.

When a layer of GaN is grown on sapphire, as the wafer cools thermal stress is induced in both materials, due to a difference in the thermal expansion coefficients, and this leads to a maximum shear stress at the heterointerface. We take advantage of that with our approach:

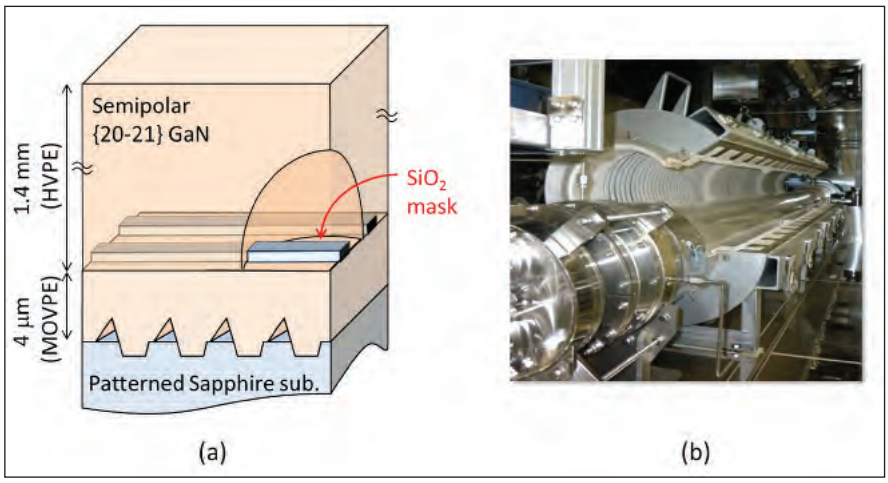


Figure 4. Experimental set-up. (a) A 1.4 mm-thick GaN layer was grown on a SiO_2 masked template. (b) HVPE apparatus can accommodate a 6-inch substrate. Four, 2-inch wafers were loaded in this work

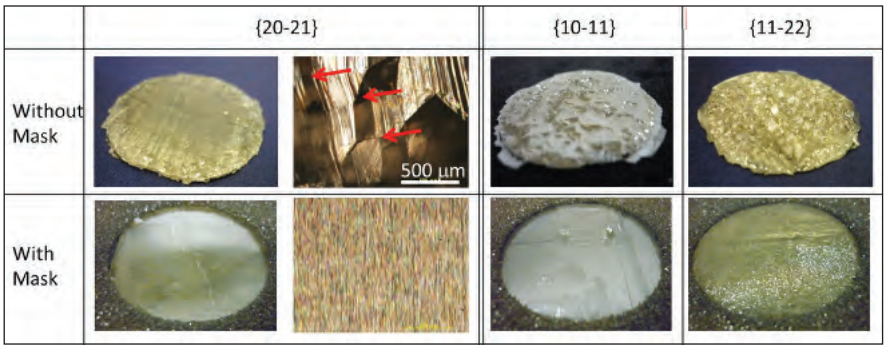


Figure 5. As grown surface of various orientations of GaN. Normarski microscope images of a {20$\bar{2}$1} GaN layer are also shown. The red arrows show the cracks

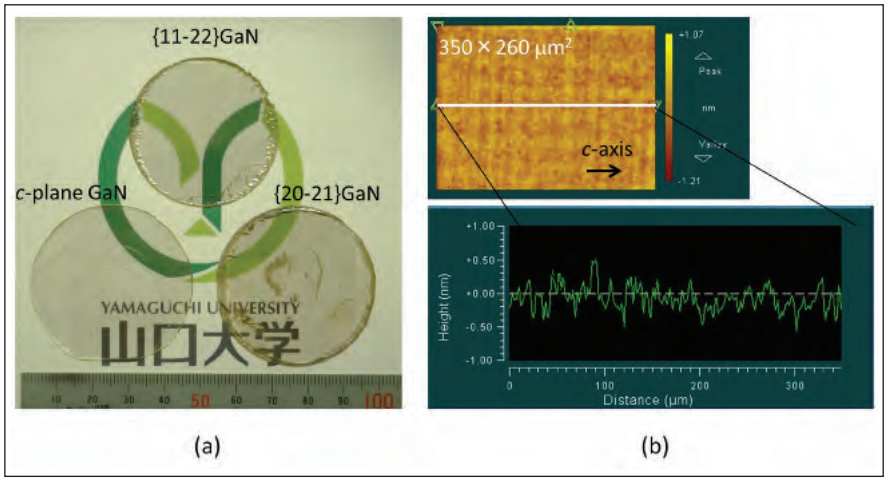


Figure 6. A GaN substrate formed by chemical mechanical polishing. (a) Photograph of 2 inch *c*-plane, {11$\bar{2}$2} and {20$\bar{2}$1} GaN wafer. (b) Surface morphology of the chemical-mechanical polished {20$\bar{2}$1} GaN substrate measured by a scanning white light interferometer

GaN layers are formed by selective area growth from the narrow sidewall of the patterned sapphire, so there is weak adhesion at the hetero-interface. Thus, mechanical failure can easily occur at the hetero-interface to yield free-standing GaN without additional processing.

Chemical mechanical polishing of our thick layer of GaN, which has been separated from sapphire, enables the formation of a 2-inch semi-polar substrate. According to measurements acquired with a scanning white light interferometer, the typical root mean square roughness of this free-standing GaN is just 0.2 nm, implying that the surface is atomically flat. X-ray diffraction indicates that the radius of lattice curvature of the substrate is approximately 4 m. The dislocation density depends on the orientation of GaN. It is low 10^8 cm^{-2} for {20$\bar{2}$1}, low 10^7 cm^{-2} for {10$\bar{1}$1}, and mid 10^6 cm^{-2} for {11$\bar{2}$2}. One of our goals is to reduce this density by optimizing growth conditions and SiO_2 mask geometry.

Our substrates have formed the foundation for the growth, by MOCVD, of an LED epiwafer structure featuring InGaN/GaN multiple quantum wells. X-ray diffraction measurements of this epistructure reveal satellite peaks, indicative of the abrupt heterointerface between the InGaN well and GaN barrier layers (see Figure 7). Meanwhile, transmission electron microscopy reveals the high quality of the active region.

We have also measured the current-voltage characteristics of these LED structures, with results showing that these devices can be fabricated on the {20$\bar{2}$1} GaN substrate. If the dimensions of this platform can improve, it could play a major role in increasing the performance of commercial InGaN LEDs.

The development of thick layers of semi-polar and non-polar GaN was carried out within the projects Regional Innovation Cluster Program (Global Type) and Low-Carbon Research Network in the MEXT Japan.

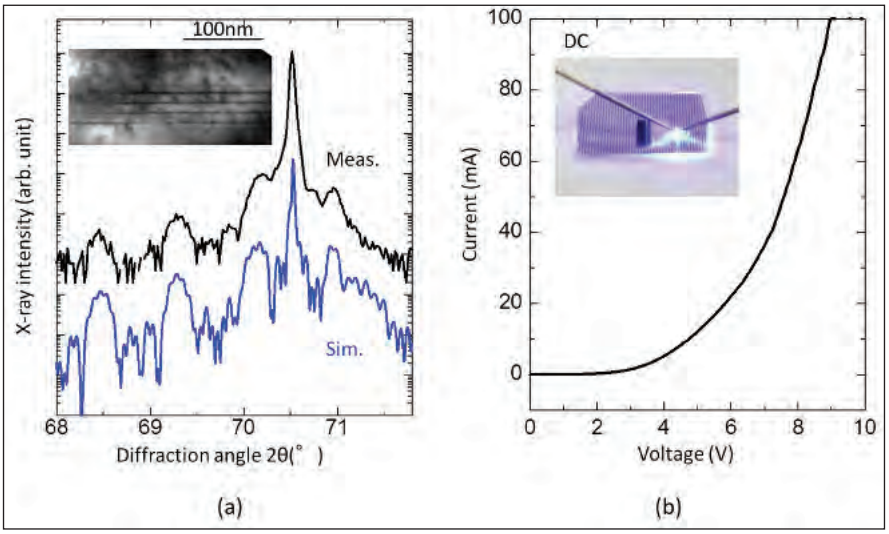
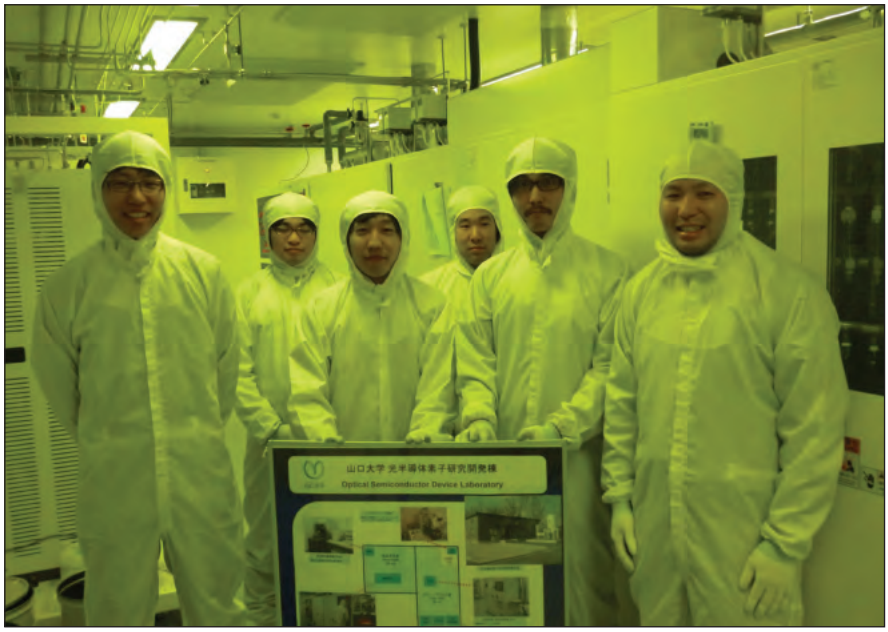


Figure 7. X-ray diffraction and current-voltage curves of {20$\bar{2}$1}GaN LED. (a) Measured and simulated X-ray diffraction profiles of InGaN/GaN multiple quantum wells. The inset shows a transmission electron microscopy image of InGaN/GaN multiple quantum wells. (b) Typical current-voltage curves of {20$\bar{2}$1} GaN LED



Core researchers. From left to right: Keisuke Yamane, Yusuke Mitsui, Takashi Inagaki, Yusho Denpo, Yasuhiro Hashimoto and Narihito Okada

Ultra-high voltage devices for future power infrastructure

Fast growth of high-quality SiC epilayers has paved the way to the fabrication of power devices with blocking voltages exceeding 20 kV.

By TSUNENOBU KIMOTO FROM KYOTO UNIVERSITY, JAPAN

FOLLOWING RESEARCH stretching back more than 40 years, shipments of SiC power devices are now significant and rising fast. Two of the biggest sellers are Schottky barrier diodes (SBDs) and power MOSFETs, which are increasingly displacing silicon incumbents and enabling the construction of smaller, more efficient power converters and inverters. Thanks to this, SiC chips will be winning deployment in power supplies, motor controls, photovoltaic converters, telecommunications equipment, heating, robotics, electric/hybrid vehicles, traction and electric power transmission (see Figure 1). According to several institutes, one impact of this trend is that by 2025, SiC power devices will produce a combined electric power saving exceeding 10 GW – that's comparable to the power generated by about ten nuclear plants.

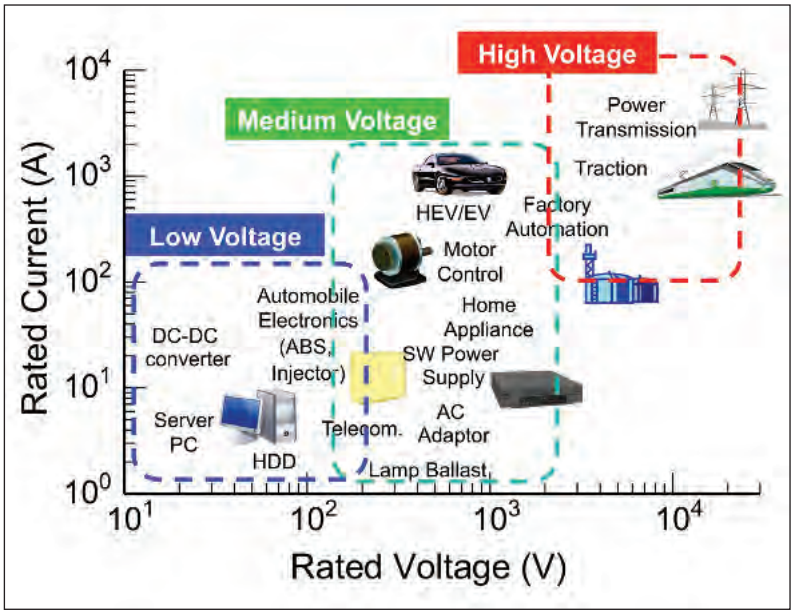


Figure 1. Different voltage ratings are required for different applications

Today, a time when the revolution in power electronics is still in its infancy, the operating voltages of commercial SiC diodes and transistors are predominantly in the 600 V - 1.7 kV range. But that's by no means the limit of what is possible – recent progress in the labs shows that blocking voltages of more than 20 kV are attainable. This opens up the possibility for innovative hardware for electric power infrastructure, advanced traction applications and accelerators of particles, such as electrons and protons.

Devices that combine ultra-high blocking voltages with very low losses can also play a key role in the future of electric power transmission/distribution infrastructure and smart grids. They could feature in distributed power lines, which operate in the 6.6–7.2 kV range, and could be the 13–15 kV power devices required for the construction of single-level converters. Another attractive opportunity for the deployment of ultra-high-voltage SiC devices is in solid-state transformers (see Figure 2). In high-voltage DC power transmission, voltages can be as high as 150–250 kV. Today, a number of 6–8 kV silicon thyristors are stacked in series to provide conversion of electrical power at such high voltages, but this has the downsides of enormous energy dissipation and self-heating. If ultra-high-voltage SiC chips could replace these devices, this would lead to considerable energy savings.

To help turn this dream into a reality, our team of researchers at Kyoto University has been developing SiC devices that are now setting a new benchmark for high-voltage operation. These chips, which are formed using the high epitaxial growth rates needed for a viable production process, can withstand voltages of almost 27 kV.

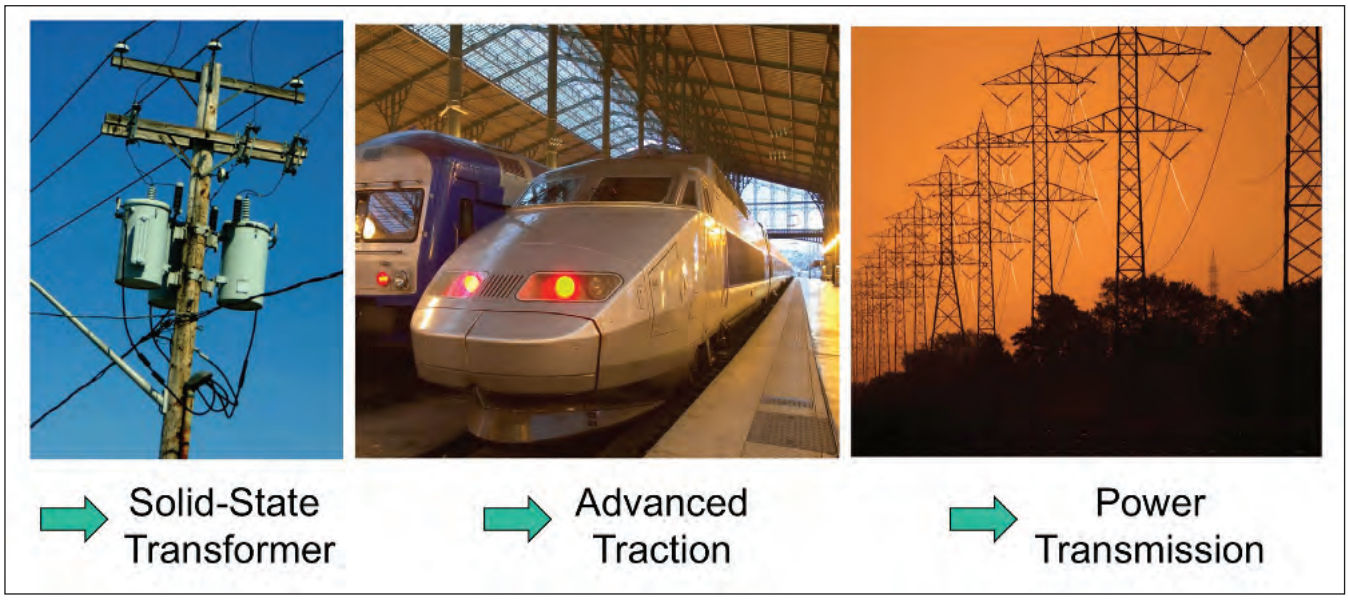


Figure 2. Ultra-high-voltage SiC power devices can enable a substantial trimming of the size and weight of power converters

Why SiC?

Interest in SiC has been driven by its wide bandgap – it is 3.26 eV in the 4H polytype commonly used for making power devices. This wide bandgap is responsible for a breakdown electric field strength ten times that of silicon and a thermal conductivity that is three times that of silicon. Furthermore, SiC is an exceptional wide bandgap semiconductor, which offers the opportunity to control the doping concentration over a very wide range (*n*-type: 10^{14} – 10^{19} cm^{-3}, *p*-type: 10^{14} – 10^{20} cm^{-3}). In addition, SiC devices can operate at high temperatures, such as in excess of 250°C. Drawing on all of these attractive attributes enables the simplification of the bulky cooling units often required in silicon-based power converters.

The higher field strengths permitted with SiC aid device design. Compared to silicon, blocking-layer thickness can be tens times thinner, while the doping concentration can be increased by two orders of magnitude (see Figure 3). Thanks to this, it is possible to realise huge reductions in the voltage-blocking region resistance, and ultimately achieve low levels of power dissipation.

The tried and tested route for realising a high blocking voltage in any semiconductor device is to increase material thickness and trim doping concentration in the voltage-blocking region. Calculating the impact of these changes is easy, and helps to guide device designers that must also consider the doping-dependent breakdown electric field of the material (see Table 1).

Blocking Voltage	Silicon		SiC	
	Thickness	Doping	Thickness	Doping
1 kV	80 µm	2×10^{14} cm^{-3}	8 µm	2×10^{16} cm^{-3}
5 kV	500 µm	2×10^{13} cm^{-3}	40 µm	2×10^{15} cm^{-3}
10 kV	1100 µm	8×10^{12} cm^{-3}	90 µm	1×10^{15} cm^{-3}
20 kV	2300 µm	3×10^{12} cm^{-3}	170 µm	4×10^{14} cm^{-3}
30 kV	3500 µm	1×10^{12} cm^{-3}	250 µm	2×10^{14} cm^{-3}

Table 1. Typical thicknesses and doping concentrations required for specific blocking voltages in silicon and SiC devices. Calculations took into account the doping-dependent breakdown electric field of the materials

These back-of-the-envelope calculations also reveal why it is impossible to build a 20 kV device from silicon: the required doping concentration would have to be close to the intrinsic carrier concentration at room temperature, while the required thickness would be impractical. Fortunately, with SiC, it's an entirely different story – a 20 kV device falls easily within the limits of what is possible.

Manufacturing such a device in high volumes is not out of the question, given the rapid progress in SiC bulk growth processes that has led to the availability of single crystalline SiC wafers of reasonable quality with 100 mm and 150 mm diameters. There have also been remarkable advances in SiC epitaxy and device processing technologies, such as ion implantation and metallization, and, on top of this, it is possible to draw on the development of devices operating at lower voltages. Back in 1991 NASA reported the first 1 kV SiC *pin* diode, while our group announced the first SiC Schottky barrier diode operating at that voltage two years later, and since then many more groups from all over the world have started to develop high-voltage SiC power devices (see Figure 4 for an overview of the increases in SiC blocking voltage).

Why bipolar?

One decision facing designers of power electronic systems and modules is whether to select a unipolar device, such as an SBD or a FET, or deploy a bipolar device, such as a *pin* diode, thyristor, or insulated-gate bipolar transistor (IGBT). The decision partly depends on the blocking voltage required. An SBD is an attractive

option at lower blocking voltages, such as 1 kV, because in this regime it exhibits very good on-state characteristics. However, when the voltage requirement increases to 20 kV, the on-resistance climbs to unacceptable levels (see Figure 5). So, at these ultra-high voltages, the SiC *pin* diode is a better choice, thanks to the long lifetime of its injected carriers. This long lifetime is due to the indirect band gap and high crystalline quality, and is a key factor for attaining the conductivity modulation effect.

However, a long carrier lifetime is not guaranteed in a SiC device. Back in 2007 we identified a carrier-lifetime killer in this wide bandgap material – a deep level, known as a $Z_{1/2}$ centre, that is located 0.62 eV below the conduction band. But by 2009 we had succeeded in eliminating this defect, an acceptor level of a single carbon vacancy, by thermal oxidation.

This thermal oxidation process leads to the formation of SiO_2 on the surface of SiC. But what happens to the carbon? That's a long-standing and still-open question, but in our view most carbon atoms diffuse out as a form of CO, while a smaller number remain near the SiO_2/SiC interface. Here they can even be emitted into the SiC side, where they will diffuse in the bulk region. Carbon vacancies here are filled with diffusing carbon interstitials, ensuring that the lifetime killer is eliminated from the surface right down to deep in the epilayers.

Armed with this this innovative defect-elimination technique, we realised a lifetime of over 30 μs (see Figure 6). Surface recombination is now the barrier to longer lifetimes, which should be in excess of 50 μs. But even with our current values for carrier lifetime, we can realise conductivity modulation of 20 kV devices.

To ultra-high voltages

Fabrication of 20 kV SiC devices requires the growth of a voltage-blocking layer at least 150 μm-thick and doped to a carrier concentration of no more than low ~10^{14} cm^{-3}. Such a film can be grown homoepitaxially by CVD at 1650°C on low-resistivity *n*-type SiC (0001) substrates. Fast growth rates are very attractive for such a thick layer. In our group, we have successfully increased the SiC growth rate from 10 μm/h to beyond 50 μm/h. This has been accomplished while avoiding issues related to nitrogen donor contamination, by either reducing the growth pressure or increasing the ratio of carbon-to-silicon in the precursor gases. These refinements enable background doping concentrations in the SiC epitaxial layers of less than 1×10^{13} cm^{-3}, which is sufficiently low for the development of ultra-high voltage devices.

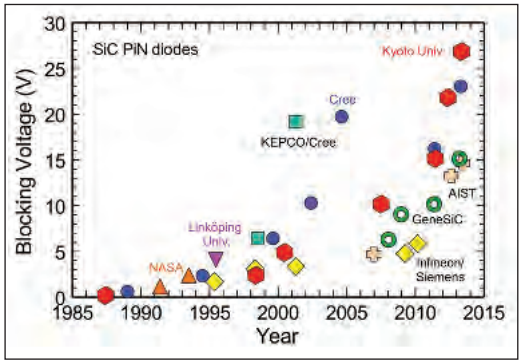


Figure 4. The last decade has witnessed a significant increase in blocking voltages of SiC *pin* diodes

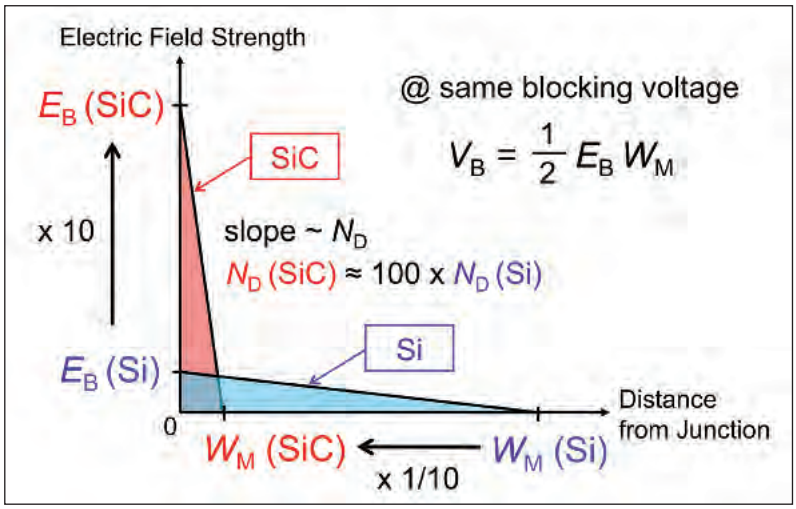


Figure 3. Electric field distributions in one-sided abrupt junction in SiC and silicon are markedly different, even though they have the same breakdown voltages. That's because: the breakdown field strength for SiC is ten times that for silicon, so the thicknesses of the voltage-blocking layers of SiC power devices can be one-tenth of that in the corresponding silicon devices; and the doping concentration in the SiC devices can be two orders of magnitude higher than that in the silicon counterparts

Fabrication of our SiC *pin* diode involved epitaxial growth of an *n*-type, very thick voltage-blocking layer, and a highly doped *p*-type emitter that acts as an anode. Diode isolation followed, using an improved bevel mesa structure with a rounded bottom. To alleviate electric field crowding near the junction edge – which causes the device to breakdown at a much lower voltage than what should be expected from calculations based on thickness and doping concentration – we then employed an Al^+ implantation process and subsequent activation annealing to create an appropriate junction termination structure (see Figure 7). After this, we added ohmic contacts for the *p*-type anode and the *n*-type cathode from Al/Ti layers and a nickel layer sintered at 1000 °C. Thermal oxidation and deposition of a 4 μm-thick polyimide film passivated the surface and prevented surface arcing. Note that fabrication also involved a thermal oxidation-based lifetime enhancement process, performed after the epitaxial growth of the *n*-type voltage-blocking layer.

Alleviating electric field crowding is one of the greatest challenges associated with forming an

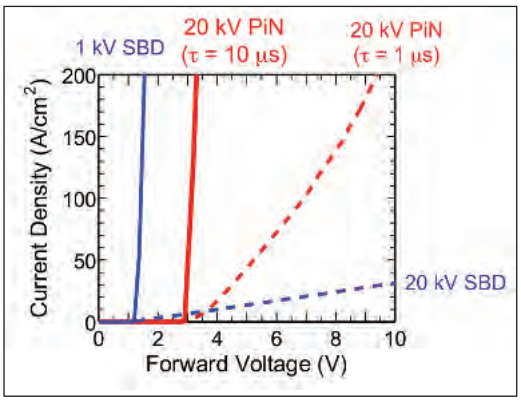


Figure 5. Forward characteristics for a 1 kV SiC SBD, a 20 kV SiC SBD, and a 20 kV SiC *pin* diode with two different carrier lifetimes (simulated). For 20 kV applications, a *pin* diode with sufficiently long carrier lifetime is the most promising

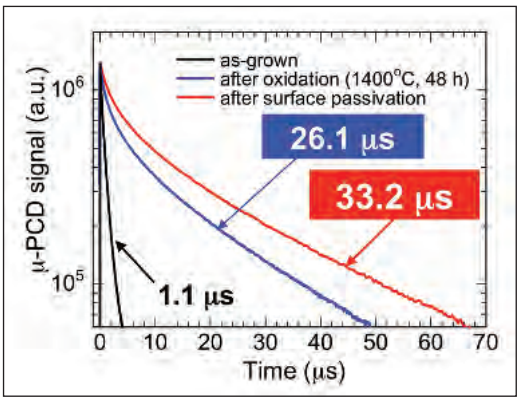


Figure 6. Eliminating defects increases the carrier lifetime in SiC. Lifetimes are revealed by microwave-detected photoconductance decay measurements, which show the improvement in a 220 µm-thick epilayer that results from the defect-elimination process

ultra-high-voltage SiC device. To prevent this from impacting device performance, the structure and the doping profile of the Al^+-implanted junction-termination-extension (JTE) region have to be carefully designed and optimised. If the aluminium doping concentration is too low, severe electric field crowding occurs near the mesa edge; but if this doping is too high, crowding is present at the outer edge of the JTE region.

We address this issue with a 'space-modulated' JTE structure featuring multiple rings formed inside a reduced surface field-type, Al^+-implanted JTE region. By modulating the widths and spacing of individual rings, the effective JTE dose gradually decreases as it progresses toward the outer edge. In turn, this minimises electric field crowding and provides a wide optimum JTE dose range. Device simulations enabled optimisation of the structure and the doping profile of the JTE region (see Figure 8).

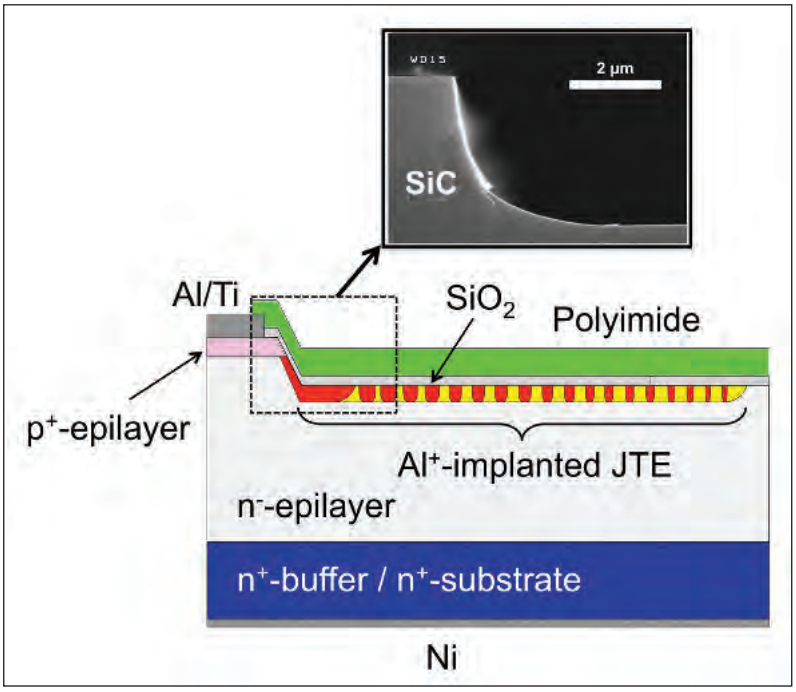


Figure 7. Fabrication of the SiC *pin* diode involved epitaxial growth of a very thick *n*-type voltage-blocking layer and a highly-doped *p*-type emitter, followed by diode isolation that resulted from formation of an improved bevel mesa with a rounded bottom. This alleviates electric field crowding near the junction edge

Our most recent *pin* diodes have a 260 µm-thick voltage-blocking layer. Mesa diameter and the JTE length are just 300 µm and 1050 µm, respectively – that's because the aim of producing this diode is to provide a proof of the concept and not a power device capable of handling very high currents.

Device testing involved immersion of the diode in the dielectric liquid Fluorinert, and on-wafer testing with a DC voltage sweep (see Figure 9). Determining device performance is not easy, because no suitable commercial UHV testing systems are available at present, and we had to address several technical issues related to cable connections and the probe configuration to prevent air sparking.

Our devices can withstand voltages up to 26.9 kV (see Figure 10), the limit of our measurement set-up, and they set a new benchmark for any solid-state device. We estimate that the real breakdown voltage is more than 30 kV, but we will only be able to prove this after improving our measurement system. On-resistance of this diode is just 19 mΩ cm², compared with 430 mΩ cm² for a SBD (no carrier injection) processed on the same wafer without a *p*-type anode. This pair of results underlines how the conductivity modulation effect can slash the resistance of a very thick, lightly-doped layer. The original carrier-lifetime enhancement technique has helped to realise a low on-resistance in our devices. Analysing the resistance components with our

test-element-group characterisation tool indicates that the contact resistivity of the anode contact is approximately 4–5 mΩ cm^2. This indicates that further improvements in on-resistance could result from increasing the acceptor concentration in the anode's top layer and optimising the process.

One of our next goals is to eliminate basal-plane dislocations in SiC. These imperfections, which lead to carrier-recombination-induced dislocation glide that can in turn create Shockley-type stacking faults, degrade device performance: on-resistance and leakage current both increase. In our latest devices, the device area is typically just 2–3 mm in diameter, including the termination region. But if this class of device is to be considered for electric power infrastructure, its area will need to increase to more than 1 cm^2, so that it can handle currents far greater than 100 A. The density of basal-plane dislocations in our latest SiC epitaxial layers is in the 0.1–3 cm^{-2} range, and this must be plummet to below 0.01 cm^{-2} to enable high-yield production of devices with high current-handling capabilities.

Another target is the development of 20 kV-class power-switching devices, such as thyristors, IGBTs, and bipolar junction transistors (BJTs). We have started with a preliminary study on UHV BJTs, demonstrating a 21 kV BJT with a current gain of 63. Now we will try to improve the performance of these devices, while undertaking trials to fabricate other types of UHV power switching device.

The author would like to acknowledge J. Suda, H. Miyake, H. Niwa, T. Okuda, N. Kaji, and S. Ichikawa from Kyoto University for their contributions to this study.

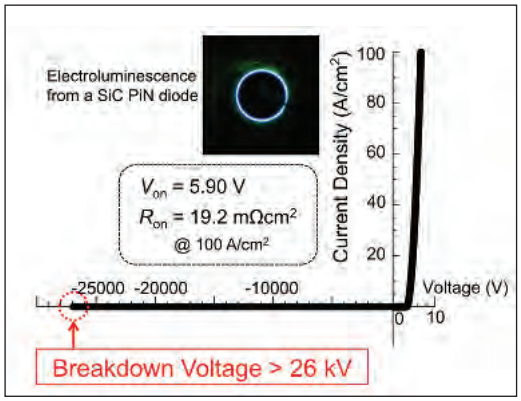


Figure 10.Current density-voltage characteristics of a mesa SiC *pin* diode with a space-modulated JTE structure (total JTE length of 1050 mm). The voltage-blocking layer is 260 μm-thick and doped to a density of 1×10^{14} cm^{-3}. At a reverse voltage of 26.9 kV (the limit of our measurement set-up), this diode did not exhibit breakdown

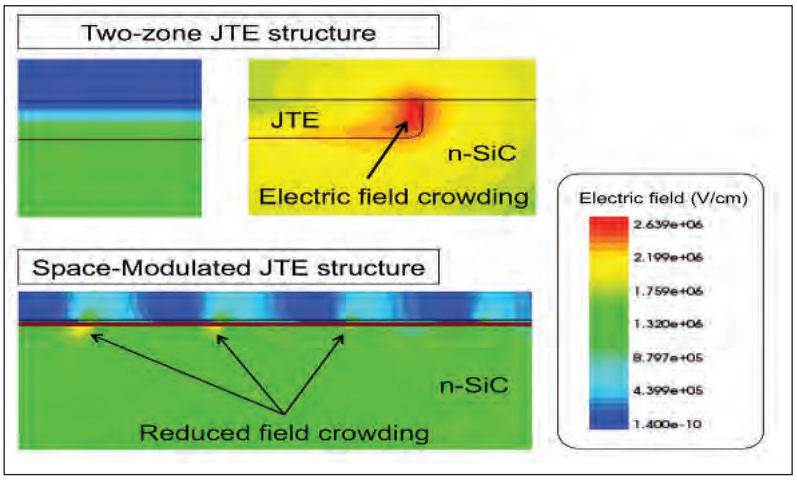


Figure 8. Device simulations enabled optimisation of the junction termination structure, which was improved by understanding the electric field strength distribution near the edge of a *pin* diode under high-voltage (18 kV) reverse bias. The original structure with its multiple space-modulated rings offers reduced electric field crowding near the edge

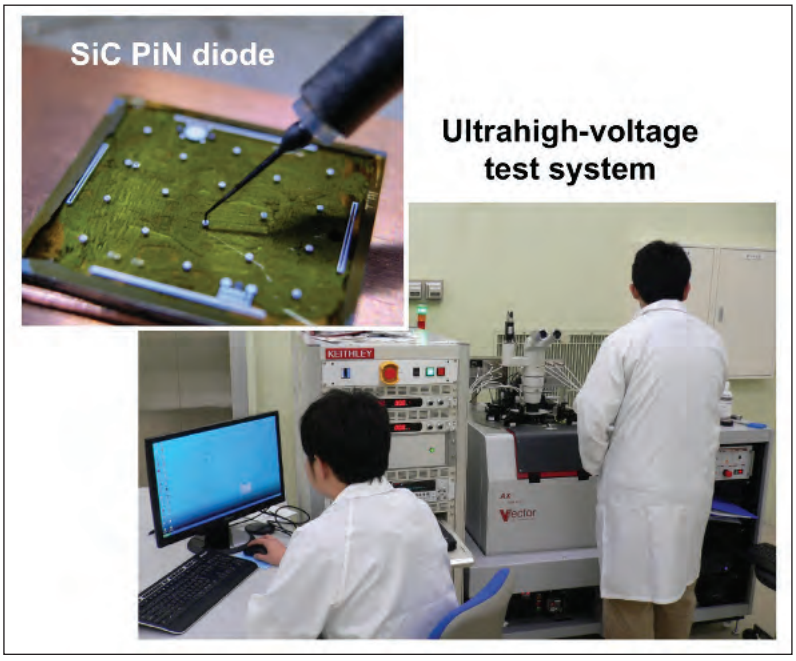


Figure 9. A fabricated diode during high-voltage testing

Further reading

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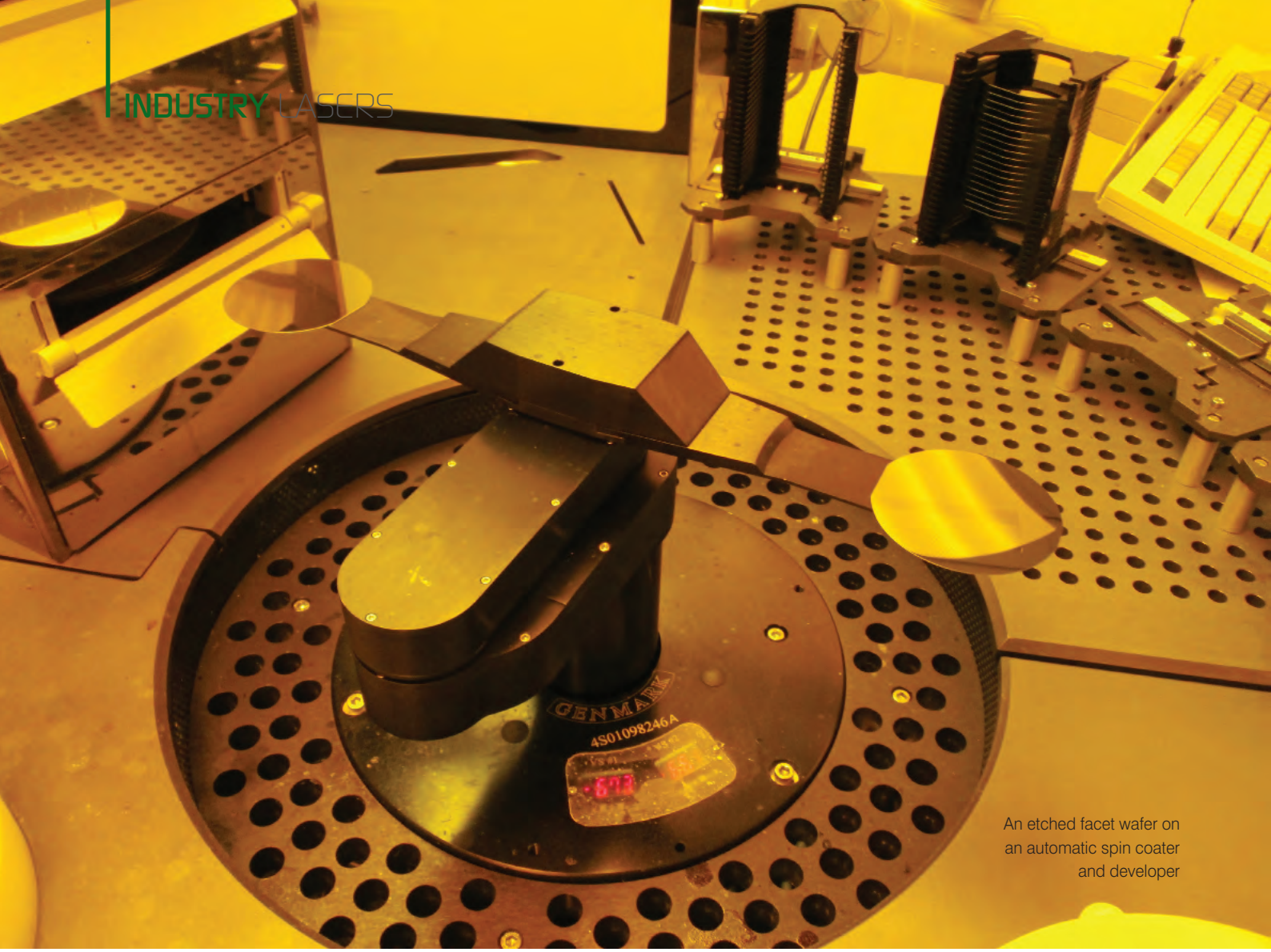


An etched facet wafer on an automatic spin coater and developer

Lighting up **silicon photonics**

The etched facet laser is an attractive candidate for silicon photonics, thanks to its small dimensions, freedom from hermetic sealing and its compatibility with passive alignment to waveguides

By ALEX BEHFAR FROM BINOPTICS

SURGING SALES of smartphones, increased video conferencing and the growth on Internet TV are placing increasing demand on computing power and the providers of data communications. To alleviate the strain, many industry experts are expecting that integrated circuits will soon get a new lease of life through the introduction of photonic links, which will predominantly come in the form of chip-to-chip and on-chip photonics.

These optical technologies will make a tremendous impact on the future of computing. Although this market is in its infancy, revenues for the silicon photonics industry are rising fast and should exceed $2 billion by 2015, according to Market&Markets.

Already active in this area are several of the leading names in the computing and communications industry. IBM, Cisco, Oracle, Mellanox and Luxtera are all publicly discussing their work on silicon photonics and their plans for its use in the future, while Intel and others are already turning to silicon photonics for data networking, in an effort to dramatically boost

efficiency in data centers. Deployment of this technology is underpinned by the efforts of researchers, who are devising ways to slash the cost of large-scale silicon photonics development.

A key component in any photonic circuit is the light source. This tends to be an InP laser, because its spectral range is transparent to silicon. Today, three formats of this device are being used for this application: the cleaved facet laser, the hybrid silicon laser and the etched facet laser.

By far the most mature of these three is that based on a cleaved facet – chipmakers have manufactured hundreds of millions of them. As its name suggests, this type of laser is produced by cleaving an epiwafer to form an atomically flat surface. During the production process, engineers make edge-emitting lasers by cleaving wafers into bars, applying mirror coatings to the facets and then separating the bars into discrete chips. These are often hermetically sealed to ensure reliable operation.

One company that has fabricated a cleaved facet laser in a hermetic enclosure for use with silicon photonics chips is Luxtera. Its package, which also features a ball lens and a reflector, provides a reliable source of light that can be coupled into the silicon photonics chip.

An alternative light source, the hybrid silicon laser, is formed using a glass glue to fuse an InP gain chip to silicon. This relatively new approach, which has been championed by Intel for silicon photonics applications, uses the InP-based structure for light generation and amplification, with the laser cavity formed via the hybrid integration of the InP-based structure to the silicon-based waveguide.

The third approach – etched facet technology – has been pioneered by our team at BinOptics of Ithaca, NY. Its merits include the definition of facets through high-precision photolithography, rather than imprecise, hit-or-miss, mechanical cleaving. This ensures unprecedented uniformity and yield, as well as the capability to build structures that cannot be made with conventional techniques. Since our founding in 2000, we have fabricated over 50 million etched-facet lasers with this technology.

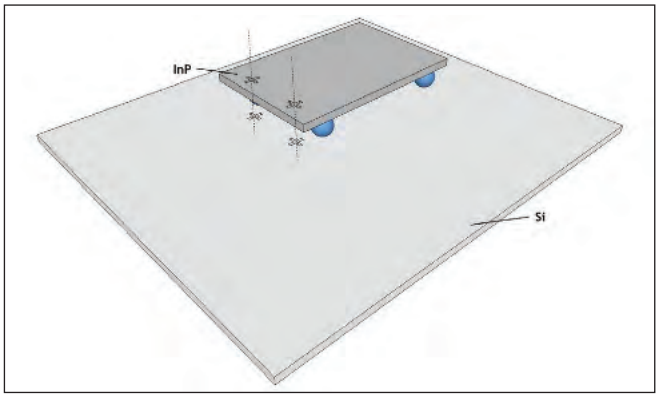


Figure 1. BinOptics facet-etching technology enables passive alignment of the laser to the waveguide. This is possible because the location of the InP chip relative to an alignment mark or a fuducial can be known to within 0.1 μm

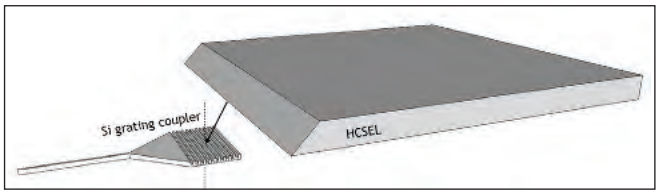


Figure 2. BinOptics' horizontal cavity surface emitting laser (HCSEL) features an etched facet at an angle off from 45°. This ensures that the laser beam emerges at an angle to the gratings on the silicon photonics chip. The HCSEL has its electrical contacts on its surface and is flip-chip mounted onto the silicon photonics chip.

Ticking the boxes

For wide-scale adoption in silicon photonics, there are three key requirements for the light source: it must be available as known good die; it has to survive without a hermetic package; and it must be able to be passively aligned to the silicon photonics chip, rather than requiring active alignment.

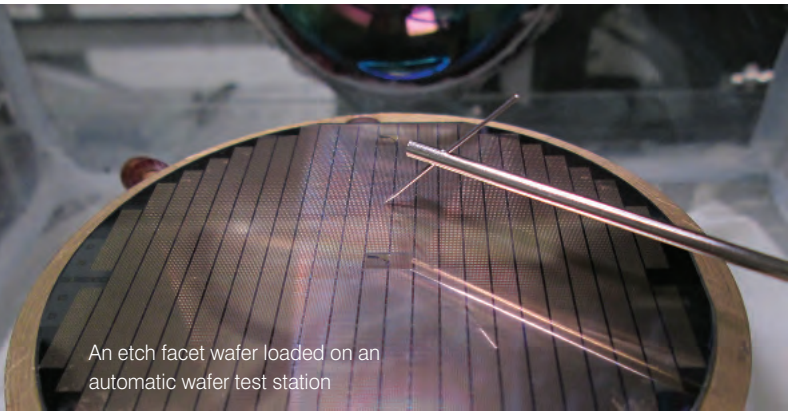
To meet the known good die criteria, the laser must deliver a high level of performance, even at temperature extremes. Device performance is evaluated by measuring light-current-voltage characteristics and spectral profiles at various temperatures. Benchmarking may include a certain threshold current for the laser to start lasing; a minimum light output at a certain current; and a side-mode-suppression-ratio – extracted from the spectral measurements – that exceeds a minimum value.

One of the weaknesses of a silicon hybrid laser is that the InP chip cannot be assessed for whether it conforms to known-good-die criteria until after it has been integrated with the silicon platform. If a bad chip is to blame for a faulty final package, it is costly, if not impossible, to replace this sub-standard gain chip.

Applying a hermetic seal is a common approach to increasing the reliability of an InP laser. But this is not an option for the entire silicon photonics circuit, due to cost and size requirements. To reap the size benefits that silicon photonics offer, the InP laser must be flip-chip mounted to the silicon photonics chip or wafer. And if the InP chip normally requires a hermetic package, this has to be applied to the integrated package of the InP chip and silicon photonics chip — and that would create a component that would be too expensive and bulky for most applications of silicon photonics. So, given all this, it is easy to see why InP light sources that do not require a hermetic package are very attractive for InP photonic applications.

Hermetic sealing is widely used with cleaved facet edge-emitting lasers, which typically feature a waveguide between the front and back facet to ensure the guiding of the light within the semiconductor. Deposition of dielectrics aids waveguiding and can tune the reflectivity of the facets, leading, for example, to a highly reflective back facet and a low reflectivity front facet.

Degradation can occur in this class of laser if it is housed in a non-hermetic environment. If there is a discontinuity between the dielectrics on the facets and the waveguide then, over time, moisture will penetrate through this discontinuity and compromise the quality of the semiconductor. And if the dielectric is permeable to moisture, this will be absorbed,


An etch facet wafer loaded on an automatic wafer test station

leading to increases in the dielectric volume and stress in the dielectric. Slow separation of the dielectric from the facet then occurs to expose the semiconductor, which degrades in this environment.

What's more, most cleaved facet lasers are impaired by a discontinuity between the waveguide dielectric and the dielectrics on the facets. So, to avoid degradation, a hermetic package is added. It is worth noting that the dielectrics, which are deposited with an electron-beam evaporator, do offer some protection from the external environment for the facets that they coat. However, in general, their quality is insufficient to provide protection for any extended period of time in a non-hermetic environment.

In comparison, with our lasers that have facets formed by etching rather than cleaving, it is possible to provide continuous coverage of the waveguide surface and the facets with a dielectric. This coating may be applied by plasma-enhanced CVD, which can produce high quality films that are impermeable to moisture. Thanks to this, etched facet lasers do not require a hermetic package. This claim is supported by our study, which revealed that etched facet lasers can successfully operate in 85 percent relative humidity and 85°C for at least 5000 hours, without the need for a hermetic package.

One opportunity for significant cost reductions associated with the fabrication of photonic circuits is to switch from active alignment to passive alignment – it can be up to ten times cheaper. With active alignment, the laser is powered up and moved around until sufficient light is coupled into the silicon photonics waveguide. Once that is achieved, this emitter must

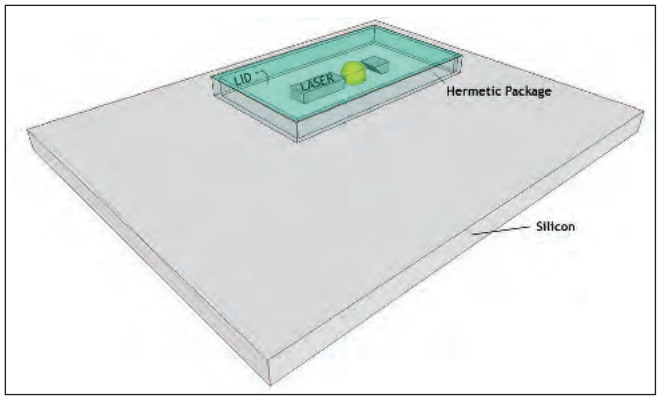


Figure 3. A cleaved fact laser can couple light into a narrow waveguide via a grating coupler

be locked down in place on the silicon photonics chip, as any additional movement would reduce the proportion of light coupled into the silicon photonics waveguide. Doing this is a slow, costly process that is not acceptable for many silicon photonics applications.

Although turning to passive alignment slashes costs, even under the best circumstances the facets of a cleaved facet InP-based laser can only be positioned to within ±2μm of the desired location. Depending on the dimensions of the waveguide – which are discussed shortly – this may not be good enough.

With our InP-based laser that has facets formed by etching, this situation is markedly different. In this case the facets are lithographically defined, so it is possible to know their location relative to an alignment mark or a fuducial to within 0.1 μm, which is more than sufficient (see Figure 1).

Note that with a hybrid silicon laser, there are no alignment issues, because the glass glue process removes the need to align the InP gain wafer to the silicon photonics wafer.

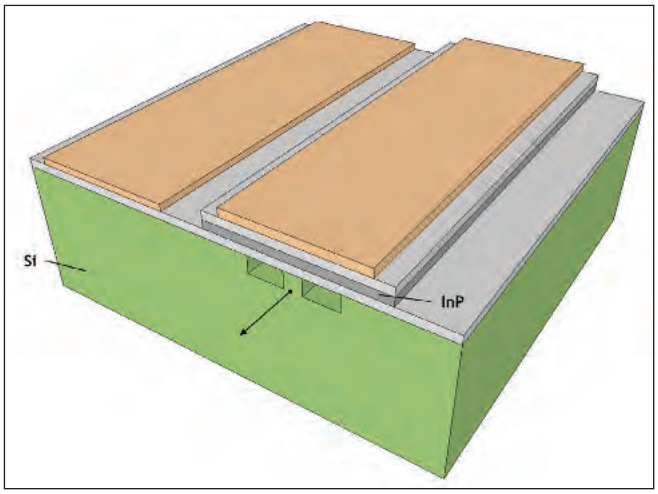


Figure 4. Hybrid silicon lasers offer alignment-free coupling of a laser into a silicon wavguide

Waveguide dimensions

Silicon waveguides have a range of dimensions, and this has a big impact on how difficult it is to couple light into them. In general, there are two types of silicon photonics waveguides: large ones with dimensions of around 3 μm, which are used by Mellanox (formerly Kotura); and those that are 400 nm or narrower, used by IBM and others.

Large waveguides are well matched to the mode size of a typical InP-based laser. Thanks to this, it is relatively easy to realise efficient, direct coupling of the laser into these large silicon photonics waveguides. Edge-emitting lasers, as opposed to their surface-emitting cousins, are well suited to coupling light into these types of waveguides. Shrink the dimensions of the waveguide, however, and the situation changes dramatically. In this regime, some form of mode convertor is often employed to aid the coupling of laser light into the silicon photonics waveguide. One option is to use an adiabatic taper. Ideally, the light from the laser has a narrow beam divergence and

impinges on the grating with an incidence angle that is off from perpendicular. If this angle is optimal, any back-reflection from the grating to the laser is eliminated.

With our InP-based, horizontal-cavity surface-emitting laser that features etched facets at an angle off from 45°, the laser beam emerges at an angle to the gratings on the silicon photonics chip (see Figure 2). Light is then directed to the narrow silicon photonics waveguide through the gratings and an adiabatic taper.

A cleaved facet laser, packaged with a ball lens and a reflector in a hermetic enclosure, is also capable of directing the laser emission at the right angle to ensure a high intensity of light in the narrow waveguide (see Figure 3). If this cleaved-facet laser package is mounted to the silicon photonics chip, a hermetic package is not required around the combined chip. Although this means that additional optical elements beyond the laser are required, on the plus side only a relatively small hermetic package is needed around the cleaved facet laser.

It is not yet clear whether a hermetic package is needed for a hybrid silicon laser that is employed to couple light into a narrow waveguide on the silicon photonics chip (see Figure 4). If it's not needed, this approach that Intel introduced is attractive, given that it is also alignment-free when the InP wafers are bonded to the silicon wafer.

Another issue to consider is the significant difference in the dimensions of the different InP lasers being considered for silicon photonics. Cleaved and etched facet laser chips are relatively small, with typical lengths and widths of around 300 μm and 250 μm, respectively. This means that they use up just 0.075 mm^2 of InP real estate, which is several orders of magnitude less than that of the hybrid laser – it is expected to have similar dimensions to the silicon photonics chip, such as 5 mm by 6 mm. However, this issue may be alleviated with an InP die attach process that involves using glass glue to bond the InP gain chips, rather than the full InP wafer, to the silicon photonics wafer.

Our survey of the three different light sources for silicon photonics – cleaved lasers, hybrid lasers, and etched fact

One of BinOptics' vacuum systems used in the production of etched facet lasers.

lasers – shows that they all have some pros and cons. The ideal approach will ultimately depend on the desired final function, and how these technologies progress as silicon photonics continues to gain popularity in the computing and datacom worlds. Whichever way you look at it, silicon photonics has a bright future, and it will be exciting to witness how this technology transforms the world as the digital age continues to unfold.

	Hybrid Silicon Laser	Etched Facet Laser	Cleaved Facet Laser
Attachment of InP to Silicon	Glass-glue fuses InP to silicon	Flip chip mounting	Flip chip mounting
Alignment	Alignment free	Passive alignment	Active alignment
InP Non-Hermetic Capability	Unknown	Yes	No
InP Known Good Die (KGD)	No laser is formed until integration of InP with Si	Yes; enabled by on-wafer testing over full temperature range	No; bar-level testing is usually only at room temperature
InP Laser	N/A	Yes	Yes
Maturity	New	50M+ devices shipped	100's of millions of devices shipped
Surface Emission	N/A	Yes	Yes, but requires external optical elements
InP Real Estate	Same size as silicon photonics chip if InP wafer bonding is used	300µm x 250µm	300µm x 250µm

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The 2014 CS Industry Awards recognise success and development along the entire value chain of the compound semiconductor industry The nomination process has now closed and the shortlist has been decided. The following companies are all worthy winners but only one can lift the trophy. Who wins, you decide. Please use your vote and make your nomination count. Reward and recognise the companies who are driving the industry to new heights.

www.csawards.net

Winners will be announced at CS International on March 18th 2014

The 2014 CS Industry Awards shortlist:

- Substrates & Materials Award
  - **IQE, Plc**
    150mm GaN on SiC
  - **Kyma Technologies**
    PVDNC AlN Templates
  - **Rubicon Technology, Inc**
    Patterned Sapphire
  - **SEMI-GAS Systems**
    Low Vapour Pressure Liquefied Gases for MOCVD
- Metrology, Test and Measurement Award
  - **Bruker Corporation**
    LumiMap Electroluminescence Tool
  - **Lake Shore & Emcore**
    8500 Series THz System
  - **LayTec**
    Pyro 400 Gen2
  - **Tektronix, Inc**
    PA1000 Single-phase Power Analyser
- Most Innovative Device Award
  - **Infineon AG**
    Direct Drive for CoolSiC
  - **Kyma Technologies**
    PVDNC AlN Templates
  - **M/A-COM Technology Solutions, Inc**
    X-Band Core Chip (MAMF-011015
- Compound Semiconductor Manufacturing Award
  - **DAS Environmental Expert GmbH**
    LARCH
  - **EV Group**
    EVG®PHABLE™
  - **Veeco Instruments, Inc**
    GENxplor MBE Deposition System
- Device Design and Packaging Award
  - **Cree, Inc**
    45mm SiC Six-Pack Power Module
  - **Infineon AG**
    5th Gen 650V SiC Diodes
  - **Soraa**
    GaN on GaN LEDs
- R & D Award
  - **Imec**
    III-V FinFETs
  - **Soitec SA**
    4 Junction Cell

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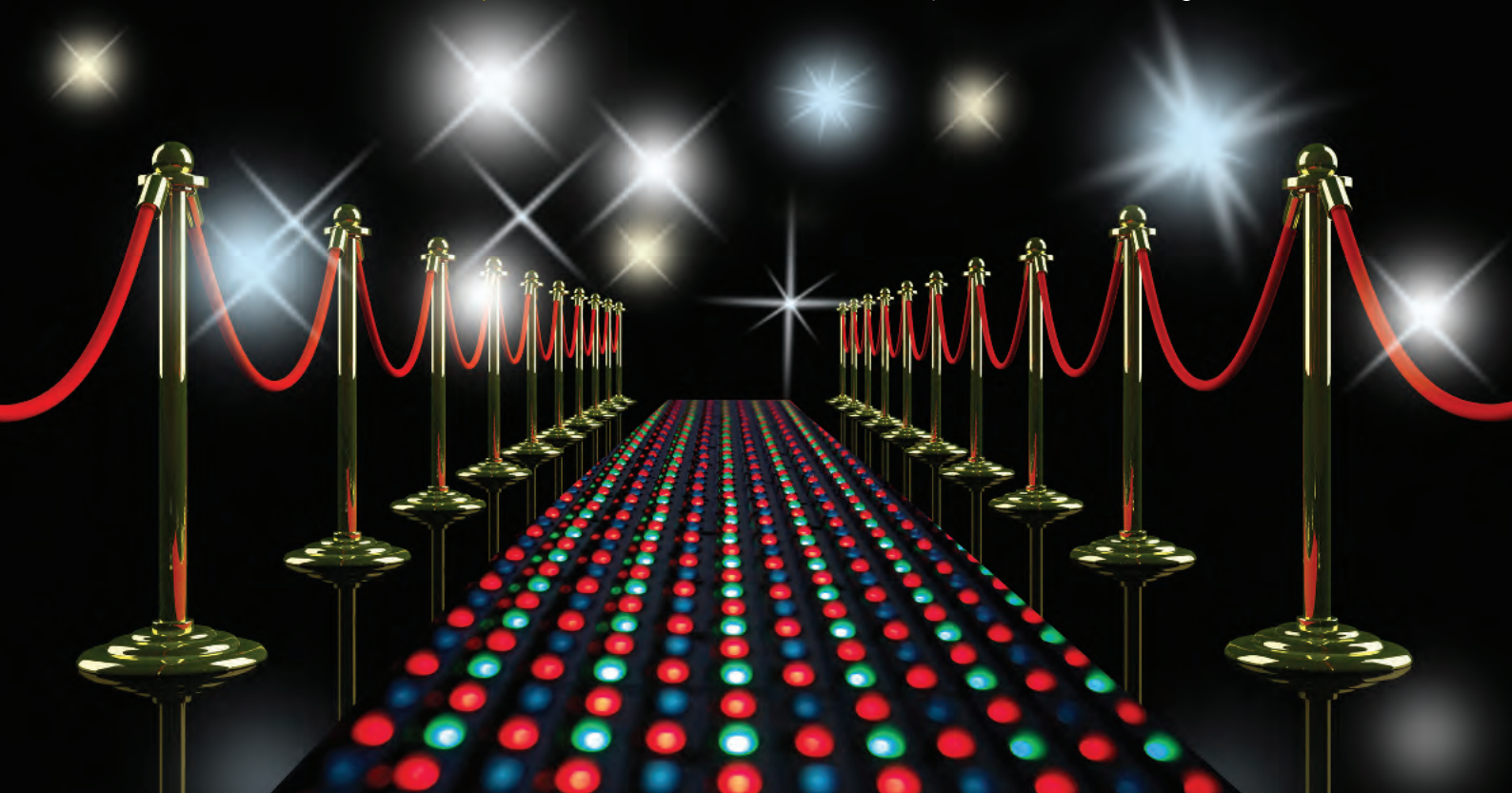


Substrates & Materials Award

IQE

150mm GaN HEMT epi wafers on SiC substrates

Last May, IQE launched gallium nitride based; high electron mobility transistor (GaN HEMT) epitaxial wafers on 150mm diameter semi-insulating SiC substrates*. IQE believe that GaN power amplifiers offer superior power capability, efficiency, bandwidth and linearity compared to silicon or GaAs-based technologies. They provide significant benefits in terms of higher performance and lower overall system costs.

GaN-based low-noise amplifiers also exhibit improved robustness, noise figure and dynamic range when compared to incumbent solutions In addition, GaN-based transistors can operate at high temperatures, thus reducing system cost, size and weight. As a result, GaN transistors are now established as a leading new technology for a wide range of defence applications.

The 150mm GaN HEMT epi wafer products also enable cost reduction, production capacity and yield improvement, as well as potential for insertion into a wider range of chip fabrication facilities. To date, commercial market penetration of GaN HEMTs has been limited by the higher cost of epitaxial material grown on 100mm SiC substratesGaN HEMT fabrication using LDMOS (laterally diffused metal oxide semiconductor) process lines has been demonstrated by IQE's customers and the firm's 150mm products are compatible with existing LDMOS processing lines that have been made available as a result of the silicon industry's transition to 200mm technology.

*The substrates are supplied by the WBG Materials subsidiary of II-VI Inc.

Kyma Technologies

PVDNC AlN Templates

PVDNC AlN stands for plasma vapour deposition of nano columns. Kyma deposits nano column AlN on silicon and sapphire substrates to create a great nucleation surface for growth of GaN devices thereupon. Device fabricators realize better (lower defect density) GaN buffer layers earlier in the buffer layer growth process. A lower defect density translates to higher thermal conductivity and presents other benefits depending on the device application. Kyma supplies both materials and equipment for making PVDNC AlN templates, which is growing in importance in supporting GaN on sapphire based LEDs and GaN on Si power electronics.

The most difficult part of growing a GaN device on sapphire or silicon is in the initiation of the buffer layer. Kyma's PVDNC AlN materials present the ultimate in terms of a great nucleation surface for growing GaN based devices on top of it.

The PVDNC process creates a nanostructured AlN surface which is optimal to nucleate GaN growth on top. The process works on both flat and patterned substrates. PVDNC puts an important nano structure on top of flat or micro structured substrates. PVD was thought to be a low-tech approach to growing crystalline films. However, Kyma's PVDNC process can create perfect nanowires of GaN. When applied to AlN for GaN device applications, PVDNC produces a unique ensemble of highly oriented, highly perfect, AlN nano columns that together present an optimal surface for GaN nucleation.

Rubicon Technology, Inc

Patterned Sapphire

Last October Rubicon Technology Inc., announced the launch of the first commercial line of large diameter patterned sapphire substrates (PSS) in four-inch through eight-inch diameters. This new product line provides LED chip manufacturers with a ready-made source of large diameter PSS to serve the needs of the rapidly growing LED general lighting industry.

Most high-brightness LED manufacturers etch a pattern into the sapphire wafers in order to both improve epitaxial growth and extract more light from each chip. Patterned sapphire substrates have been available for purchase in smaller diameters, but Rubicon is the first to offer highly customizable 6" and 8" PSS. The larger substrates increase chipmakers' throughput and efficiency.

Rubicon offers fully customizable sub-micron patterning capability with tight dimensional tolerances, within ±0.1 μm. With the edge exclusion zone as small as 1 mm, Rubicon offers LED chip manufacturers more usable area to maximize the number of chips per wafer. Patterning is available in a range of shapes including cone, dome and pyramid, and in a range of orientations.

SEMI-GAS Systems

Low Vapour Pressure Liquefied Gases for MOCVD

Last year SEMI-GAS Systems introduced a new Xturion custom gas source system that delivers low vapour pressure liquefied process gases in vapour phase. VaporX is suitable for hazardous and non-hazardous gas applications and is designed to accommodate many of the low vapour pressure gases used in semiconductor, LED and solar cell production as well as in research and development and other high purity markets.

Xturion VaporX systems are available in one and two process cylinder models, each featuring a GigaGuard PLC controller and an ergonomically positioned 8" touch screen. The unit's intuitive display schematics enable easy control over all the system's operations including gas delivery, system alarms automatic cylinder switchover and auto-purge capabilities. The GigaGuard controller automatically interrupts gas flow and initiates a shutdown in the event of a sensor alarm trip, while an Emergency Shutoff (EMO) button offers

immediate manual operator shutdown. LED lights display the systems' status, while an audible alarm accompanies flashing lights alerting the operator should a hazardous condition occur. Each system is CE certified and is manufactured with ultra-high purity components. The system features pneumatically operated valves; Magnehelic and pressure switch exhaust monitoring as well as an optional point-of-use mass flow controller box with heated low vapour pressure mass flow controllers.

To guard against undesirable process gas liquefaction and to help sustain the system's cylinder temperatures and flow rates, VaporX is designed with an integrated fully automatic multi-zone heat control package which includes process gas cylinder heating blankets, gas manifold heat tracing, and process gas line heat tracing. All heat zones are independently controlled and employ redundant temperature measurement with over-temperature protection.

The standard two cylinder (2CE) model is 86" tall, 33" wide and 23" deep, including the external side-mounted heater controller enclosure. Various safety features come standard, such as a UL-approved fire sprinkler, a 1/4" thick safety glass window, a self-closing, self-latching door, and a stainless steel cylinder scale. Heavy cast aluminium cylinder brackets and adjustable cylinder shelves ensure safe and secure gas cylinder fit-up.

Compound Semiconductor Manufacturing Award

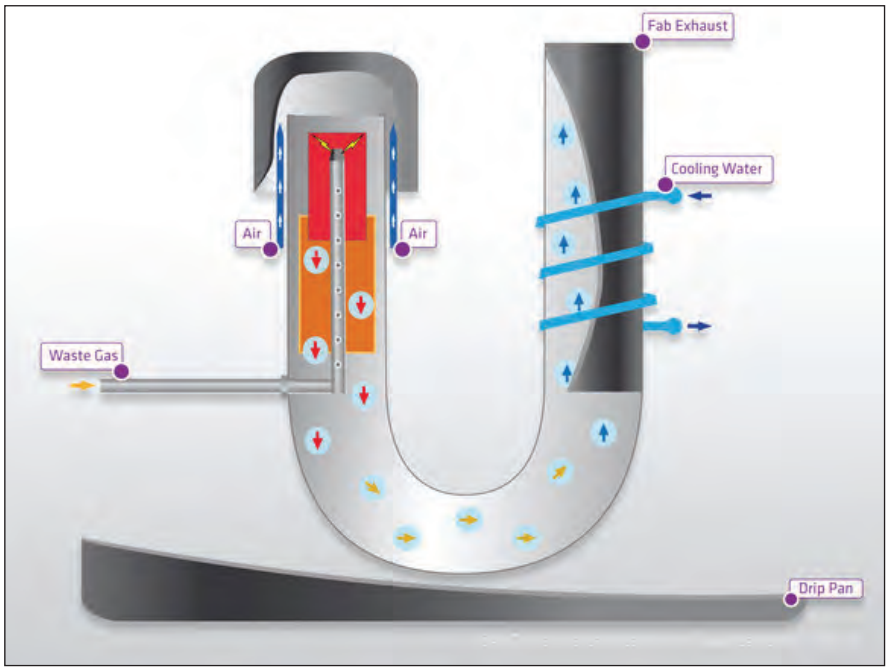
DAS Environmental Expert GmbH

LARCH

LARCH is a Point-of-Use waste gas treatment system especially designed for MOCVD processes. It is capable of treating large flows of Hydrogen and Ammonia as well as small flows of metal-organics and dopants, which are typically found in common LED processes. Low investment and operating costs, simple, robust design and low environmental impact (no CO2 emissions, minimum NOx emission) characterize LARCH. The maintenance interval is expected to exceed six months. The system operates in three steps.

First, the process waste gases are introduced through a special packed inlet into the decomposition zone. There decomposition of Ammonia (2NH3= N2 +3H2) takes place. Following the Hydrogen is electrically ignited and oxidized. The waste gases are burned and oxidized within the reactor (2H2 + O2 = 2H2O). Finally the waste gases are cooled (< 60 °C), which can be released into the environment without any further treatment as they meet the strict German standards for air pollution (TA Luft).

Advantages include: No CO2 emissions: no greenhouse gases, low NOx emissions, no wastewater: no trouble with NH4+wastewater limits, treatment of H2 at the Point-of-Use, maximum security regarding H2, Simple and robust design: low investment costs, low CoO, low maintenance, internal security: H2 dilution in case of fire.



Veeco Instruments, Inc

GENxplor MBE Deposition System

The GENxplor is a revulutionary new molecular beam epitaxy (MBE) deposition system specifically developed to address the needs of university-based compound semiconductor researchers. Starting from a completely new, innovative architectural concept, the GENxplor system records a number of industry firsts. The GENxplor is the first MBE system of its size to package all elements into a single platform. Combining the growth/process chamber, buffer chamber, load-lock chamber, and the electronics and controls into a single monolithic frame reduces its footprint by 40% compared to similar MBE systems.

The flexible system platform is capable of growing on up to 3” wafers with a wider variety of compound semiconductor materials than ever before including:

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nitrides, arsenides, phosphides, antimonides, oxides, and novel materials such as graphene. In addition, a modular transfer backbone allows the system to be expanded to add other deposition and metrology technologies. The GENxplor is able to accommodate more configurations than many other MBE system on the market. The process chamber contains new technologies that expand flexibility and capabilities. The first system specifically designed to work with a full complement of bellows-free retractable sources, sources can be maintained, refilled, or changed in isolation from the growth chamber, allowing customers to use the system continuously for years or perhaps even decades without venting.

In addition, the single-frame design with cantilevered growth chamber allows users more convenient access and easier maintenance than ever before. Inside the process chamber, water-cooling is integrated to efficiently remove heat from the system. This can dramatically reduces liquid nitrogen consumption and lowers the operating cost of the system by thousands of dollars a year. Since its introduction in mid-2013, the GENxplor is the best-selling MBE system with five systems sold and counting to customers including University of Oklahoma, University of Nottingham, and McGill University.

EVG®

EVG PHABLE

The PHABLE (for “photonics enabler”) is a patented technology that is targeted for low-cost fabrication of periodic nanostructures that are mainly needed for patterned sapphire substrates (PSS) and photonic applications right now. PHABLE is a mask based UV photolithography technology, enabling existing photo resist and photomask infrastructure. It enables the creation of periodic structures, such as arrays of holes or pillars on a hexagonal or square lattice, or linear gratings over large areas, with high throughput. The unique feature of PHABLE is the very large depth of focus for optical printing. Unlike any conventional proximity, contact or projection lithography technologies, the printed features are independent of the exposure gap over several hundred micrometres. Therefore printing on non-flat surfaces, such as LED wafers, is easily accomplished.

The EVG PHABLE technology is based on a Displacement Talbot lithography approach, producing features ranging from three microns down to 200 nm. This technology effectively provides no depth-of-focus limitation or stitching and can be used on substrates with poor total thickness variation. This technology enables pattern substrates up to six inches in diameter in a single exposure step and therefore the system consistently maintains high patterning throughput independent of wafer size. The very large exposure gap between the mask and wafer, avoids process-related mask contamination.

The system can produce both one-dimensional patterns, such as lines and spaces, as well as two-dimensional patterns, such as hexagonal or square lattices. Thus, it supports a variety of approaches to enhance the light extraction from LEDs or to create patterned substrates. Possible applications include LED surface structuring, PSS, photonic crystal applications, nano-wire LEDs and optical gratings.

Metrology, Test and Measurement Award

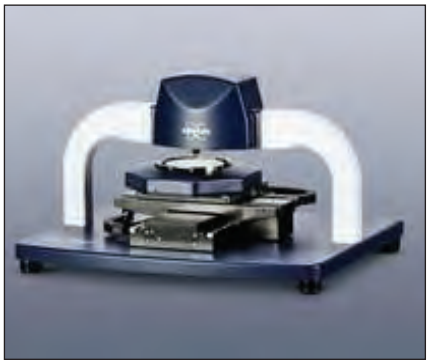
Bruker Corporation

LumiMap Electroluminescence Tool

In 2013 Bruker Corp. introduced the LumiMap electroluminescence system for optical and electrical characterization on epitaxial (epi) growth wafers for high-brightness (HB) LEDs.

LumiMap is a value-oriented alternative to conventional, multistep, operator-dependent indium dot methods of epi (made by epitaxial growth) wafer characterization. The system features rapid, non-destructive, no post measurement chemical cleaning, software-controlled measurement locations, and repeatable optical and electrical measurement capabilities through forming a temporary LED (light-emitting diode) device on an epi wafer.

The results obtained by LumiMap are well correlated with those on the final HB-LED (high brightness LED) device, providing an early warning of process shifts, which in turn reduces the risk of expensive scrap events and improves yields. Simple wafer exchange and intuitive software provides the industries easiest to use interface for production quality control, as well as epi process development. The long measurement lifetime of the proprietary conducting probe meets the strictest industry cost of ownership requirements.



Lake Shore Cryotronics and EMCORE

8500 Series THz System for Material Characterization

The Lake Shore 8500 Series THz System for Material Characterization is a measurement platform that provides the materials development community with a fully integrated solution for exploring THz frequency electronic, magnetic, and chemical properties of materials in cryogenic and magnetic field environments. The system features a coherent, variable frequency continuous wave (CW) THz spectrometer from EMCORE and specially designed THz emitter and detector components which offers high spectral resolution THz-transmission measurements of materials in these extreme environments. Integrated software operates the temperature controller, helium level monitor, superconducting magnet supply, and spectrometer for automated turn-key experimental control.

In the quest to develop high-speed computing, storage, imaging, and communications applications, novel and existing electronic and magnetic materials with favourable high frequency material properties will need to be identified and characterized. The Lake Shore 8500 Series THz System addresses the challenge of the development community seeking to explore the THz-frequency properties of bulk and thin film semiconductors, organic electronics and oxides.

Cryogenic temperatures and high magnetic fields are used to tune the THz-frequency response in order to help elucidate the physical mechanisms underlying the material's electronic or magnetic properties. What's more, the continuous-wave THz source offers a more cost effective approach, compared

to the more conventional time-domain THz (TDS) spectroscopy, for THz materials characterization. The fully integrated Lake Shore THz system is offered at a cost-point comparable to a stand-alone pulsed-laser source. Also important:

The system provides a solution for researchers who do not have the means to build a custom THz characterization system and who lack off-the-shelf software for management and analysis of their experiments. Going into the development of the system, one of Lake Shore's primary objectives was to develop software that was easy to use. The company knew this would be key to how well the system is adopted by the materials development industry – particularly scientists and engineers who do not consider themselves terahertz experts.

Conventionally, low-temperature, high field THz measurements would be performed by placing a sample in the beam path of an optical cryostat and then painstakingly align the terahertz source and detector onto the sample.

Lake Shore, in close collaboration with EMCORE, developed robust THz emitter and detector components that have

proven to operate quite well at liquid helium temperatures and in magnetic fields up to 9 T. In the 8500 Series THz system, fiber-coupled THz source and detector are mounted within the cryogenic environment and in proximity to the sample. Custom designed optical stages maintain good optical alignment of the THz devices over temperature and multiple thermal cycles.

The Lake Shore system uses CW measurements to enable variable temperature measurements of electronic and magnetic materials in two distinct sample types — semiconducting wafers (like InSb or InP) and thin conductive films supported by an insulating substrate (like ZnO/sapphire, graphene on silicon, or 2DEGs).

By replacing terahertz time domain technology with less costly, higher resolution CW spectroscopy, instrumentation cost can be reduced by 50 to 75%, opening the technology to a much broader market. What's more, these capabilities are provided in a completely integrated platform that has the software to conduct proceduralized experimental methods and reliably analyse the spectral results.

LayTec

Pyro 400 Gen2

Pyro 400 Gen2 is a unique optical metrology system for in-situ measurement of the GaN-wafer temperature during LED-structure growth in MOCVD. Pyro 400 Gen2 uses 400nm pyrometry to measure the temperature of the GaN buffer. It can be integrated into the control loop for the growth temperature of the MOCVD system and allows precise control of the wafer temperature during the critical growth steps of an LED structure:

The growth of the multi quantum wells. Pyro 400 Gen2 uses a robust state-of-the-art PLC based measurement scheme and is designed for 24/7 use in LED production. In addition to earlier LayTec

Pyro 400 generations it offers as a unique feature: real-time emissivity correction to compensate for emissivity changes that occur during the growth of different materials.

Pyro 400 Gen2 is controlled and operated by LayTec's EpiNet software. It is also fully integrated into LayTec's fabwide visualization software that allows easy stop-or-go decisions for operators based on traffic lights. Part of the Pyro 400 Gen2 package is the unique calibration tool AbsoluT 400 that allows for an easy but very precise calibration of the Pyro 400 Gen2.

Therefore not only wafer-to-wafer and run-to-run variations can be detected and controlled, but also the very important tool-to-tool variations. Pyro 400 Gen2 can be applied to a wide range of MOCVD systems.

Pyro 400 Gen2 solves the challenge of measuring and controlling wafer surface temperatures during the growth of GaN LED-structures on sapphire, even when AlGaN layers or superlattices for better carrier confinement or electron blocking are introduced. Such layers produce changes in the emissivity of the growing layers, directly affecting the measured surface temperature.

Earlier versions of 400nm pyrometers were unable to account for emissivity changes and have failed to correctly measure the surface temperature on these structures. Pyro 400 Gen2 also solves the challenge of tool-matching, because the pyrometer can be easily calibrated with LayTec's patented AbsoluT 400 calibration device. Pyro 400 Gen2 is the first and only 400nm pyrometer on the market to perform emissivity correction pyrometry.

Besides the thermal emission from the wafer, the reflectance is also measured, allowing for real-time emissivity measurement. An established technique for IR-pyrometers, emissivity correction has never been implemented in the blue/near-UV spectral range before.

The main challenge has been providing a reflectance measurement spectroscopically fitting the black body emission. The emission from the same light source integrated in a regulated device (AbsoluT 400) emulates the emission of a black body at a given temperature and allows for a precise calibration.

Tektronix, Inc

PA1000 Single-phase Power Analyser

New semiconductor technologies such as GaN (gallium nitride) and SiC (silicon carbide) are emerging to meet the greater demands of today. To meet these requirements, new test and measurement tools are needed to keep pace. Last year Tektronix expanded its family of precision power analysers with the introduction of the PA1000 single-phase power analyser.

Featuring a patent pending Spiral Shunt design, the PA1000 provides engineers designing and testing power supplies, consumer electronics and other electrical products with accurate power measurements in the shortest possible time.

Features such as a colour graphical display, one-button application modes and intuitive menu system enable optimum instrument set up in seconds, and the powerful PWRVIEW PC software includes comprehensive reporting features such as a full compliance

IEC62301 standby power certificate. Engineers developing power supplies for single-phase electronics face new demands for greater energy efficiency and lower line pollution, along with a growing array of government regulations and commercial demands to reduce energy consumption.

As new semiconductor technologies emerge, test and measurement tools such as the PA1000 will assume more importance. The PA1000 claims 0.05 percent basic accuracy and 1 MHz measurement bandwidth. Two internal current shunts are included on each PA1000 - one for current measurements up to 1 A, for precise low-current measurements, and another for current measurements up to 20 A.

The 1 A shunt is particularly useful for maintaining measurements resolution and accuracy on demanding low-current signals common to standby power testing.

A full-colour graphics display, unusual in this instrument class, makes setup and other tasks easy and intuitive, with one-button access to measurement results, power waveforms, harmonic bar graphs, and menus.

Application-specific test modes for standby current, lamp ballast testing and energy integration help to simplify optimisation of instrument settings, saving engineers time and reducing mistakes. PWRVIEW PC software further simplifies testing with one-click test automation for compliance-test applications. The PA1000 offers standard features including LAN, USB and GPIB interfaces, harmonic analysis, and PC software that cost extra on many analysers. A five-year warranty and Tektronix worldwide support and service add to the value proposition.

Based on recent field and metrology analysis, Tektronix has released improved accuracy specifications for the PA4000 power analyser and extended the standard warranty to five years from the previous three years. The new accuracy specifications apply to RMS voltage, RMS current and Power. For instance RMS voltage accuracy was rated at ± 0.04 percent and has now been improved to a rating of ± 0.01 percent.

CSindustry awards2014

Device Design and Packaging Award

CREE

45mm SiC Six-Pack Power Module

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

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

When compared to state-of-the-art silicon modules, the SiC 1.2 kV, 50A modules deliver performance equivalent to silicon modules rated at 150A. The efficient switching of the SiC module also allows for significantly less derating than silicon IGBTs. This enables significantly higher frequency operation, which both increases fundamental output frequency and reduces passive component size in applications like motor drives, solar inverters, uninterruptible power supplies, and industrial power supplies.

Even when designers simply substitute Si modules with SiC in motor drive applications, the improved performance of SiC reduces power losses, leading to reduced cooling requirements and, in turn, to a reduction in size, weight, complexity, and the overall cost of the power electronics system.

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

Infineon AG

5th Gen 650V SiC Diodes

The new SiC diode technology of Infineon combines a couple of innovations – smallest die area and thus lowest cost for a given power handling capability, optimized trade-off between static and dynamic losses and the worldwide first implementation of thin wafer technology for SiC devices.

This new chip technology will soon be implemented in a newly developed packaging platform offering small footprint and very low stray inductance compared to existing solutions. Thus, it is an optimized combination of best in class chip technology with the optimum package in order to utilize the benefits offered by the chip to full extent.

The new product addresses the trend towards thinner chips in SiC in order to remove the contribution of the substrate to the on resistance as well as the issue of high stray inductance in standard packages which limits the high frequency performance of ultrafast SiC components ad acts as source of unwanted EMI problems.

Infineon developed a grinding process for SiC wafers as well as a high temperature technology to form a reliable and high performing ohmic backside contact after grinding without affecting the at this stage in the process chain

already finished front side structure. The resulting chip will be implemented in a newly developed low profile SMD package offering lowest stray inductance by multiple short thin wire bond connections to the terminals and pin free connection to the PCB.

Soraa

GaN on GaN LEDs

The main advantage of Soraa's GaN on GaN (Gallium Nitride on Gallium Nitride) LED material is that it allows reliable operation at very high current densities. It has 1000x fewer defects than conventional LEDs, which have GaN layers on cheaper foreign substrates like sapphire, silicon carbide, or silicon.

This enables Soraa LEDs to emit 10x more light per unit area of LED material than conventional LEDs. GaN on GaN's optical transparency and high thermal and electrical conductivity also enable a very robust, simple LED design that delivers maximum light output and performance.

In February 2013, Soraa announced world-record performance from its GaN on GaN LEDs. For applications that require very high light output from tiny form factors – e.g. MR16 lamps – Soraa's Gen 2 LEDs deliver unprecedented performance and colour rendering. The SORAA PREMIUM 2 and VIVID 2 LED MR16 lamps use these Gen 2 LEDs.

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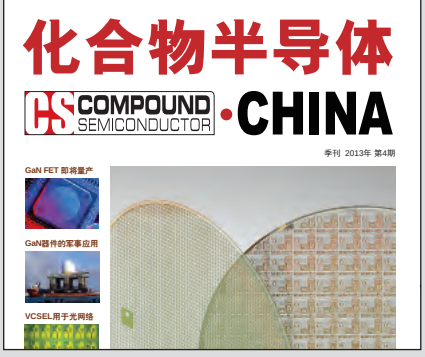


Taiwan Magazine

LinkedIn

CSindustry awards2014

Innovation Award

Infineon AG

Direct Drive for CoolSiC

Infineon's CoolSiC transistor is a normally on JFET device, combining the well known low ohmic performance of high voltage SiC transistors with an extraordinary level of ruggedness since no susceptive gate oxide with questions about interface quality and lifetime is used in the component. However, the device is normally on and a way to make it familiar with system requirements must be identified. For comparable wide band gap devices like earlier JFETs or today's normally on GaN HEMTs the traditional cascode arrangement is used. This simple concept offers by a series connection of the normally on component with a normally off low voltage silicon MOSFET (the blocking voltage of the MOSFET must exceed the voltage required to block the device) and connecting the gate of the normally on transistor with the source of the MOSFET. The concept can be easily derived from the equivalent circuit of each DMOS today.

However, this concept has some disadvantages like potential dynamic avalanche stress on the MOSFET or limited controllability of the switching slopes. Thus, a modified setup was developed at Infineon, sill being based on the series connection of the two devices, but now controlling each gate separately. To enable an easy implementation a driver IC was developed to operate the setup. In this mode, the switching is no longer performed via the MOSFET gate, but directly via the JFET. The MOSFET is passive in this configuration and just acts as a safety switch for start up or failure mode in which the original cascode idea is maintained. The concept is called Direct Drive.

The idea deals with the challenge of operating a normally on device safely under modern system aspects and securing lowest losses at the same time. It addresses as well ruggedness problems of competing solutions and requirements from the application with respect to the dv/dt control in PWM operation.

The idea extends the original cascode idea in a way that their negative points are diminished. By disconnecting the gate contact of the normally on JFET from the MOSFET source we can access the main switching devices directly for easy dv/dt control. Furthermore, the MOSFET is no longer switched in each dynamic cycle and thus, no additional MOSFET losses have to be considered. Finally, the MOSFET is not driven in each cycle into avalanche what increases the ruggedness of this circuit.

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

Kyma Technologies

PVDNC AlN Templates

PVDNC AlN stands for plasma vapor deposition of nanocolumns. Kyma deposits nanocolumn AlN on silicon and sapphire substrates to create a great nucleation surface for growth of GaN devices thereupon. Device fabricators realize better (lower defect density) GaN buffer layers earlier in the buffer layer growth process. A lower defect density translates to higher thermal conductivity and presents other benefits depending on the device application.

Kyma supplies both materials and equipment for making PVDNC AlN templates, which is growing in importance in supporting GaN on sapphire based LEDs and GaN on Si power electronics.

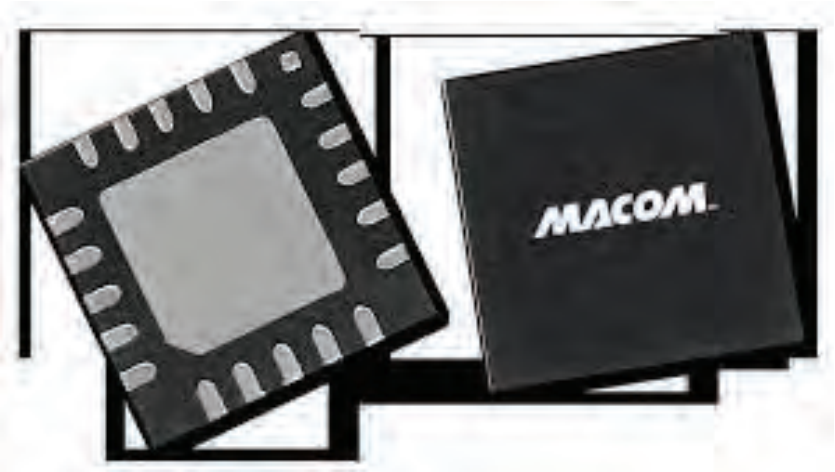
The most difficult part of growing a GaN device on sapphire or silicon is in the initiation of the buffer layer. Kyma's PVDNC AlN materials present the ultimate in terms of a great nucleation surface for growing GaN based devices on top of it. The PVDNC process creates a nanostructured AlN surface which is optimal to nucleate GaN growth on top. The process works on both flat and patterned substrates. PVDNC puts an important nanostructure on top of flat or microstructured substrates.

PVD was thought to be a low-tech approach to growing crystalline films. However, Kyma's PVDNC process can create perfect nanowires of GaN.

When applied to AlN for GaN device applications, PVDNC produces a unique ensemble of highly oriented, highly perfect, AlN nanocolumns that together present an optimal surface for GaN nucleation.

M/A-COM Technology Solutions, Inc

X-Band Core Chip (MAMF-011015)



M/A-COM Technology Solutions Inc. claims an industry first with an integrated core chip for the 8 GHz – 11 GHz frequency range. Containing 6-bits of phase control, 6-bits of attenuation control and 26 dB of gain, the Core Chip is an easy to use serial/parallel interface in a surface mount QFN package. Ideal for commercial radar applications, this integrated MMIC enables radar systems in early detection and warning for severe impending weather.

The X-Band Core Chip (MAMF-011015) is a highly integrated solution setting new standards for size, weight, and performance (SWaP) enabling the next generation of radar system design. The X-Band Core Chip integrates a CMOS logic driver with a GaAs Transmit/Receive MMIC within a single QFN package. The surface mount 7x7mm plastic package offers a cost-effective, easy to implement solution. The device's versatility and flexibility make it ideal for weather, wildfire and related commercial radar applications.

The X-Band Core Chip development is a product of a joint investment between MACOM and FIRST RF Corporation to support new weather radar programs such as the Collaborative Adaptive Sensing of the Atmosphere (CASA) Weather Radar Program. CASA is a multi-sector partnership among academia, industry, and government - dedicated to engineering revolutionary weather-sensing networks. These innovative networks save lives and property by detecting the region of the lower atmosphere currently below conventional radar range - mapping storms, winds, rain, temperature, humidity, and the flow of airborne hazards.

The packaged device comprises of a common leg circuit which includes digital attenuators, phase shifters, a low noise receive chain, and a transmit driver amplifier, as well as a CMOS logic driver. This integrated circuit utilizes MACOM's advanced 0.25um PHEMT process, which has been optimized for high power and low noise amplifiers, passive and control components and allows for a high level of integration on a single MMIC.

CSindustry awards2014

R&D Award

Imec

III-V FinFETs

In 2013 Imec, a nano-electronics research centre successfully demonstrated the first III-V compound semiconductor FinFET devices integrated epitaxially on 300mm silicon wafers, through a silicon fin replacement process.

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

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

The proliferation of smart mobile devices and the ever growing user expectations for bandwidth and connectivity will drive the continual need for software and hardware advancements that extend from networks to data servers and mobile gadgets. At the core of the hardware will be new process technologies that allow for more power-efficient CMOS transistors and increased integration, enabling a higher level of functionality.

This prompts process technologies that enable heterogeneous devices spanning operating ranges for targeted circuits, maximizing the system performance. During the last decade, transistor scaling has been marked by leaps in process technologies to provide performance and power improvements.

The replacement of poly-silicon gate by high-k metal-gate in 45nm CMOS technology represented a major inflection in new material integration for the transistor.

The ability to combine scaled non-silicon and silicon devices might be the next dramatic transistor next step ending the all-silicon reign over digital CMOS. This work could represent an important enabling step.

At the finest grain, co-integration of high-density heterogeneous transistors has been challenged by the ability to combine disparate materials and structures while maintaining low enough complexity and defectivity.

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

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

Soitec SA

4 Junction Cell

Soitec SA claims the industry's first four-junction solar photovoltaic (PV) cell. The design comprises two dual-junction sub cells. The four-junction design uses two dual-junction sub cells grown on different III-V compound materials, which allows band-gap combinations to capture a broader range of the solar spectrum.

In developing the cell, Soitec used its proprietary semiconductor bonding and layer transfer technologies, which have been used in the semiconductor industry for decades.

The cell was developed in collaboration with Fraunhofer ISE and the Helmholtz Center for Materials and Energy (Berlin), which developed and deposited III-V epitaxial layers on new base materials as well as fabricating and characterizing the device. CEA-Leti (Grenoble, France) also participated in the project.

In 2013 Soitec surprised the industry (after three years of research) by entering a new record efficiency of 44.7 percent which was measured at a concentration of 297 suns. This indicates that 44.7 percent of the solar spectrum's energy, from ultraviolet through to the infrared, is converted into electrical energy.

Last year, during a press briefing at Intersolar North America, Soitec announced its plans to produce a 50 percent efficient cell, pushing the NREL efficiency roadmap ahead by 5-10 years.

Ceramic foundation boosts brightness

Superior thermal conductivity enables an output power hike for high-voltage LEDs

ENGINEERS FROM Epistar and National Central University in Taiwan have increased the output power of a blue LED by turning to a ceramic substrate.

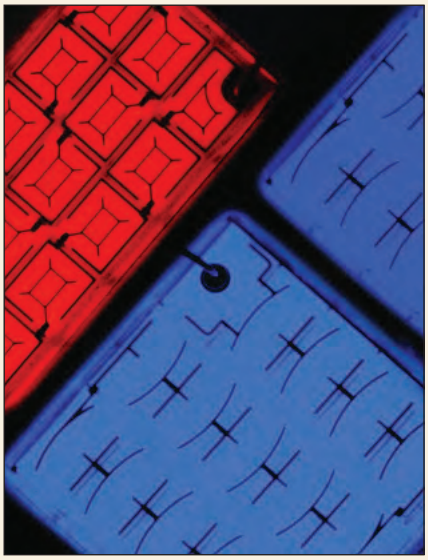
The ceramic-based emitter, which operates at a high voltage and features 16 LEDs connected in series, can deliver an unsaturated output of 1800 W cm^{-2} at a current density of 450 A cm^{-2}.

This chip could help to increase the uptake of solid-state lighting, which needs to be more competitive in terms of its performance-to-cost ratio. The team's work offers a route to making bigger LED chips operating at higher powers, and this could lead to cheaper solid-state lighting products, thanks to material cost savings associated with fabrication and packaging.

Producing larger chips while maintaining performance is not easy, because it requires addressing thermal degradation and current crowding, two contributors to LED droop. This pair of impediments to high performance is particularly difficult to address when LEDs are formed on sapphire – despite its poor thermal conductivity, it is the most common platform for the device.

Several groups have addressed thermal issues and current crowding with vertical devices formed by wafer-bonding and laser lift-off. These LEDs feature an input current flowing through a conductive substrate, and benefit from superior current spreading within the device.

Another way to minimise thermal issues and current crowding is to turn to high-voltage devices, which feature several LEDs connected in series on the same chip. This combination of a high bias voltage and low driving current not only improves current spreading, thanks to the reduced area of the individual LEDs, but also simplify demands on the transformer that converts the supply from the mains into a voltage for powering the bulb.



Epistar is one of the pioneers of high-voltage LEDs, which feature an array of cells connected in series

Epistar is one of the pioneers of the high-voltage LED, and it late 2011 it unveiled chipsets with blue and red emitters. In this latest work, the company has built on that previous success and partnered with National Central University, Taiwan, to demonstrate the benefits of high-voltage chips on ceramic substrates.

This recent study involved a comparison between a thin-film LED wafer-bonded to a silicon substrate – which is said to be the most popular device type for the thin-film process – and high-voltage LEDs with foundations of sapphire and ceramic AlN.

All three devices had an identical chip size of 1.14 mm by 1.14 mm, emit at around 450 nm, and featured an InGaN/GaN multi-quantum well structure and a magnesium-doped AlGaN electron-blocking layer.

Light extraction from the LED with a ceramic foundation is enhanced by forming a reflective mirror on *p*-type GaN via deposition of 1 nm of nickel, followed by 200 nm of silver. The growth of additional metallic layers aids bonding to an AlN ceramic substrate, which is supplied by Maruwa and has a thermal conductivity of 230 W m^{-1} K^{-1}. Laser lift-off removes the sapphire, before photolithography and dry-etching cut the mesa area into a 4 x 4 array, and a potassium hydroxide etch roughens the *n*-type GaN to increase light extraction. Finally, the walls are passivated with Al_2O_3 before a combination of chromium and aluminium forms metal bridges and electrodes.

The silicon-based LED is fabricated in a similar manner. Isolating individual LEDs is very difficult on this foundation, due to the high conductivity of silicon that leads to undesired leakage paths, so the team decided to not attempt to form a high-voltage structure.

Sapphire provided the foundation for the third type of LED: a high-voltage device featuring an array of 4 x 4 cells formed by dry etching. Reflective layers deposited on the backside of the sapphire increased reflectivity by 15 percent. The high-voltage LED with the ceramic foundation produced the highest level of uniformity, in terms of optical intensity, followed by its high-voltage sapphire cousin and then the low-voltage silicon device.

This order reflects current spreading uniformity, which is lowest in the silicon device, due to the long lateral current path. The ceramic-based LED produces the most uniform emission, thanks to the low sheet resistance of its window layer.

Driven towards output power saturation, the high-voltage sapphire and low-voltage silicon peaked at 200 A cm^{-2} and 250 A cm^{-2}, respectively, while the ceramic-based device continued to emit more power up to 450 A cm^{-2}.

"Such a high operation current density of 450 A cm^{-2} is rarely found in the literature," wrote the team in its paper.

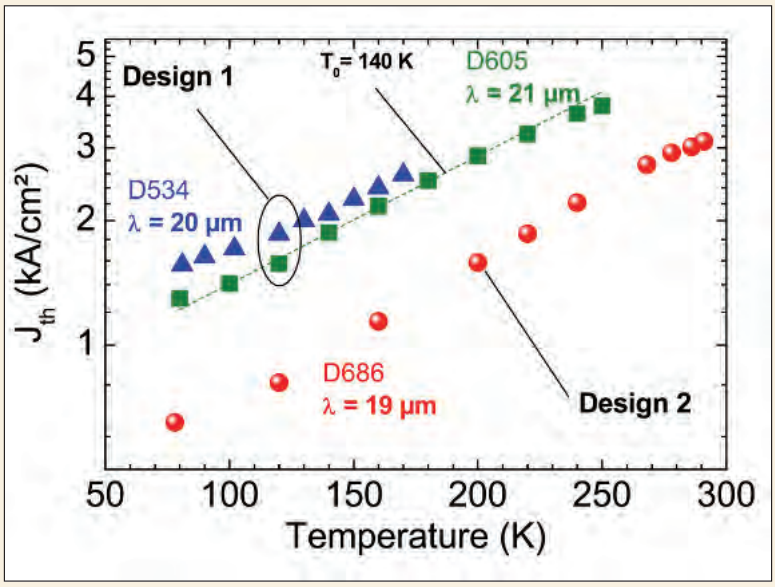
M. –L. Tsai *et. al.*
Appl. Phys. Express **7** 022103 (2014)

Expanding the spectral range of QCLs

Refinements to waveguides and active regions enable QCL room-temperature operation at 19 μm.

A TEAM FROM FRANCE is claiming to have set a new benchmark for the performance of quantum cascade lasers (QCLs) operating in the long infrared.

One device based on the InAs/AlSb material system delivered emission at 19 μm at temperatures up to 291 K, while a cousin at 21 μm produced lasing up to 250 K. According to the partnership between researchers at University Paris Sud and the University of Montpellier, these values represent the best performance to date for QCLs operating above 16 μm.



The QCL that lases via a diagonal intersubband transition (D605) has a higher threshold current density than the device that operates using a vertical transition (D686)

The team's QCLs operate in a spectral range that corresponds to an atmospheric transparency window. This spectral range is of interest to astronomers, because it allows signals from space to reach the earth without undergoing excessive absorption.

"Since these signals are very weak, lasers can be used as local oscillators to perform heterodyne detection," explains Raffaele Colombelli from University Paris Sud.

It is possible to construct QCLs emitting in the 19 - 24 μm range with InGaAs-based and GaAs-based devices, but lasers built with these material systems more than a decade ago did not produce encouraging results.

The pairing of InAs and AlSb is far more promising, because very low effective electron mass in the quantum wells leads to elevated optical gain. In 2013, the team at Montpellier reported QCLs emitting at around 20 μm that were based on InAs and AlSb, and device improvements are detailed in its latest paper that is produced in collaboration with the University Paris Sud.

The latest lasers feature metal-metal waveguides. These structures produce very divergent far fields for terahertz QCLs, which are defined as emitting at 65 μm or more. However, for the French team's lasers, undesirable diffraction effects appear to be absent. Laser structures were created in a Riber Compact 21 MBE reactor, using growth runs that could take 10 hours.

Roland Teissier from the University of Montpellier explains that one of the main difficulties associated with MBE growth is the control of the very thin AlSb layer – which has a thickness of the order of one atomic monolayer – with high interface quality. "[The second challenge is] the stability of the growth rate, in order to keep uniform layer thickness throughout the growth of the 7 μm-thick active region."

To create the metal-metal waveguide, the researchers used wafer bonding and active region transfer. "This required the development of a specific etch stop layer and substrate removal procedure," explains Teisser.
He and his co-workers produced two types of QCL: one design was very similar to the laser made in 2013, but employed a modified injector, plus higher doping of the active region to increase carrier dynamics; while the other had a modified active region, which replaces a diagonal intersubband transition with a vertical transition that maximises oscillator strength.

These lasers have a beam divergence that is only a little larger than that of commercial QCLs operating at shorter wavelengths, such as 8 μm. "However, a larger beam divergence can be corrected by a judicious optical system," says Colombelli, who added that the team is also designing new laser geometries that should reduce divergence.

Compared to the QCL of 2013, the laser with higher doping had a similar threshold current, but a larger current dynamic – and the latter permitted a significantly higher operating temperature. An even higher operating temperature of 291K was possible with the QCL that featured vertical transitions in its active region. To obtain controllable side-mode emission, the team plans to use this laser design to make distributed feedback lasers capable of higher temperature operation.

"We are also planning to exploit the high optical gain of InAs in order to extend the wavelength, ideally up to 30 μm to 32 μm, where QCLs based on GaAs or InGaAs cannot operate, given the presence of photons," says Colombelli.

D. Chastanet *et. al.*
Appl. Phys. Lett. **104** 021106 (2014)

Refining periodically orientated GaN

Non-linear optics could benefit from alternating layers of N-polar and Ga-polar GaN.

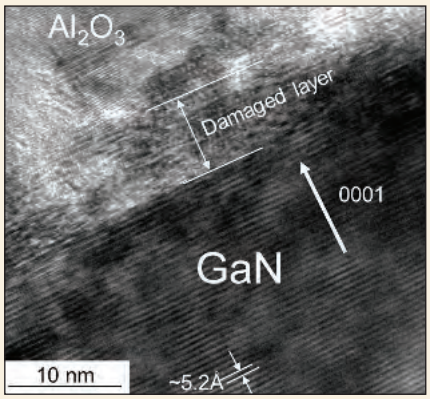
Researchers from the US Naval Research Laboratory are claiming to have developed a superior approach to making a structure with selectively switched GaN polarity.

"[Our work] is a breakthrough," says team-member Jennifer Hite. She explains that the team have demonstrated a simple method for forming a thin sapphire-like layer on Ga-polar GaN. This process holds the key to polarity changes from Ga-polar to N-polar material.

Kite believes that this simple method is preferable to the previous best approach: That required a magnesium-based layer for inversion of GaN, and had unwanted side effects, such as uncontrolled formation of inversion domains and faceted interfaces.

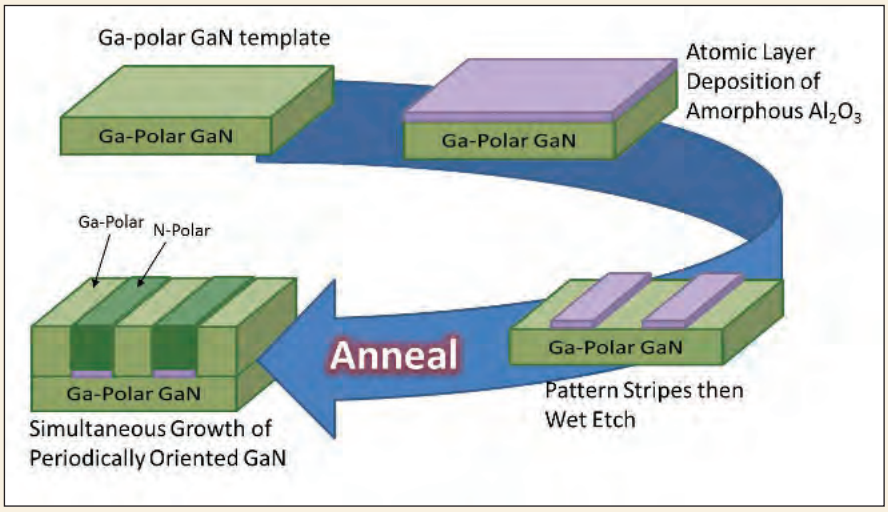
"The biggest application space for our work is in non-linear optics, basically using the alternating polarity for frequency conversion through quasi-phase matching." For a semiconductor structure to realise quasi-phase matching, its crystal orientation must be periodically altered to produce a large second order non-linearity.

Quasi-phase matching in GaN was reported in 2003 by a team from Bell Laboratories, New Jersey. However, in that case the researchers employed GaN heteroepitaxial thin films on sapphire, which add strain and limit the thickness of the structure. A thickness of a millimetre or more is needed, which accounts for the interest in GaN-on-GaN structures for high-power, non-linear optics.



Transmission electron microscopy reveals the damage to the annealed Al_2O_3 near the interface with GaN

The starting point for forming such structures is a 2 μm-thick film of *c*-plane GaN deposited on *a*-plane sapphire by MOCVD. Following chemical cleaning, this epiwafer is placed in an ALD tool and a 15 nm-thick film deposited. After patterning 16 μm-wide stripes with a positive photo-resist and photolithography technique, etching in hydrofluoric acid removes Al_2O_3 from designated regions of the wafer.



Periodically orientated GaN is formed with a process involving atomic layer deposition (ALD) of amorphous Al_2O_3, which takes on a more crystalline form after annealing

Stripping the photoresist leaves stripes of Al_2O_3 on Ga-polar GaN, before the wafer is loaded into an MOCVD chamber. Annealing in an ammonia atmosphere at 1100 °C for 40 minutes converts amorphous Al_2O_3 to a crystalline form, before a GaN buffer is deposited at 670 °C, followed by GaN growth at 1100 °C.

Using two growth steps and an intermediate clean is the only way to make periodically orientated semiconductor structures. That may mean it's viewed as a complex process, but this not a barrier to volume manufacturing, insists Kite: "Silicon technologies require multiple tools and growth steps – Intel has actually incorporated ALD to deposit high-κ dielectrics."

Researchers confirm the presence of N-polar and Ga-polar regions by etching samples for up to 40 minutes in potassium hydroxide. N-polar material is far more chemically reactive than its Ga-polar cousin, with etching creating hexagonal faceting, while the Ga-polar material maintains a smooth surface.

Studies of initial structures identified N-polar regions with 'lips' of material along the border and 'troughs' in the middle. Lowering the V/III ratio enables a coalesced, more uniform N-polar structure. However, further optimisation is needed, because there are Ga-polar inclusions in the N-polar areas.

Scrutinising structures with a transmission electron microscope reveals that all the GaN is *c*-orientated. The interface between the Al_2O_3 and the upper GaN is sharp, but the bottom 10 nm of Al_2O_3 is damaged, due to annealing.

Plans for the future begin with reducing Ga-polar inclusions by optimising the N-polar initiation on the ALD layer. "The following step will be to grow thick structures by HVPE, and then test the material for quasi-phase matching," says Hite.

J. Hite *et. al.*
Appl. Phys. Express **7** 025502 (2014)

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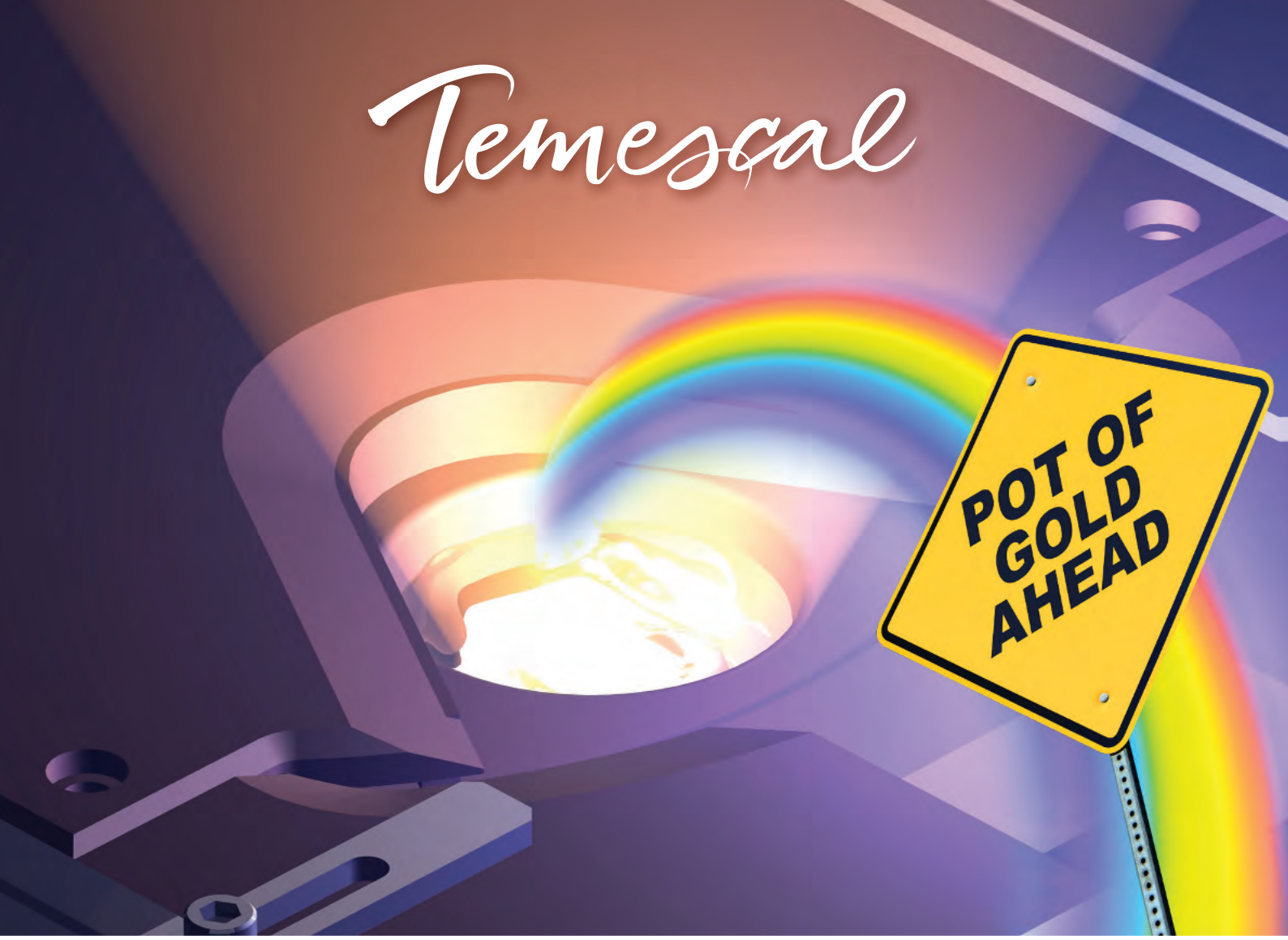

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LEDs

GaN LED performance moves forward with drivers

By 2020 it is predicted that LEDs will have captured between 88 and 90 percent of the lighting market. Applied to a smaller surface capable with GaN, it is possible to make switching cheaper

LED lamps use less energy and provide more light than Incandescent light bulbs which are now banned in the EU, while energy-saving lamps remain a bone of contention.

In 2016, it will be lights out for halogen bulbs over 10 watts as well. LEDs therefore have the best chance of becoming the light source of the future.

Experts reckon that LED retrofit lamps for use in standard bulb fittings will overtake traditional energy-saving bulbs for the first time from 2015.

GaN transistors enable the compact design of this 2090 lumen retrofit LED lamp (exploded diagram for purpose of illustration) (Credit: Fraunhofer IAF)

The tiny diodes offer a whole host of advantages as the most environmentally friendly source of light - they contain no harmful substances, consume less energy and, with a lifetime of between 15,000 and 30,000 hours, last longer than conventional light sources. They also work at full brightness as soon as you flick the switch.

Coping with higher temperatures

LEDs do have one weakness, though - they are extremely sensitive to variations and spikes in power. To function properly, they need a driver that ensures a constant supply of power at all times.

This driver, which takes the alternating current from the grid and converts it into direct current with a reduced voltage, has a profound influence on the light yield and lifetime of the LED lamp as a whole.

The demands placed on the driver electronics are correspondingly high. This has prompted researchers at the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg to focus their attention on voltage transformers featuring GaN transistors.

During practical testing, the scientists found that the drivers developed using this new semiconductor material were extremely robust. Components made of GaN can operate at higher currents, voltages and temperatures than standard silicon transistors.

“Heat plays a role both in the brightness and the service life of LED lamps,” says Michael Kunzer, group manager at Fraunhofer IAF.

GaN transistors can also switch at high frequencies. The switching speed has a significant impact on the size of the coils and condensers built into the drivers for energy storage. In a GaN-based driver, the switch speed can be made as much as a factor of 10 faster than that of its silicon equivalent.

“Applied to a smaller surface, this means it is possible to make switching cheaper. The whole LED lamp can be made lighter and more compact while delivering the same or even improved illumination,” explains Kunzer. Since the energy storage component plays a decisive role in manufacturing costs, this could have an extremely positive effect on the end price.

Thanks to GaN’s properties, Kunzer and his team have been able to boost the efficiency of the GaN driver to 86 percent - between one and four percentage points better than its silicon equivalent.

When compared with the silicon transistor LED lamps available on the market, the scientists were able to increase the light output: while the luminous flux of commercial LED retrofit lamps featuring silicon components is around 1000 lumen (the unit used to measure the light produced), researchers from the IAF have been successful in increasing this to 2090 lumen.

“20 percent of energy consumption worldwide can be attributed to lighting, so it’s an area where savings are particularly worthwhile. One shouldn’t underestimate the role played by the efficiency of LED drivers, as this is key to saving energy. In principle, the higher the light yield and efficiency, the lower energy consumption is. If you think that by 2020 LEDs will have carved out a market share of almost 90 percent, then it is obvious that they play a significant role in protecting our environment,” says Kunzer.

The researchers will be showcasing a retrofit LED from April 7th to 11th at the Hannover Messe, where they can be found at the joint Fraunhofer booth in Hall 2, Booth D18.

Towa inaugurates packaging development centre in Netherlands

Due to the increase in development in new semiconductor devices, sensors, LEDs and electronic products the Towa corporation of Japan has established a new centre in Europe

Following an announcement in January, the packaging development centre (PDC) of Towa Europe B.V., in the Netherlands officially opened in the presence of the staff and a large group of people.

The opening included suppliers and other relations and representatives of the Duiven municipality, the Netherlands Foreign Investment Agency (NFIA) and Oost N.V.

After a word of welcome and an introduction by the director of Towa Europe B.V., Huub Claassen, a message from the president of the Towa Corporation of Japan, Hirokazu Okada, was read by Pete Molenaar, marketing manager of Towa Europe B.V.

In this message Okada said, “I am extremely happy that we can open this PDC here in Duiven in Europe today and I hope that companies here in the Netherlands and in the other European countries will find the way to work together with Towa Europe PDC”.

Then Muneo Miura, representing the Japanese headquarters, pressed a button on one of the Towa systems after which the first product was produced and after a toast by H.B.I de Lange, mayor of the Duiven municipality, the official opening became fact.

Before and after the opening ceremony there was an opportunity for all present, to discover the offices and laboratory rooms with the Towa molding systems and test- and measuring equipment as well as samples, produced on Towa machines.

Because of the increase in development in Europe of new semiconductor devices, sensors, LED’s, MEMS en other electronic products it has been decided by the Towa corporation of Japan to establish this Packaging Development Centre in the Netherlands.

The staff of the research centre consist of a team of experienced engineers. There is a well equipped laboratory with 2 Towa molding systems, test- and measuring equipment. Therefore support can be given in all phases of packaging development, from concept up to test, qualification and industrialization.

Also the European Marketing, Sales and Service department for the Towa systems is located at this new facility.

The Towa Corporation of Japan develops molding processes and equipment for leadframe, substrate, large panels and wafer level packaging applications in end-user markets including electronics, computer, automotive, industrial, RFID, LED and solar energy.

Sapphire market to fire up

The highlighting features of sapphire are high efficiency, good thermal and electric properties, and longer life. The material is best suited for LEDs, power electronics devices and display covers for consumer electronics

The global sapphire market by substrate is expected to reach $3.01 billion by 2020 at a CAGR of 12.31 percent, where as the Global Sapphire Technology Market for devices is expected to reach $6.17 billion by 2020 at a CAGR of 12.24 percent.

So says the report, "Sapphire Technology Market by Growth Technologies (Substrate Wafer (Si-on-Sapphire, SiC-on-Sapphire, GaN-on-Sapphire, and Others), Devices, Applications, and Geography - Analysis & Forecast to 2013 - 2020," from marketsandmarkets.com.

The analyst says sapphire is gaining attention due to an effective cost matrix and leads to a longer life cycle with greater reliability.

The Sapphire Technology Market is expected to captivate essentials for new entrants as well as winning opportunities for the established players

The Americas has been identified as the fastest growing region, with U.S leading the way. Europe also has a very promising market with Germany and the U.K. while the ROW also impetus to the growth.

The competitive landscape of the market presents a very interesting picture, where a large number of small players have become a force to reckon with. The market is witnessing a large scale collaboration and partnership across the value chain with number of tier-one players around the globe.

Major players in this Sapphire Technology Market include: GT Advanced Technology (U.S.), Rubicon Technology (U.S.), Namiki Precision Jewel Co. Ltd (Japan), Monocrystal Inc. (Russia), and DK Aztec Co. Ltd (Korea).

Nichia's appeal of blue LED patent denied

Everlight filed invalidation request against Nichia's blue LED patent JP2735057 on July 23rd, 2012

In response to Nichia's press release on February 20th related to the U.S. Patent No. 6,653,215, Everlight clarifies that the decision made by the U.S. Patent and Trademark Office (USPTO) is not final and still appealable.

The decision itself has no effect on Everlight's products. Everlight will appeal to the U.S. Court of Appeals for the Federal Circuit (CAFC) against the USPTO's decision.

Japan Patent Office (JPO) granted Everlight's request and found claims 1, 3, 16-18 of the '057 patent invalid. Nichia appealed to the Japan Intellectual Property (IP) High Court.

The IP High Court affirmed the JPO's decision on July 18th, 2013. Nichia appealed to the Supreme Court of Japan.

The Supreme Court on February 7th, 2014 denied Nichia's appeal and affirmed the lower court's decision. The invalidation finding of JPO is therefore final and the claims 1, 3, 16-18 of Nichia's '057 patent are for certain invalid.

Everlight says it will continue to defend the rights and benefits of its customers and shareholders.

Nichia started accusing Everlight of infringing its patents since 2006. Both civil infringement and administrative invalidation actions in Taiwan resulted in favourable rulings for Everlight.

Everlight also has filed patent litigations against Nichia in the United States, Germany, Japan and mainland China in order to defend its rights and benefits.

Laytec enables crack free a-plane GaN layers

To achieve thick crack free a-plane GaN buffer layers, low temperature AlN interlayers (LT AlN IL) are used for strain engineering

It is known that some properties of GaN based light emitting quantum wells (QWs) can be improved by *a*-plane III nitrides.

However, during the hetero-epitaxial growth on *r*-plane sapphire substrates, *a*-plane GaN layers are tensely strained in the growth plane resulting in crack formation.

At the annual conference of the German Society for Crystal Growth (DGKK) last December, Matthias Wieneke of Otto-von-Guericke University in Magdeburg (Germany) reported about the impact of LT AlN IL on *a*-plane GaN films.

For the studies, his team applies EpiCurve TT AR -

an *in-situ* metrology system with advanced curvature resolution (AR).

This tool uses three laser spots for the curvature measurements as shown in the figure below, and also provides information on wafer curvature asymmetry along two perpendicular directions as it is typical for *a*-plane III-N growth.

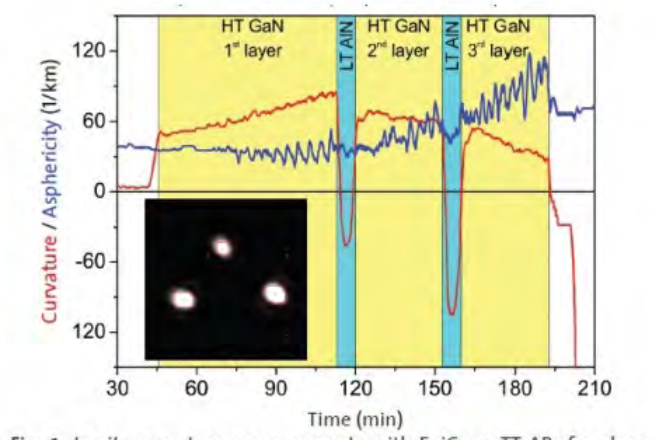


Fig. 1: In situ curvature measurements with EpiCurve TT AR of a-plane GaN samples containing two LT AlN ILs [2].

The *in-situ* curvature measurements are demonstrated in the figure by a red line for (spherical) curvature and a blue line for curvature asphericity. During the growth of the tensely strained a-plane GaN buffer layer, the curvature (red) increases, while it decreases after the insertion of LT AlN IL.

Thus, the interlayer reduces the tensile strain as in the case of *c*-plane GaN growth.

However, after the growth of the interlayers, the asphericity (blue in the figure) increases, which indicates an increase of anisotropic strain. This anisotropy has been proven by subsequent *ex-situ* X-ray diffraction measurements [2].

[1] M. Wieneke *et.al*., abstract book ICMOVPE 2012
[2] M. Wieneke *et al*., abstract book DGKK 2013

EVG and BMT brighten up LEDs

An anti-reflective materials combined with coating equipment and process create 'total' AR coating solution to increase lumen output by up to eight percent

EV Group (EVG) and Brisbane Materials Technology (BMT), have introduced a new anti-reflective (AR) coating solution based on BMT's XeroCoat materials, which is designed to substantially increase lumen output of LED devices.

The jointly developed manufacturing solution, which leverages a combination of AR coating processing equipment and tuneable, durable, inorganic coating material, enables lumen output increases of up to eight percent. The AR coating manufacturing solution can be seamlessly integrated with established production schemes, allowing the coating of LED components at room temperature and atmospheric pressure.

"Improving light efficiency is a constant goal for LED chip and luminaire manufacturers in order to drive down the total cost of LED lighting. However, extracting further improvements in light output from the LED chip design and epitaxial layer growth process has become increasingly difficult and costly.

As a result, any incremental improvements in light output that can be gained from other areas with minimal cost or disruption to the LED manufacturing flow can have a significant impact on reducing overall system cost," says Antun Peic, business development manager at EV Group.

"Through our partnership with BMT, we've developed a turnkey manufacturing solution that has achieved a significant breakthrough in improving LED light efficiency, which can help accelerate new applications for solid-state lighting such as smart lighting and smart building."

Under a strategic cooperation agreement, EVG has optimized its precision coating systems for BMT's unique materials and processes, enabling high-yield fabrication of AR coatings with industry-leading performance and cost.

The technology enables the creation of a nano-porous SiO2 coating from a liquid precursor at room temperature and atmospheric pressure on plastic and glass lenses and luminaires. The SiO2 film, which has undergone rigorous testing, including a 2.5-year accelerated aging test equivalent to more than twenty years of field application, is covalently bonded to the surface to give maximum durability and field reliability.

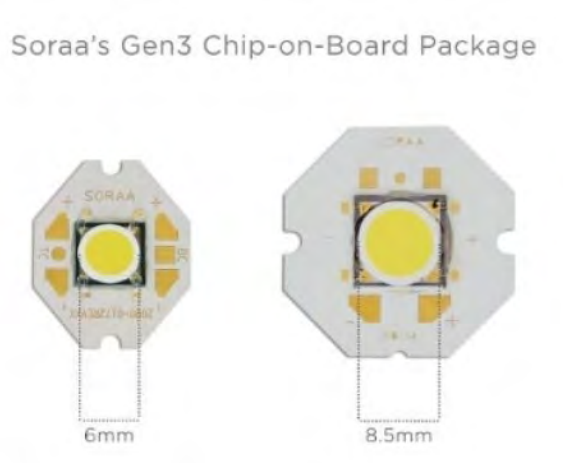
"Our collaboration with EV Group in the solar market over the past several years has proven the ability of our joint-AR coating solution to provide significant improvements in solar cover glass transmission," comments BMT founder and CEO Gary Wiseman. "We are very excited to begin providing our patented XeroCoat anti-reflective materials to LED lighting customers. Our unique solution provides a simple and cost-effective way for customers to increase lumen output. Working with our equipment partner, EVG, we provide the equipment, materials, and process as a turnkey solution to our customers."

The large-area spray deposition method employed for this new process provides maximum processing flexibility as well as scalability.

According to Paul Lindner, executive director of technology at EVG, “The large-area spray coating technology used in this process has been in commercial production in the display technology space for well over ten years. This field-proven equipment solution, combined with BMT’s novel material, allows us to quickly and uniformly coat nano-scale films onto a large number of luminaires, a key requirement to meet the challenging volume and cost targets of our LED customers. In addition, spray coating allows for coating over a large range of form factors. For instance, lenses with highly curvilinear features, which is another important requirement for the LED luminaire market.”

Soraa Gen3 LED breaks barriers

The GaN on GaN innovator has achieved a 30 percent lumen/W increase over the previous generation Soraa has announced it has made the world’s most efficient LED, which it will integrate into the market’s first full-visible-spectrum, large form factor lamps. Soraa says its third generation (Gen3) GaN on GaN LED achieves world-record setting wall-plug-efficiency, outperforming the nearest competitor by 20 percent at normal operating conditions.



Soraa›s GaN on GaN Gen3 LED

In a year, Soraa has achieved a 30 percent increase in white lumen per watt (lm/W) efficiency over its prior generation LED, setting a pace of technology evolution which it believes is unrivalled in the LED industry. Soraa›s Gen3 LED will be available in the second quarter of this year in a variety of product offerings: modules, large form factor PAR and AR lamps, and MR16 lamps.

Soraa says its full-visible-spectrum PAR30L lamp, powered by its Gen3 LED, will lead the market not only in light output, but also in colour and whiteness rendering; at CRI-95 and R9-95 it will achieve centre-beam intensity (CBCP) of 28,250cd at 8° beam angle, 10 percent higher than the CRI-85 offering of the nearest competitor. Soraa claims its large form factor lamps will feature natural and accurate rendering of colours and whiteness, perfectly uniform beams of exceptionally high intensity, and clear single shadows. «Soraa›s Gen3 GaN on GaN LED package is a major milestone for the LED industry and a truly disruptive innovation. We have achieved a 30 percent lm/W efficiency improvement over our previous generation white LEDs, and what›s amazing is that we expect to repeat these significant year-over-year performance gains in the future,» says Jeff Parker, CEO of Soraa.

The company›s Gen3 LED runs at 75 percent wall-plug-efficiency at a current density of 35A/cm2 and a junction temperature of 85°C, efficiency levels that are out of reach for other LED manufacturers. With a proprietary three-phosphor combination, Soraa says its Gen3 LED emits full-visible-spectrum light (all the colors of the rainbow, including violet), which excites optical brightening agents and perfectly renders whiteness as well as colours.

Plessey appoints ex Cree sales officer as CCO

With a new man on the block, the firm’s aim is to drive global uptake of its patented GaN-on-silicon technology as a cost-effective alternative to existing lighting systems, and expand its UK manufacturing facilities

As it gears up to grow global sales of its LED technology, Plessey Semiconductors of Plymouth, UK has appointed Jose (Joe) Lopez as chief commercial officer (CCO).

Reporting to Plessey’s CEO Michael LeGoff, he will assume overall responsibility for the commercial and customer aspects of the organisation, with the main focus being to grow Plessey’s LED sales.

Plessey says that, during a twenty-five year career in the semiconductor industry, Lopez has been a key player in the solid-state lighting (SSL), communications and consumer market segments.

Plessey's new chief commercial officer Jose Lopez

"Having spent the last three and a half years at Cree in a leading global sales role, Joe brings a wealth of LED commercial experience, key customer contacts and senior-level relationships within the SSL industry," comments LeGoff. "Joe will drive new levels of customer engagement and revenue growth as we move into commercialising our LED technology."

Plessey has developed a process to produce high-brightness LEDs at what is reckoned to be a fraction of the current cost. Its GaN-on-silicon LEDs are produced using standard silicon-based semiconductor manufacturing processes, in contrast with existing generations of LEDs that use expensive sapphire and other materials.

The firm's aim is to drive global uptake of its patented MAGIC (Manufactured on GaN-on-silicon I/C) technology as a cost-effective alternative to existing lighting systems, and expand its UK manufacturing facilities in Plymouth.

"Plessey is one of UK's leading technology brands and I believe it is years ahead of the industry with its proprietary GaN on silicon process technology," comments Lopez. "Plessey's LEDs offer performance comparable to that of sapphire, but at a substantially lower cost."

He adds, "This makes the Plessey LEDs ideal for high-volume, cost-sensitive applications such as linear fluorescent tube replacement, indoor commercial and retro-fit bulb markets that characterize the high-growth general lighting segment."

Lopez has a degree in Computer Science and a PhD in Computer Engineering from the University of Sussex and an MBA from the Open Business School. He has lived and worked in the UK, Germany, France and Spain and speaks a number of European languages.

Scotland energises Commonwealth Games with LEDs

One of the key changes is to lead up to the Opening Ceremony in Glasgow is to install 10,000 new LED light bulbs across the city. This is aimed to ensuring they will win the gold for energy-efficiency throughout the games

The Commonwealth Games will take place this year in the Scottish city of Glasgow, and final preparations are underway to welcome the world's sportsmen and women, as well as swathes of tourists and masses of press and media personnel to town.

BLT Direct is thrilled that another one of UK's leading cities will be adopting the efficient technology and taking the leap into a world of lower energy bills and reduced emissions.

Steven Ellwood, Managing Director, says of the move, "It is fantastic to see another city taking a step towards energy-efficiency, especially with such an important event coming up. From what we know, Glasgow's inception of the LED light fittings has been exemplary, and many cities across Britain hoping to make the same switch in the future will have a great model to learn from."

By summer 2014, when the games are set to commence, Glasgow will shine with the crisp white light of 10,000 LEDs and CFLs, dramatically cutting bills across the board. Energy bills will be greatly reduced, and not only that, maintenance teams will not need to carry out bulb replacement nearly as often, allowing them to channel funds into other areas of the city.

Glasgow are also pioneering a unique scheme for their lights, equipping them with digital sensors that will allow them to be controlled remotely and respond to changes in their environment. Increase in traffic or a decrease in pedestrians in a certain area will cause the bulbs to react accordingly, sending their efficiency rating skyrocketing. It is expected that the intelligent controls will push the lighting solutions' efficiency from around 50 percent to more than 70 percent, as stated by an independent commission.

With the city pouring money into energy-efficiency, the focus turns to other cities around the country that are yet to adopt such cost-effective methods.

Major hubs of business, tourism and commerce, as well as large residential towns and cities, are investing in LEDs and CFLs for the future, and watching as their costs and bills tumble. Manchester, Bath, Bristol, Llandough, South Gloucestershire, Edinburgh, and areas

of the capital have already seen the light, as it were; which city will be next?

Boosting efficiency of green-blue-ultraviolet LEDs

Growing III-nitride based quantum wells could enhance solid state lighting, low threshold lasers and high power LEDs

Scientists at the U.S. Naval Research Laboratory (NRL) have suggested a method that could significantly increase the efficiency of green-blue-ultraviolet LEDs based on GaInN/GaN, AlGaN/GaN, and AlInN/GaN quantum wells.

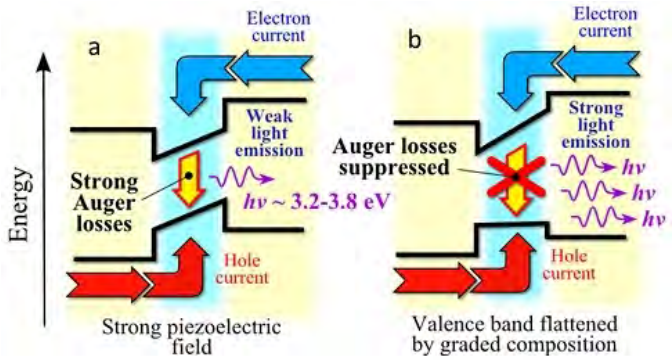
Their approach could enable advances in solid state lighting and the creation of low threshold lasers and high power LEDs. Their research is published in the January 25th and November 26th, 2013 issues of *Applied Physics Letters*.

Epitaxial perfection in the growth of quantum wells has been the key to achieving light emitting and laser diodes of superior power, efficiency, and performance. Ternary group-III nitrides LEDs based on GaInN/GaN, AlGaN/GaN, and AlInN/GaN quantum wells now find widespread application in energy-efficient as well as decorative solid-state lighting.

But their use in high-power lighting applications is currently hindered by a significant loss in efficiency even at modest electrical currents. Indeed, the quantum efficiency of the LEDs peaks at relatively low currents-a few tens of amperes per square centimetre-and then steadily drops, by almost half, as the current increases. This "droop" in the efficiency is observed in the visible, blue, as well as ultraviolet spectral regions.

Scientists at NRL's Centre for Computational Materials Science, in collaboration with researchers at the Technion, Israel, and Ioffe Physical-Technical Institute, Russia, have created computational models showing that the observed droop effect arises from non-radiative Auger recombination of the injected carriers.

The rate of the Auger recombination is proportional to the cube of the carrier concentration. As a result, the non-radiative Auger decay rate grows rapidly with current density, quenching the generation of light.



This a schematic description of processes responsible for LED operation. The thick black lines show the energy band diagram of the conventional (a) and proposed (b) LEDs based on GaN/AlN QWs. In the conventional GaN/AlN QW LEDs the polarisation field in the GaN layer enhances strongly the rate of the nonradiative Auger processes leading to reduction of the photoluminescence quantum yield and, consequently, to the "droop" effect with increase of the electrical current. In the proposed LEDs (b) the electric field acting on holes in the QW is compensated by a gradual composition variation of the variable-gap GaAlN alloy resulting in a flat valence band potential. The Auger processes in these QWs are completely suppressed and no droop effect is expected to be seen in such LEDs (Photo: U.S. Naval Research Laboratory)

To suppress these non-radiative Auger processes one needs to create quantum wells with a soft confinement potential. Alexander Efros, a senior researcher in NRL's Materials Science and Technology Division, previously showed theoretically that a softened electrostatic potential prevents carriers from acquiring the momentum necessary for non-radiative Auger processes, and thus suppresses the Auger decay rate.

This concept was patented by NRL in March 2013.

The latest calculations by the NRL-Technion-Ioffe research team demonstrate that softening the confinement potential-by varying the alloy composition along the growth direction-also completely suppresses the piezoelectric field that normally enhances non-radiative Auger processes in GaN/AlN QWs. The calculations show that the droop effect in such quantum wells can be significantly or even completely suppressed.

In addition to Efros at NRL, the members of the research team include Roman Vaxenburg and Efrat Lifshitz from the Israel Institute of Technology, Haifa, Israel, and Anna Rodina from the Ioffe Physical-Technical Institute, St. Petersburg, Russia.

Bridgelux takes ex Micron executive on as CTO

Cem Basceri will serve as CTO and oversee the LED technology and product development programs at Bridgelux

Bridgelux, the manufacturer of LED lighting technologies and solutions, has taken on semiconductor industry veteran Cem Basceri to its Executive Staff.

Prior to his CTO position, Basceri held a seat on the company's Advisory Board. His charter will be to propel innovation, provide technology vision, drive technology differentiation and strategic technology investments, and increase intellectual property (IP) development.

He will fuel core technology programs, thrust forward fast-cycle product creation; delivering efficient, high performance and cost effective product solutions for customers. In doing so, he hopes to help the company increase its technology leadership and expansion into new markets.

Basceri will also be responsible for driving Bridgelux's fabrication partnership with Toshiba and additional joint technology development activities related to this critical partnership around GaN on silicon technology optimised for solid-state-lighting applications.

"Basceri's recruitment to the company further re-enforces both Bridgelux's strategy and leadership in the convergence of LED and semiconductor technologies," notes Bridgelux's chief executive officer, Brad Bullington.

He continues, "Our next generation SSL solutions will leverage GaN on silicon and high scale, chip-centric packaging technology to drive dramatic cost down while delivering improvements in features and functionality to our products. Basceri is well known in the industry as a pioneer of next generation LED's, and we look forward to aggressively driving our roadmap forward under his leadership."

Basceri has a broad and distinguished career. Prior to joining Bridgelux, he served as Senior Director and Chief Technologist in Corporate Development and Corporate R&D at Micron Technology, Inc. for more than 10 years (Fortune 500, NASDAQ: MU, specialised in high performance memory, non-memory and energy efficient semiconductors, and integrated systems solutions).

During his time in Corporate R&D at Micron, he was responsible for establishing and mapping out technology, business and IP development strategies for existing and new market opportunities. Additionally, he managed and directed technology and product development teams, provided vision and guidance to the teams and organization.

As part of his responsibilities, he also managed Micron's Core Partnership Program at imec (Leuven, Belgium) for 8-inch GaN Power and LED technology development programs. Most recently, Basceri's responsibilities included strategic M&A, partnerships, investments, divestitures and technology licensing deals within Micron's Corporate Development organization.

He also served as the Chair of the Silicon & Systems Group's Advisory Board and business unit representative in Micron's TLP Global Technical Committee.

Previously he held management positions at Cree and Intrinsic Semiconductor where he led various wide band gap (WBG) technology development programs. Basceri earned his Ph.D. degree in Materials Science and Engineering from North Carolina State University.

Throughout his career, Basceri has sparked innovative technology and commercial product development programs. He has conceived and designed numerous technology innovations, evident by his 213 issued US patents.

Basceri has deep expertise in semiconductors and integrated solutions, including WBG technologies such as LED, SSL and Power/RF. He is viewed as an industry expert and luminary; he has published more than twenty-five technical articles in refereed journals and has been a notable speaker as part of numerous industry conferences and panels.

"Bridgelux has a legacy of technology innovation and leadership. Basceri is one of the brightest minds in LED and SSL with his unique technology and business skill set. He is an extremely valuable addition to our team," says Bullington. "Basceri will be Bridgelux's technology catalyst in driving innovation and high performance product solutions, and cementing Bridgelux's technology leadership. Through significant investments in its technology capabilities, Bridgelux will continue to increase its market share and expand into new markets."

Lumileds LUXEON Lime LEDs break 200 lm/W barrier

The III-nitride based Rebel ES Lime emitters enable efficient, tuneable white light

Lime, the newest addition to the LUXEON colour portfolio of LEDs from Philips Lumileds enables lighting designers to take the next step in delivering high quality, tuneable

white light in bulbs and fixtures.

LUXEON Rebel ES Lime is the proprietary LED technology in the Philips hue bulb, where it combines with LUXEON Rebel Red - Orange and Rebel Royal Blue emitters to deliver over sixteen million colour options - all controlled from an iOS device. Philips hue can use colour tuneable Light Recipes to help set mood and energy level in the home, office, retail, classroom and hospital environments .

“This really represents a new frontier in lighting, because LUXEON Rebel ES Lime emitters can be combined with other Rebel colour and white emitters to achieve higher CRI and R9 combinations than any previous generation emitters or arrays,” says Rahul Bammi, VP of Product Management

Lumileds claims Lime is the highest efficacy LUXEON LED manufactured to date. Therefore it enables highly efficient colour mixing by providing a convenient above - blackbody colour point with optimal standalone efficiency of 200 lm/W at 350 mA and 85 °C. The spectral output of Lime is closely aligned with the wavelength that human eye cones are most sensitive to, 555 nm.

“We are finding that all our customers are very interested in Lime due to the outstanding efficiency and flux it brings to every lighting application,” says Bammi .

In addition to LUXEON Rebel ES, the Lime technology is offered in the LUXEON Z format, an undomed, 2.2 mm LED that is 75 percent smaller than most high power LEDs. In spotlight and downlight applications, the LUXEON Z enables tighter packing density and better colour mixing control. The LUXEON Z Lime can be combined with Red and Blue LEDs to achieve a broad spectrum of saturated colours.

Alternatively, tuneable white light with high efficacy can be achieved from 1800 - 6500K along the blackbody curve. Because Lime is closer to the blackbody curve than green LEDs, much less inefficient red is needed to make white light with Lime instead of green, especially at warmer colour temperatures.

For instance, colour tuning of 2250 - 2950K can be achieved with an R9 greater than 90, CRI over 90 and efficacy of 90 lm/W using a LUXEON Z combination.

When using a similar combination of red, green and blue LEDs to create 3000K white light, the CRI is close to 20.

Soraa unveils first full visible spectrum LED AR111 lamps

The new AR111 lamp uses the firm’s patented GaN on GaN technology
Soraa, an innovator in GaN on GaN LED technology, will display its new AR111 lamp at Euroshop this month.

The lamp is the market’s first full-visible-spectrum LED AR111, and brings Soraa’s signature elements of light quality to the large lamp arena: vivid colours, unique whiteness rendering, and perfectly uniform beams casting sharp single shadows. To this, Soraa’s AR111 adds unmatched light intensity, creating the perfect lamp for retail lighting.

“Soraa’s lamp is a game-changer in the LED AR111 landscape. With it, we bring to the market an energy-efficient AR111 lamp of exceptionally high intensity and quality of light,” says Nick Farraway, Senior Vice President - International at Soraa. “This year, we will expand our portfolio beyond our award-winning MR16 GU5.3 and GU10 lamps to create a full line of four inch lamps powered by our GaN on GaN LED technology.”

This month, Soraa will display at EuroShop a full-visible-spectrum 8o AR111 LED lamp, with CRI of 95 and R9 of 95. Available in June, this lamp will have a peak luminous intensity of 27,500 Cd and light output of 980 lumens, the best in the market. Soraa will also offer 80 CRI AR111 lamps with a peak luminous intensity of 34,000 Cd, twice that of the nearest competitor.

The high lumen density of the GaN on GaN LED enables the single source, high luminous intensity, and superior beam control which characterize all of Soraa’s lamps. The violet light in Soraa’s full-visible-spectrum LED excites the Optical Brightening Agents present in many white products, so a brilliant white shirt shows brilliantly under Soraa light, but yellow and dull under any other LED.

Soraa’s AR111 lamp is dimmable, will be available in a wide range of colour temperatures and beam angles, works in fully enclosed fixtures, and conforms to the IEC/ANSI AR111 form factor, ensuring compatibility with a broad range of fixtures. The 8o AR111 lamp works with Soraa’s SNAP system, a set of easy-to-use magnetic beam spreaders and colour shifters that allows endless design and display possibilities.

Osram Sylvania and Lowe`s reveal light bulbs for Iris

The ULTRA iQ LED bulb is claimed to be the first with remote dimming capabilities designed for Lowe's Iris home management system

North American lighting designer Osram Sylvania has united with Lowe's to introduce SYLVANIA ULTRA iQ, as the first LED bulb designed to work with the Lowe's Iris home management system.

SYLVANIA ULTRA iQ LED bulbs are flood lights that work with Iris to eliminate the need for conventional wall dimmers by allowing consumers to control lighting and set lighting scenes wirelessly from anywhere in the world with access to the internet.

Now available on Lowes.com and in most Lowe's locations, SYLVANIA ULTRA iQ bulbs offer superior dimming quality and wireless dimming controls that are compatible with smartphones, tablets, and the Iris system. SYLVANIA ULTRA iQ bulbs are easy to use and are up to 80 percent more efficient than traditional lighting.

"With ULTRA iQ and Iris, consumers can now remotely control their lighting through smart devices while saving on electricity costs," says Ellen Sizemore, product portfolio manager LED lamps, Osram Sylvania. "These light bulbs are long lasting, energy saving options designed to easily integrate with the smart homes of today."

SYLVANIA ULTRA iQ bulbs have a rated bulb life of 35,000 hours, which reduces maintenance and bulb replacement costs. In a typical home, with lights in use three hours a day, that 35,000 hours translates to nearly 32 years.

Using only 11 W, SYLVANIA ULTRA iQ LED bulbs are replacements for 65 W incandescent bulbs and feature integrated-wireless dimming control within the bulb. These ULTRA iQ bulbs are designed for optimum use in kitchens, family rooms, bedrooms, hallways and hard to reach areas in the home. The products contain no mercury, lead or other hazardous materials.

Iris, Lowe's exclusive smart home solution, allows consumers to monitor and control virtually everything in the home anytime, anywhere. Iris offers consumers the ability to lock or unlock doors, change thermostats, turn on and off lights, set security alarms, monitor smoke and water detectors, and more - all from a single app controlled from a smartphone, tablet, or computer.

Iris is easy to set up; do-it-yourself installation typically takes approximately one hour. Retail prices start at $179, with free basic service.

Lowe's Companies, Inc. serves approximately fifteen million customers a week at more than 1,825 home improvement and hardware stores in the United States, Canada and Mexico.

Momentive extends manufacturing capacity of TaC

The expansion will help to enable next generation SiC epi tools and provide improved dimensional control for current GaN tools

Momentive Performance Materials Quartz Inc. (MPM) has increased and expanded its manufacturing capacity of tantalum carbide coatings (TaC) in response to the larger demand for SiC power devices and increased need for improved dimensional control for GaN LEDs.

With the expansion, MPM has the capability to produce up to 750 mm diameter parts, versus the 500 mm previous limitation. The diameter increase can help enable next generation SiC epi tools and can provide improved dimensional control for the current GaN tools now using alternate protective coatings.

MPM's TaC is manufactured using a proprietary coating process, which yields excellent resistance to hot hydrogen during epitaxial processes. SiC coatings can start to decompose at 1200 to 1400oC, whereas TaC generally is stable to over 2000oC.

Additionally, the coatings can provide exceptional dimensional control and, therefore, a uniform and conformal coating, even on wafer pockets and complex shapes. TaC coatings are used in MOCVD tools for the production of GaN and SiC devices.

Seoul Semi, LEDLab and UC Davis unite in luminaire design competition

The gallium nitride based LED modules will use Seoul Semiconductor's Acrich2 AC-LED module

Students enrolled in 'Designing with Light' at the University of California Davis (UC Davis) this semester will be competing in the 10th Annual Luminaire Design

Competition this spring.

The students must create original luminaire prototypes for outdoor pathways using an energy-efficient LED module manufactured by LEDLab using Seoul Semiconductor's Acrich2 AC-LED module.

This year marks the 10th Annual Luminaire Design Competition for students enrolled in Designing with Light (DES 136 B) at the University of California, Davis.

UC Davis CLTC 'Designing with Light' class

The competition gives students the opportunity to work with state-of-the-art lighting technologies and to share their designs with professionals in the lighting industry.

Led by Michael Siminovitch, the course is a ten week design challenge. This year, students must create original luminaire prototypes for outdoor pathways. Each student is provided an energy-efficient LED module manufactured by LEDLab using Seoul Semiconductor LEDs and components and packaged into a ready-to-use product distributed by Seoul Semiconductor.

On March 13th, as students present their final class projects, they will also be participating in the competition, presented by the California Lighting Technology Center (CLTC) at UC Davis. Guest judges, including representatives from Seoul Semiconductor and LEDLab, will help to select the winners.

"We are excited to sponsor this year's class and to be inspired by the young minds working on this intriguing outdoor LED project," says Seoul Semiconductor North America Marketing Representative Megan Silkman.

In June the top two students to place in the competition will bring their winning designs to LightFair International, the industry's largest annual lighting conference and trade show. The students' expenses will be covered by Seoul Semiconductor.

At LightFair 2014 the students will have the opportunity to present their luminaires in a special section of the Seoul Semiconductor booth, giving them valuable opportunities to meet industry experts and explore job opportunities. The winners of past years' competitions embarked on careers in architecture, lighting design, and other design fields, many finding positions immediately after graduation.

Seoul Semiconductor's Acrich2 AC-LED modules can be easily connected directly to AC line power with no driver or ballast, and they are available in a variety of form factors and light output levels. LEDLab designed this custom Acrich2 module to be integrated into energy-efficient lighting projects.

The modules' compact design allows them to be used in areas with space constraints and enables cost-effective installation, as the modules can fit in a standard electrical J-Box. A unique cooling system extends the life of the modules for maintenance-free lighting that lasts for more than 60,000 hours.

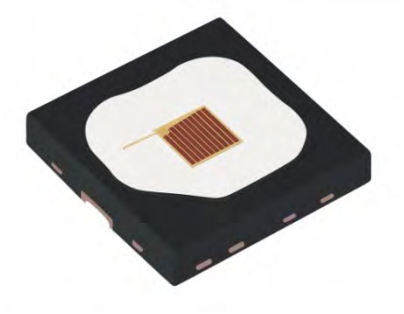
Osram reinvigorates rear lighting

The Oslon Black Flat LED family covers indicators, taillights and brake lights

The latest addition to the Osram Oslon family emits yellow light and various red tones and is exceptionally bright.

Specially designed for light guide applications, these LEDs can also be used for more complex solutions in the rear lighting for vehicles.

A single type of LED, the new Oslon Black Flat, can now be used to create complex taillights.



Oslan Black Flat

The different brightness requirements for the various functions are simply met by a variable number of LEDs and different current levels.

While small LED types are typically sufficient for standard taillights, the Oslon Black Flat opens up new solutions thanks to a possible current draw of up to 1000 milliamps (mA).

A peak brightness level of 66 lumen (lm) at 350 milliamps (mA) is achieved by the amber version at a wavelength of 617 nanometers (nm). White encapsulation, combined with state-of-the-art thin-film chip technology, ensures that the light from these LEDs is extracted very efficiently.

The new yellow and red tones extend this family of robust LEDs which are renowned for their high light output and which also includes converted yellow and white versions. With no lens in the way, the light from this new version can be injected into light guides from very close range and therefore with extremely low losses.

Osram Flat product in a car

Designers therefore have enormous freedom, allowing them to create large unmistakable rear lighting solutions for top-of-the-range models. The new Oslon Black Flat can also be used however to create compact taillights for city cars and electric vehicles, and cost-effective taillights for the compact class. This is thanks to high efficiency at moderate current levels and to high light output at high current levels.

The low thermal resistance of 4 kelvin/watt (K/W) for red (electric) is due to the special optimized package. One of the benefits of this package is the high luminous flux at high temperatures. Since the thermal coefficient of expansion of the copper-based black QFN package (Quad Flat No Leads) is matched to the coefficient of expansion of the pc boards, Oslon Black Flat LEDs are particularly stable through the temperature cycles on these boards and therefore have a long life.

The LEDs are additions to the portfolio of rear automotive lighting from Osram Opto Semiconductors, which includes Golden Dragon, Oslon Black with lens, Power TopLED and Advanced Power TopLED.

Soraa brings sunshine indoors

The firm has launched new high colour temperature, full visible spectrum Vivid 2 MR16 LED lamps using GaN-on-GaN technology

Soraa has launched the world's first high colour temperature (CCT), high colour rendering MR16 LED lamps - a brilliant choice for gemstone jewellery and high-end retail displays.

Soraa Vivid 2 lamps

The new 4000K and 5000K CCT, full visible spectrum Soraa Vivid 2 LED MR16 renders colours and whites exactly as they would appear in natural light; without the high heat/UV emissions associated with CMH/halogen lamps and beam striations, artefacts or multiple shadows visible in other manufacturer's LED products.

"With Soraa's LED lamps, you can create a perfectly lit - yet energy efficient - space. Our full spectrum technology renders colours vividly and whites accurately; our single source LED and innovative optics create perfectly uniform beams of exceptionally high intensity light, casting clear single shadows; and our lamps are ideally suited for fully enclosed, non-ventilated fixtures - a place where other LED lamps struggle to perform," says Jeff Parker, CEO of Soraa. "And now with our 4000K and 5000K products, you can bring the energizing feel of natural light indoors without sacrificing light quality and compatibility."

In certain environments, higher correlated colour temperature light is preferred because it helps create an engaging and energising environment. However, because of their broken spectra, LED and CMH lighting products of 4,000K and 5,000K CCT create spaces that feel unnatural and cold.

The Soraa Vivid 2 MR16 solves this trade-off by representing every visible colour in the right proportion, resulting in scenes that feel energizing, yet warm and natural. The full visible spectrum emission of these LEDs results in a CRI of 95 and R9 greater than 90. Plus, the violet component of the spectrum makes whites stand out in their natural brightness and tint.

Soraa's LED lamps are available in 12V and line voltage configurations, as well as in a wide range of colour temperatures (2700K, 3000K, 4000K, and 5000K) and beam angles (10°, 25°, 36°, and 60°), allowing lighting flexibility for any type of indoor or outdoor environment.

This includes lighting suitable for smooth and textured fabrics, gold, diamonds, skin tones, and a broad array of other applications. The company's narrow 10° lamp works with its award-winning magnetic accessory SNAP System. With a simple magnetic attachment, beam shapes and colour temperature can be modified, allowing endless design and display possibilities.

Soraa's LED lamps are compatible with a very wide range of dimmers, having been tested and characterized extensively through its Works with Soraa program. And the company's novel heatsink design and thermal management system allows its lamps to run cool and deliver efficient light intensity over a long period of time.

Toshiba launches family of transistor output photocouplers

The devices significantly help to reduce power consumption for industrial devices such as LEDs

Toshiba America Electronic Components, Inc., (TAEC) has introduced a new family of low input current-type transistor output photocouplers that offer a high CTR (Current Transfer Ratio) at low input current.

The TLP182, TLP183, TLP292, and TLP293 significantly contribute to a reduction in power consumption by reducing the LED current of the photocoupler.

Available in both SO4 (TLP292 and TLP293) and 4-pin SO6 (TLP182 and TLP183) packages, by employing Toshiba's original high-output LED, these products provide not only a high current transfer ratio at the conventional input current of 5mA, but also at the same current transfer ratio at the low LED current of 0.5mA.

This makes it possible to minimize the current to the LED and therefore reduce power consumption.

The TLP182, TLP183, TLP292, and TLP293 also support operation at up to an ambient temperature of 125 degrees C, making them ideal for use in industrial devices such as PLCs and inverters, compact power supplies, AC line detection for household appliances, and other devices operating in extremely hot environments.

The devices come in a smaller, thinner package produced in high efficiency production lines (SO6 and SO4) and have a high CTR at low input current of 0.5mA.

Proper operation is at ambient temperatures up to 1250C

Characteristics		TLP182	TLP183	TLP292	TLP293
Package		4-pin SO6		SO4	
Input type		AC	DC	AC	DC
Current transfer ratio (%)	@I_F=5mA, V_{CE}=5V	50 to 600	50 to 600	50 to 600	50 to 600
	@I_F=0.5mA, V_{CE}=5V	50 to 600	50 to 600	50 to 600	50 to 600
Topr (degrees C)		-55 to 125	-55 to 125	-55 to 125	-55 to 125
BVs (Vrms)		3750	3750	3750	3750

The new photocouplers are available now.

EpiGaN honoured for revenue and growth

The company has been recognised by Trends Magazine for its progress in gallium nitride on silicon technology

EpiGaN, a provider of III-nitride epitaxial material solutions, was awarded the 'Trends Gazelle Starter 2014 'in the Province of Limburg by Trends Magazine.

The annual award recognises EpiGaN to have fostered positive momentum in revenue and employee growth in a three year time span.

"EpiGaN has experienced positive revenue and cash flow since its inception in 2010," says Marianne Germain, co-founder and CEO of EpiGaN.

She continues, "We are honoured by this award to be recognised by Trends Magazine for our stellar growth over the past few years. It is the dedication of our team that has enabled us to maintain consistent growth by shipping products to customers worldwide from our facility in Hasselt."

The company now has ten employees and is planning to grow the organisation further in 2014 to support its manufacturing expansion.

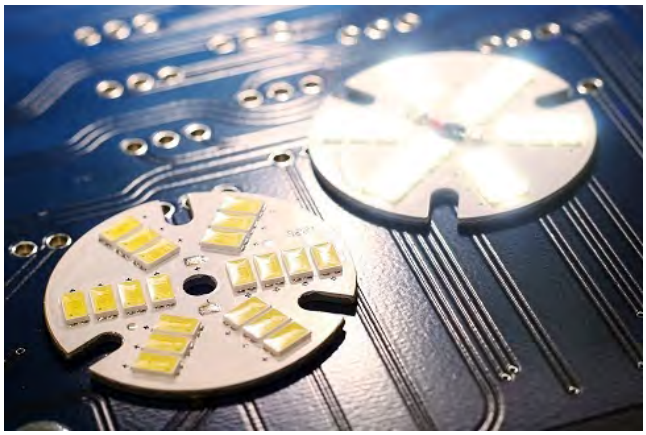
EpiGaN has a strong technical foundation with leading-edge semiconductor material products. Its GaN - on -silicon wafers are being used to create high voltage power and high frequency RF devices that in turn are being used to save energy in consumer electronics, industrial power supplies, AC drives, cellular base stations, cable TV infrastructure and other things.

The company has its cleanroom manufacturing facilities locally in Hasselt, Belgium located in the triangle Aachen, Eindhoven and Leuven . EpiGaN is one of the few Flemish companies that does not outsource manufacturing of high tech products, making it a valuable contributor to the local economy.

Lumex high voltage LED offers high output at low cost

The firm's latest TitanBrite product provides up to 20 percent cost and 50 percent in real estate savings

Lumex is announcing the global launch of its TitanBrite high-voltage, low-current LED, the newest addition to the TitanBrite family of high-power LEDs.



Lumex TitanBrite 25W LED

The TitanBrite high-voltage, low-current LED can run at a higher voltage with a lower current than alternative technologies (such as a traditional10W LED) while providing up to 45 percent brighter light output and superior light distribution.

This allows for up to 20 percent cost and 50 percent real estate savings for applications requiring low current, but high light output.

Though high-voltage, low-current LEDs provide key performance benefits for applications that use LED drivers that offer higher voltages to drive a high-power LED, few design engineers are aware that these technologies are available and can produce the comparable if not brighter light output.

TitanBrite High-Voltage, Low-Current LEDs are a good option for lighting and fixture designers for a number of applications across a wide range of industries including:

- *Industrial: Inspection lighting; anywhere you use high voltage application, such as automated visual inspection, backlight sorting machines, and warning lights*
- *Medical: Spotlighting, backlighting (for x-rays), operating lighting*
- *Commercial: Backlighting for electronic signage (large illuminated ads at train stations, airport terminals and fast food restaurants), machine lighting, production lighting*

• *General: Lighting fixtures (parking garages), light arrays, spotlights*

Simplified Heat Dissipation = Real Estate & Cost Savings

Because a high-voltage LED (33 volts and up) runs at a lower current, it doesn't conduct as much heat, simplifying heat dissipation design considerations and ensuring less energy loss in heat generation and control.

The need for bulky heat sync elements is eliminated as the high-voltage LED has a built-in metal core PCB and doesn´t require additional heat sync components. This results in real estate savings of up to 50 percent as well as up to 20 percent cost savings.

Power Conservation & Safety

The current level of an LED is a primary concern because power must be conserved, particularly for power-intensive applications. A low-current unit is also less hazardous than a high current one

Visual Performance

Light Distribution

This low-current LED design also offers greater light distribution than traditional standard LEDs that provide light in concentrated area or "hot spot". A cluster of LEDs offer a viewing angle of 120˚, eliminating hot spot issues.

Brightness

The TitanBrite High-Voltage, Low-Current LED also offers up to 45 percent brighter light output than a traditional 10W LED. With almost double the amount of light in a single unit, the cluster array of LEDs are placed in a unique pattern, that allows the design to achieve this output.

Lumex´s new TitanBrite LED measure 38mm in diameter and feature a 120° viewing angle. They are available in standard cool and warm white as well as custom colours. The technology is competitively priced at $10 to $15 per unit in production volumes, with lead times of ten to twelve weeks.

Osram simplifies LED upgrade for interior lighting

Nearly all surfaces in a car can be individually illuminated with the III-nitride LED modules. All products are wireless, feature four dimming levels and light up in red, blue, green, orange, pink, turquoise or white sram is now providing what it says is the simplest upgrade solution for vehicle interior lighting on the market with LEDambient.

Three LED modules enable the individual lighting of various surfaces in the vehicle, and with seven colours.

Wallwasher and Spots enable individual lighting of various surfaces in the car

LEDambient modules are battery-operated, so that vehicle interiors can be retrofitted with ambient light without having to route cables. Mounting is carried out simply with a velcro strip or magnets. In addition, all modules feature four pre-set brightness levels and can be operated via remote control.

The portfolio consists of three different LED modules: the door entrance ledge lets door strips radiate in light, activating as soon as the car door is opened.

The door entrance ledge lets door strips radiate in light, activating as soon as the car door is opened

The so-called "wallwasher" bathes larger areas of the interior, for example vehicle pillars or the foot room, in the desired light, and the spot with its flexible light guide is ideal for accenting lines inside the vehicle, and also brings light to inaccessible, tight or intermediate spaces.

Support for sales

Osram supports dealers with special advertising material. A video is available that demonstrates to customers how simple it is to install the LEDambient modules, and also the light effects in the vehicle, as well as a special floor display.

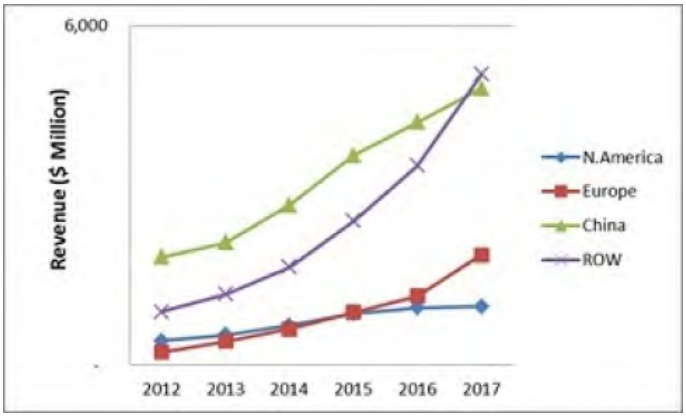
The display shows the complete range and offers information about the individual products. It links directly to the list of cars compatible with the door entrance ledge via QR code. This compatibility list is also made available to dealers by Osram as a printed flyer.

Super high power LEDs to be in 50 percent of lighting shipments

By 2017, revenues for LEDs in lighting applications are expected to reach a total value of $13 billion

According to "The Market for High-Brightness LEDs in Lighting Applications," report released by Strategies Unlimited, revenues for LEDs in lighting applications, which includes both replacement lamps and luminaires, are expected to have a CAGR of 30 percent and reach a total value of $13 billion by 2017.

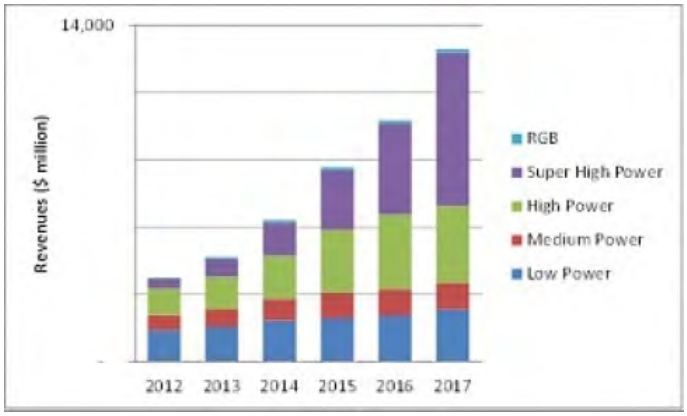
The chart below shows the market growth for LEDs in Lighting by major region.



HB-LEDs saw a precipitous fall in prices over the last several years, which helped reduce the price of LED lamps and luminaires, but this decrease in prices has been slowing down in recent times.

According to Philip Smallwood, Research Director of LEDs and Lighting at Strategies Unlimited, "ASPs of packaged LEDs are declining at a slower rate than previous years, as super high power LEDs increase in the market.

While prices for all LEDs are decreasing, the increased penetration of these SHP LEDs (which have a higher price) is raising the overall ASP for all packaged LEDs." The graph below represents the growing market share of Super High Power (>5W) LED packages in the coming years.



Efficacy improvements are continuing to take place in the market as well, with the average efficacy of commercially available LEDs for lighting applications increasing to greater than 100 lumens per Watt for 1W packages while multichip arrays reached efficacy of 200 lumens per Watt.

LED efficacy is no longer the gating factor for LED applications – cost is. Lighting Applications have seen a variety of different packages used over the last year, including arrays, high CRI, tighter colour bins, directional, multi-directional and high voltage LEDs.

Strategies Unlimited reports that the growth rate for LED package units and revenues are both expected to be in double digits for the forecast period. According to Smallwood, "While growth in the market can be attributed to improvements in the technology and decreases in its price, the largest penetration increases seem to be coming from government mandates that either restrict incumbent lighting technologies or push the usage of LEDs."

One of the largest impacts of these regulations will be seen in 2014 in the United States, as the implementation of the Energy and Independence Security Act of 2007 is phasing out 60 and 40W incandescent A-lamps.

Showa Denko boosts ammonia production capacity in China

The company is strengthening its supply of gases for LED semiconductor production

Showa Denko (SDK) has increased the production capacity for high-purity ammonia at its manufacturing subsidiary in Zhejiang Province, China, from 1,000 t/y to 2,000 t/y. The expanded facility started operation this month.

Zhejiang Quzhou Juhua Showa Electronic Chemical Materials Co., Ltd. Site

High-purity ammonia is used for nitride film deposition in the manufacturing processes of liquid crystal display (LCD) panels and LEDs. While LEDs are used for general lighting and backlight for LCDs, the LED market in China is growing for such new applications as landscape lighting and large screens, in addition to general lighting.

Thus, SDK has strengthened its supply system to meet the growing demand for high-purity ammonia in East Asia, where electronics production sites are integrated.

SDK is operating three high-purity ammonia plants, one each in Japan, Taiwan, and China. Following the capacity expansion in China, SDK now has a total high-purity ammonia production capacity of 6,000 tons a year.

SDK's high-purity ammonia production sites and their capacities, as of January 31st 2014 include:

1. Japan: SDK's Kawasaki Plant (Kawasaki City) 1,500 t/y
2. Taiwan: Taiwan Showa Chemicals Manufacturing Co., Ltd. (Tainan City) 2,500 t/y
3. China: Zhejiang Quzhou Juhua Showa Electronic Chemical Materials Co., Ltd. (Quzhou City, Zhejiang Province) 2,000 t/y

Under its consolidated business plan PEGASUS Phase II, SDK classifies the semiconductor-processing high-purity gas business as a "Growth" business. SDK will aim to further globalise the business this year, strengthening the production/distribution system in Asia and expanding sales.

Samsung touts COB LED packages with super high efficacy

The InGaN/GaN MQW LEDs with improved light efficacy will be available in the market next month and will be updated to have a CRI above 90 in the first half of the year

Samsung Electronics Co., Ltd., has said it has raised the light efficacy for its chip-on-board (COB) family of LED packages to the highest in the industry.

Samsung COB InGaN/GaN LC

The improved COB type LC series offers a light efficacy of 130lm/W at 3000K CCT (Correlated Colour Temperature) and 143lm/W at 5000K with a CRI (Colour Rendering Index) over 80.

This represents a significant improvement from 120lm/W at 3000K and 129lm/W at 5000K respectively, the light efficacy levels that Samsung has been offering with its LC series since April. Using its phosphor technology and chip fabrication techniques, Samsung developed the LC series enhancement to provide greater differentiated value to its customers.

Samsung's LC series is also Zhaga-compliant, making the packages highly convenient in assembling most LED lighting products. By enabling exceptional design efficiency for LED lighting, Samsung's latest LC series is expected to be applied in a wide range of interior LED lighting applications including downlights, spotlights and

directional retrofits such as MR/PAR lamps.

In addition, by leveraging the chromaticity control standard 3-step MacAdam ellipses, the LC series offer high colour uniformity and light quality. The packages also provide low thermal resistance and superior heat dissipation which enable high reliability, and have successfully completed LM-80 testing, a widely observed test method for lumen maintenance developed by the Illuminating Engineering Society.

The Samsung LC series has been available in 2700K, 3000K, 4000K and 5000K versions, with a 3500K version now added. Samsung's latest LC series also offers a diversity of wattages coming in 13W, 26W and 40W versions depending on the LED product with which the packages are used.

Cree redefines the troffer market

The firm says its new ZR series LED troffer delivers excellent light quality and aesthetics for under $100

Cree says it is redefining commercial lighting with the ZR series LED troffer.

The new troffers deliver a new category of performance, affordability and inspired design.

Featuring Cree TrueWhite Technology, the ZR Series LED troffer delivers superior colour quality (> 90 CRI) in an ultra slim, sleek package at an initial price starting from $99.

Cree ZR series troffer

The ZR Series LED troffer cuts energy consumption in half, and with standard 0-10V dimming can accelerate its already rapid two-year payback. This is based on energy consumption and payback calculated against a fluorescent three-lamp fixture (with lamp and ballast equal to 88 system watts) and based on typical commercial usage of 12 hours per day and $0.11 per kWh electric costs.

"It takes more than incremental improvements in performance to achieve widespread adoption of LED lighting. Cree innovation starts with a clean slate, designing a new troffer with an attractive appearance that provides superior light quality, high efficiency and also enables fast installation," says Norbert Hiller, Cree executive vice president, lighting.

"The ZR Series LED troffer is a winning alternative, offering uncompromised performance and an industry-leading 10-year limited warranty at a remarkably low price," continues Hiller.

The ZR Series LED troffer's thin 3.9" height and lightweight design enables faster installation without costly ceiling alterations. Offering a quick and easy one-for-one replacement of inefficient fluorescent troffers in education, healthcare and commercial building applications, the ZR Series LED troffer simplifies installation and significantly reduces labour costs during its 75,000-hour lifetime in all 1'x4', 2'x4' and 2'x2' configurations.

The Cree ZR series LED troffer is sold through Cree lighting sales channels throughout the U.S. and Canada.

Telecoms

Infinera introduces InP based multi-layer automation for transport

The combination of the Infinera DTN-X packet optical transport networking platform with new solutions hope to enable multi-layer automation of Intelligent Transport Networks

Infinera has launched new solutions for service providers planning to simplify the operation of multi-layer transport networks through increased automation.

Multi-layer transport networks blend the efficiency of digital switching with the scale of optical switching to create the communication foundation of cloud-based services and the Internet.

The solution includes one of the industry's first super-channel FlexROADM (reconfigurable optical add drop multiplexer), the first standards based multi-layer control plane for spectrum switched optical networks (SSON)

and the first 500 gigabit per second (Gb/s) flexible-grid super-channels.

“At Telefonica I+D we continuously explore innovative technologies to help create the communication services of the future,” says Juan Fernandez-Palacios at Telefonica I+D lab. “Our successful testing of the innovative FlexROADM helped shape the solution Infinera is announcing today. This is one example of how Telefonica I+D collaborates with technology innovators like Infinera to shape the next generation of optical networks.”

“Infinera continues to drive innovation in the optical communications industry,” continues Ron Kline, Principal Analyst at Ovum. “Adding super-channel FlexROADM capabilities to its unique photonic integrated circuit based architecture deepens the company’s differentiation. A unified control plane with multi-layer automation provides needed flexibility at a time when communications service providers really need it.”

Infinera claims these solutions for the Infinera Intelligent Transport Network make it easier for operators to automate the digital switching and the optical transport layers of their multi-terabit transport networks:

Infinera’s converged switching capabilities have been enhanced to feature a new, purpose-built super-channel FlexROADM. The FlexROADM is colourless, directionless and contention-less (CDC) and is available in C, CD, and CDC versions up to nine degrees.

When combined with the multi-terabit OTN switching of the DTN-X platform, service providers now have a converged multi-layer solution with digital grooming of client services and optical switching of efficiently filled super-channels.

Infinera’s standards based control plane now extends transport automation beyond super-channels to control the FlexROADM, which is compliant with the Internet Engineering Task Force’s (IETF) SSON framework.

The same standards based multi-layer control plane controls the digital OTN switching for point and click service establishment as well as the switching of flexible grid super-channels at the optical layer. This combination uniquely enables service providers to automate everything in the Intelligent Transport Network.

Flexible Grid Super-Channels for Efficient Long-Haul Transmission. Infinera’s third generation of 500 Gb/s super-channels takes full advantage of large scale photonic integrated circuit technology and the FlexCoherent Processor to deliver the industry’s first single-card long haul flexible grid super-channels. Infinera customers have deployed almost one petabit per second of Infinera’s first and second generation FlexCoherent super-channels since the introduction of the DTN-X platform in 2012.

“At Infinera we work closely with our customers to understand when and where to best introduce technology innovations that drive the most value,” says. David Welch, Infinera Co-Founder and President. “Through this collaboration, Infinera is the first to deliver multi-layer automation of transport networks to help our customers deliver services faster while simultaneously lowering operational costs.”

Oclaro ramps up production of InP 100G transceivers

The company is expanding its manufacturing and testing capacity for 100G CFP2 LR4 to reach 40km

Oclaro is increasing the production capacity for its dual-rate 100G CFP2 LR4 transceiver to respond to the fast market adoption of the smaller form factor.

With an approximately 50 percent smaller footprint and 30 percent lower power consumption when compared with the deployed 100G CFP LR4, CFP2 compatible line cards could double the port density and bandwidth of a high-end core router or optical transport system.

The Oclaro 100G CFP2 LR4 is designed to simplify work for network operators by collapsing multiple network layers while continuing to increase the available bandwidth. These new converged packet-optical networks require the most economical 100G client solutions to interconnect high-end routers to the optical infrastructure.

“It is exciting to see our customers adopt the CFP2 form factor and we are delighted to ramp its production after the ongoing success of our 100G CFP LR4,” says Yoshikazu Era, General Manager, Oclaro Japan Module Division. “Our solution is not only backward compatible with deployed CFP slots, but it also offers the flexibility of dual-rate operation to simplify our customers system and network design. Furthermore, our roadmap will not stop at CFP2 and we will continue to aggressively invest in laser, receiver and advanced packaging technology to further shrink the size and reduce power consumption of 100G client solutions.”

After Oclaro made the 100G CFP2 LR4 available to the market in 2013, several tier 1 customers re-designed their client interface line cards to accommodate the new form factor and expedited the product qualification. With most of the design slots reaching general availability

in 2014, Oclaro is now expanding its investment in manufacturing and testing capacity to stay ahead of the market demand.

Oclaro is offering a CFP2 that is fully-interoperable with existing CFP transceivers supporting both OTU-4 and 100GbE interfaces. The support of 'dual-rate operation' is critical to customers who demand the flexibility to use the product both in native Ethernet and OTN transport environments. The CFP2 dual-rate operation is made possible by leveraging the superior efficiency of the Oclaro InP Distributed Feedback laser (DFB) structure.

In addition, at OFC 2014, Oclaro is unveiling a disruptive technical solution to further expand the reach of CFP2 up to 40km. By eliminating the power-hungry Semiconductor Optical Amplifier (SOA) used in previous IEEE 100GBASE-ER4 products, power consumption can be drastically reduced to allow for the transition to a smaller form factor such as CFP2.

With the adoption of 100G from core networking into access, customers demand products that can reach beyond the LR4 10km standard.

At the show, Oclaro is demonstrating interoperability between 100G CFP2 and 25Gbps APD ROSA on a 40km transmission link.

Oclaro is planning to formally introduce this new extended reach APD-based CFP2 in 2H 2014.

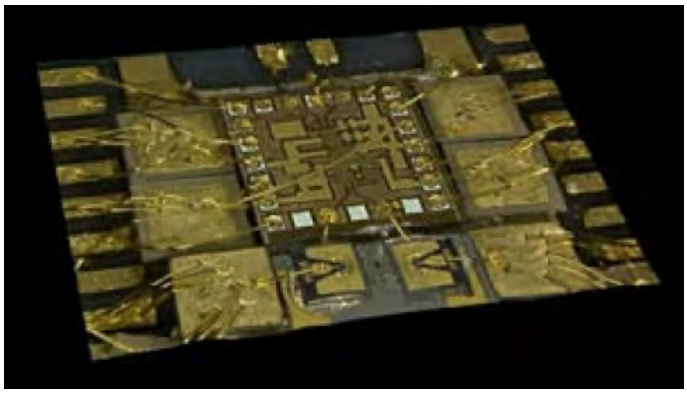
The CFP2 LR4 transceivers are fully qualified and now in volume production.

Data-transfer speeds reach new heights

SiGe and VCSELs combined could lead to a new era in short-range data transmission

Researchers at IBM have set a new record for data transmission over a multimode optical fibre, a type of cable that is typically used to connect nearby computers within a single building or on a campus. The achievement demonstrated that the standard, existing technology for sending data over short distances should be able to meet the growing needs of servers, data centers and supercomputers through the end of this decade, the researchers said.

Sending data at a rate of 64 gigabits per second (Gb/s) over a cable 57 meters long using aVCSEL, the researchers achieved a rate that was about 14 percent faster than the previous record and about 2.5 times faster than the capabilities of today's typical commercial technology.



In the foreground are 2 Chalmers VCSELs. The one on the left has a 6um aperture and could operate error free up to 62Gb/s while the one on the right has a 5um aperture and set the equipment limited record of 64Gb/s. Behind the two VCSELs is IBM's BiCMOS8HP VCSEL driver IC. On either side of the IC are the decoupling capacitors and connecting wirebonds. (Credit: IBM)

To send the data, the researchers used standard non-return-to-zero (NRZ) modulation. "Others have thought that this modulation wouldn't allow for transfer rates much faster than 32 Gb/s," notes researcher Dan Kuchta of the IBM T.J. Watson Research Centre in New York.

Many researchers thought that achieving higher transmission rates would require turning to more complex types of modulation, such as pulse-amplitude modulation-4 (PAM-4).

"What we're showing is that that's not the case at all," Kuchta continues. Because he and his colleagues achieved fast speeds even with NRZ modulation, he added, "this technology has at least one or two more generations of product life in it."

To achieve such high speeds, the researchers used the VCSELs developed at Chalmers University of Technology in Sweden and custom SiGe chips developed at IBM Research. "The receiver chip is a unique design that simultaneously achieves speeds and sensitivities well beyond today's commercial offerings," Kuchta explains. "The driver chip incorporates transmit equalisation, which widens the bandwidth of the optical link. While this method has been widely used in electrical communication, it hasn't yet caught on in optical communication," he says.

"Researchers typically rely on a rule of thumb that says the usable data-transfer rate is about 1.7 times the bandwidth," Kuchta explains. "That means that with the VCSEL laser, which has a bandwidth of about 26 GHz, the rate would be only about 44 Gb/s.What we're doing

with equalization is we're breaking the historical rule of thumb," Kuchta adds.

The fast speeds only worked for a distance of 57 metres, so this technology isn't designed for sending data across continents. Instead, it's most suitable for transmitting data within a building, he said. About 80 percent of the cables at data centres and most, if not all, of the cables used for typical supercomputers are less than 50 metres long.

This new technology, Kuchta says, is ready for commercialisation right now.

Can RFaxis` silicon FEM devices kick GaAs?

Yes it can, according to Frost & Sullivan. The market research firm says RFaxis' cost effective technology is helping wireless devices achieve performance and quality that is comparable to a wired network

Based on its recent analysis of the market for radio frequency front-end module (RF FEM) solution for wireless communication, Frost & Sullivan honoured RFaxis, Inc. with the '2014 North American Frost & Sullivan Award for Technology Innovation Leadership'.

RFaxis leveraged its single-chip/single-die RF Front-end Integrated Circuit (RFeIC) architecture to develop unique RF front-end solutions for wireless communications.

These innovative solutions, which combine superior performance capabilities with affordability, also prove to be ideal alternatives to conventional gallium arsenide (GaAs) solutions.

RF front-end solutions are traditionally built by embedding active and passive multiple components on a substrate using GaAs. The hybrid integration of passive and active compounds forms a multi-chip RF FEM, resulting in a large package size and bigger footprint on the printed circuit board (PCB).

However, with the semiconductor industry for wireless communication moving from bulky, multiple integrated chips to leaner, single chips, RFaxis' RFeIC solutions are gaining prominence for being highly integrated on a single silicon-based chip.

Frost & Sullivan's research indicates that RFaxis has succeeded in developing the world's first single-chip/single-die integrated circuit architecture based purely on standard complementary metal oxide semiconductor (CMOS) technology.

And the firm syas its quality and performance are comparable with GaAs-based RF front-end solutions, while its cost structure, thermal conductivity and ruggedness are far superior.

"Apart from reducing the time to design and market, RF front-end level of integration offers device manufacturers a very simple solution that can be implemented as a plug and play," says Frost & Sullivan Sr. Research Analyst Swapnadeep Nayak. "RFaxis' technology helps OEMs reduce their product development cycles to as low as a few weeks, while competing solutions take months. It satisfies every performance criterion set forth by component manufacturers and original equipment manufacturers (OEMs)."

F&S says that unlike CMOS, GaAs is a niche domain, which does not have adequate foundry capacity to meet the global demand from the semiconductor industry and OEMs. Migrating to CMOS technology lowers the strain on the supply chain, which helps device manufacturers cope with demands from the industry.

RFaxis' technology offers substantial price reduction in comparison to incumbent solutions. It also helps system-on-chip (SoC) vendors and OEMs integrate the company's solutions with other modules.

The comparison of all RF Front-end solutions shows that RFaxis is among the few participants that integrate the key RF front-end components of power amplifiers, low noise amplifiers, and switches into a CMOS SoC.

Such a high degree of integration has a direct bearing on RF front-end innovations for the wireless local area network (WLAN), long term evolution (LTE/4G), and Machine-To-Machine communications markets.

RFaxis' technology powers a wide range of application segments that use wireless communication as a key platform, the main ones being broadband (gateways, set-top boxes, video streaming applications), mobile devices (smartphones), and the Internet of things (IoT).

RFaxis is also looking at the smart TV and remote control segments to transform them from mere devices to gadgets that perform functions, such as music and video streaming.

"The wireless application ecosystem is evolving with the advent of Zigbee, 4G, near field communication, and the IoT, and RFaxis' technology helps OEMs ease into this transition by helping wireless communication devices perform faster," notes Nayak. "Frost & Sullivan's benchmarking shows that RFaxis is efficiently extending the range of wireless communication applications through its RFeIC solutions without increasing the form factor or cost."

Every year, Frost & Sullivan presents this award to the company that has demonstrated uniqueness in developing and leveraging new technologies, which significantly impacts both the functionality and the customer value of the new products and applications. The award lauds the high R&D spend towards innovation, its relevance to the industry, and the positive impact on brand perception.

Skyworks GaAs devices power major gaming platforms

Next generation consoles use the firm's FEMs, LNAs and analogue products

Skyworks Solutions says its front-end modules, low noise amplifiers, switches and power detectors are being utilised across the world's foremost gaming platforms such as the Sony PlayStation, Nintendo Wii and Microsoft Xbox.

Skyworks has been delivering RF solutions across nearly all gaming platforms for several generations.

"Skyworks is proud to be at the heart of all leading gaming platforms," says Liam K. Griffin, executive vice president and corporate general manager at Skyworks. "Our analogue and connectivity solutions are helping to create a truly unique user experience with social capabilities. This is yet another example of Skyworks' ability to capitalise on the unprecedented demand for wireless ubiquity across the Internet of Things, with online gaming platforms becoming an increasingly popular form of network access."

According to Gartner's "Forecast: Video Game Ecosystem, Worldwide 4Q13" report, the worldwide video game marketplace, which includes video game console hardware and software, online mobile and PC games, is forecasted to reach $111 billion by 2015, up from $79 billion in 2012. Sales of existing console hardware alone are forecast to grow from $15.9 billion in 2013 to $22.7 billion in 2015.

IDC Research also reports that the number of online console gamers around the globe is on pace to exceed 165 million by 2017. As a result, IDC states that the opportunity to sell these gamers digital assets through Wii U, Xbox One and PS4 online storefronts will grow substantially in the next several years.

Two of the devices are based on GaAs technology and include the following:

AS179-000 is a monolithic, single pole double throw switch (SPDT) fabricated using Skyworks' proprietary GaAs, pseudomorphic high electron mobility transistors as the switching elements.

AS179-92LF is an integrated circuit, GaAs field effect transistor SPDT switch in a low cost, miniature SC-70, six-lead plastic package.

SiGe chip sets new speed record

The silicon-germanium technology could be used in cold-temperature applications such as in outer space, where temperatures can be extremely low

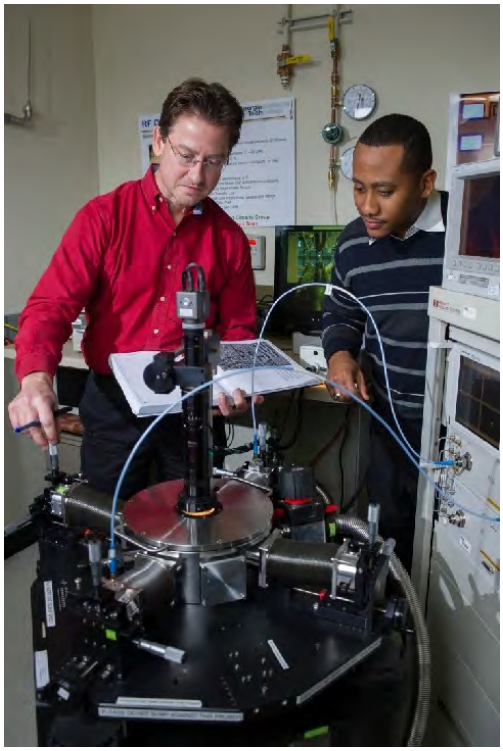
A research collaboration consisting of IHP-Innovations for High Performance Microelectronics in Germany and the Georgia Institute of Technology has demonstrated what it claims is the world's fastest silicon-based device to date. The investigators operated a silicon-germanium (SiGe) transistor at 798 gigahertz (GHz) fMAX, exceeding the previous speed record for SiGe chips by about 200 GHz.

High-speed SiGe chips and measurements probes can be seen inside a cryogenic probe station in the laboratory of John Cressler and co-workers at the Georgia Institute of Technology (Georgia Tech Photo: Rob Felt)

Although these operating speeds were achieved at extremely cold temperatures, the research suggests that record speeds at room temperature aren't far off, says John D. Cressler, a professor who led the research for Georgia Tech.

Information about the research was published in February 2014, by*IEEE Electron Device Letters*. "The transistor we tested was a conservative design, and the results indicate that there is significant potential to achieve similar speeds at room temperature - which would enable potentially world changing progress in high data rate wireless and wired communications, as well as signal processing, imaging, sensing and radar applications," says Cressler, who hold the Schlumberger Chair in electronics in the Georgia Tech School of Electrical and Computer Engineering.

He adds, "Moreover, I believe that these results also indicate that the goal of breaking the so called 'terahertz barrier' - meaning, achieving terahertz speeds in a robust and manufacturable SiGe transistor - is within reach." Cressler further says the tested transistor itself could be practical as is for certain cold-temperature applications. In particular, it could be used in its present form for demanding electronics applications in outer space, where temperatures can be extremely low.



John Cressler (left) and graduate student Adilson Cardoso work at a cryogenic probe station at Georgia Tech. (Georgia Tech Photo: Rob Felt)

IHP, a research centre funded by the German government, designed and fabricated the device, a heterojunction bipolar transistor (HBT) made from a nanoscale SiGe alloy embedded within a silicon transistor. Cressler and his Georgia Tech team, including graduate students Partha S. Chakraborty, Adilson Cordoso and Brian R. Wier, performed the exacting work of analysing, testing and evaluating the novel transistor.

"The record low temperature results show the potential for further increasing the transistor speed toward terahertz (THz) at room temperature. This could help enable applications of silicon-based technologies in areas in which compound semiconductor technologies are dominant today. At IHP, B. Heinemann, H. Rücker, and A. Fox supported by the whole technology team working to develop the next THz transistor generation," according to Bernd Tillack, who is leading the technology department at IHP in Frankfurt (Oder), Germany. Silicon, a material used in the manufacture of most modern microchips, is not competitive with other materials when it comes to the extremely high performance levels needed for certain types of emerging wireless and wired communications, signal processing, radar and other applications.

Certain highly specialised and costly materials - such as InP, GaAs and GaN - presently dominate these highly demanding application areas. But silicon-germanium changes this situation. In SiGe technology, small amounts of germanium are introduced into silicon wafers at the atomic scale during the standard manufacturing process, boosting performance substantially. The result is cutting-edge silicon germanium devices such as the IHP Microelectronics 800 GHz transistor. Such designs combine SiGe›s extremely high performance with silicon›s traditional advantages - low cost, high yield, smaller size and high levels of integration and manufacturability - making silicon with added germanium highly competitive with the other materials. Cressler and his team demonstrated the 800 GHz transistor speed at 4.3 Kelvins (-268oC). This transistor has a breakdown voltage of 1.7 V, a value which is adequate for most intended applications. The 800 GHz transistor was manufactured using IHP's 130 nm BiCMOS process, which has a cost advantage compared with today's highly-scaled CMOS technologies. This 130 nm SiGe BiCMOS process is offered by IHP in a multi-project wafer foundry service. The Georgia Tech team used liquid helium to achieve the extremely low cryogenic temperatures of 4.3 Kelvins in achieving the observed 798 GHz speeds. «When we tested the IHP 800 GHz transistor at room temperature during our evaluation, it operated at 417 GHz,» Cressler notes. «At that speed, it›s already faster than 98 percent of all the transistors

available right now.» This work is described in detail in the paper, «A 0.8 THz *fMAX* SiGe HBT Operating at 4.3 K" by P.S. Chakraborty *et al*in IEEE Electron Device Letters, 35 (2), p 151 - 153. DOI: 10.1109/LED.2013.2295214

Equipment for fibre optics set to rocket

The worldwide consumption value of fibre optic fusion splicers reached $467 million in 2013

ElectroniCast Consultants is releasing an extensive report covering the worldwide market for Fibre Optic Fusion Splicers. The report provides an analysis of 2013 and a 5-year forecast from 2014 to 2018 of the use of fibre optic fusion splice machines.

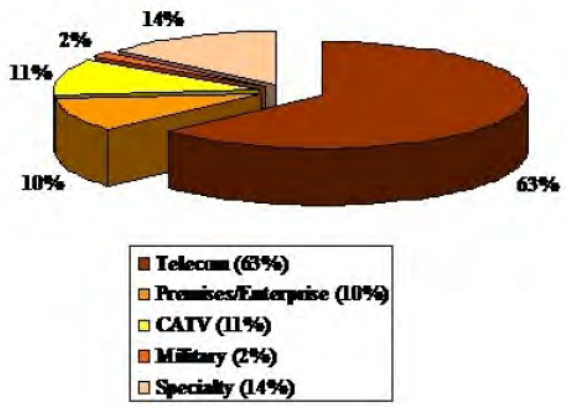
A Fusion Splicer is specialised instrument used to join optical fibres to each other.

The global consumption value of fibre optic fusion splice equipment in 2013 was $467 million. The consumption value is forecast to increase at nearly double-digit annual growth, with strongly rising quantity growth partially offset by a continuing decline of average prices. The market forecast data in the study report refers to consumption for a particular calendar year; so, this data is not cumulative data.

In 2013, the Asia Pacific region led in the consumption value of fibre optic fusion splicers. Helped along substantially by consumption in China, the Asia Pacific region is forecast increase in relative market share during the forecast period.

he North American region held the 2nd-place position, followed by the European region. Mexico is part of the North American market forecast, along with Canada and the United States.

The Rest of World regional segment covers the Middle East, Africa and Central/South America. The South America region, especially, is showing aggressive growth rates in terms of fibre optic fusion splice machine implementation.



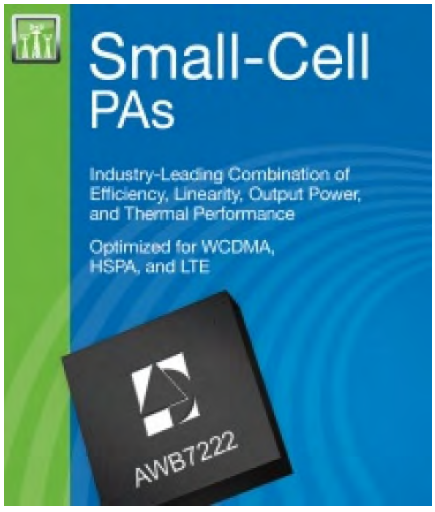
According to ElectroniCast, in 2013 Telecommunications represented 63 percent of the worldwide consumption of fibre optic fusion splicers. The use of fusion splicers in Specialty applications is forecast to increase at an average annual growth rate of 7.6 percent from 2013 to 2018.

The Fibre Optic Fusion Splicer Global Market Forecast & Analysis (February 2014) report is available immediately.

Anadigics announces small-cell InGaP power amplifier

The indium gallium phosphide expanded PA family can be used in picocells, enterprise-class femtocells and CPE devices

Anadigics has introduced the AWB7222 power amplifier (PA) optimised for WCDMA, HSPA, and LTE small-cell applications.



The AWB7222 operates in the 1805 MHz to 1880 MHz frequency band deliver a combination of excellent output

power, linearity, power-added efficiency and thermal characteristics.

This level of performance combined with exceptional integration enables manufacturers to develop compact wireless infrastructure solutions that consume less power and provide higher throughput with greater coverage.

"We continue to expand our small-cell power amplifier family with targeted solutions optimized for the most widely used 3G and 4G frequency bands," says Glenn Eswein, director of product marketing for Infrastructure Products at Anadigics.

He continues by noting, "As manufacturers develop small-cell products to help carriers address rapidly increasing wireless data consumption, Anadigics' power amplifiers stand out as critical enablers. Our small-cell product family delivers the highest output power, linearity, and efficiency in its class, enabling compact, high throughput devices that provide an economical path to expand broadband network coverage."

Anadigics' family of small-cell wireless infrastructure power amplifiers leverages the company's InGaP-Plus technology and innovative design architectures to deliver industry-leading performance and integration.

The AWB7222 offers +27 dBm linear output power for ¼-Watt small-cell applications, including picocells, enterprise-class femtocells, and high-performance customer premises equipment (CPE). With linearity of -47 dBc ACPR at +27 dBm output power and 31 dB of RF gain, the AWB7222 power amplifier enables higher data rates with a greater coverage area.

This power amplifier also provides 13 percent efficiency to minimise power consumption and offer greater flexibility in the choice of network power sources. The complete family of small-cell power amplifiers is available in a compact, low profile 7 mm x 7 mm x 1.3 mm surface mount package with integrated RF matching to reduce PCB space requirements.

Anadigics Small-Cell Wireless Infrastructure PA Family Key Facts and Highlights:

High linearity to support WCDMA, HSPA, and LTE small-cell base stations

Best-in-class efficiency for improved reliability and low-cost thermal design

Low noise, low distortion for very low spectral emission levels

Low transistor junction temperature for high long-term reliability

Integrated RF matching optimised for output power, efficiency, and linearity in a 50 Ω system

Optimised for ¼-Watt and ½-Watt linear output power to support a wide array of applications

¼-Watt Linear Small-Cell Infrastructure Amplifiers:

Product	Frequency Band	Output Power	Efficiency	Gain
AWB7124	728 to 768 MHz	+24.5 dBm	14.5%	30dB
AWB7125	860 to 894 MHz	+24.5 dBm	16%	30 dB
AWB7129	925 to 960 MHz	+24.5 dBm	16%	30 dB
AWB7122	1805 to 1880 MHz	+24.5 dBm	16%	30 dB
AWB7123	1930 to 1990 MHz	+24.5 dBm	17%	32 dB
AWB7127	2110 to 2170 MHz	+24.5 dBm	18%	32 dB
AWB7128	2545 to 2690 MHz	+24.5 dBm	16%	28 dB

½-Watt Linear Small-Cell Infrastructure Amplifiers:

Product	Frequency Band	Output Power	Efficiency	Gain
AWB7224	728 to 768 MHz	+27 dBm	13%	29 dB
AWB7225	860 to 894 MHz	+27 dBm	13.5%	29.5 dB
AWB7222	1805 to 1880 MHz	+27 dBm	13%	31 dB
AWB7223	1930 to 1995 MHz	+27 dBm	14%	29 dB
AWB7227	2110 to 2170 MHz	+27 dBm	14%	29 dB
AWB7228	2545 to 2690 MHz	+27 dBm	14%	27 dB

Pre-production samples of the AWB7222 are available now for qualified programs.

Firecomms unveils InGaN vertical transmitters and receivers

The firm has announced the availability of its full line of indium gallium nitride RedLink transmitters and receivers in vertical style packages

In response to customer demand for versatility in the RedLink connection styles, Firecomms is now offering the complete product family in both horizontal and vertical packaging options.

Firecomms RedLink fibre optic components are frequently installed in large industrial enclosures where final cable assembly can be difficult when the products are horizontally aligned with the internal PCB.

In order to provide flexibility for both the final installation on the factory floor and end user maintenance, Firecomms has expanded its RedLink product range to include vertically aligned transmitters and receivers.

“RedLink products are frequently found in large scale industrial equipment such as wind turbines, locomotive traction control units or grid tied converters,” says Hugh Hennessy, Firecomms Vice President of Sales and Marketing. “As manufacturers of these appliances appreciate any opportunity to reduce final assembly and maintenance cycle times, we are happy to respond to our customers’ demands for this greater flexibility by further enhancing our product offering.”

Drop-in compatible with the Versatile Link range of products, Firecomms RedLink product line extends the company’s well-known capabilities for high-speed POF transceivers and interface innovation into highly reliable industrial grade optical transmitters and receivers.

The RedLink product line includes DC-1 Mb, DC-5 Mb, DC-10 Mb, and DC-50 Mb transmitters and receivers, all rated at the extended industrial temperature range of -40°C to +85°C for use in even the harshest industrial environments.

All vertical RedLink devices are now available for sampling through Firecomms’ sales offices and distribution channels.

Digi-Key to distribute MACOM GaAs and GaN products

The global electronic components distributor will supply MACOM’s RF, microwave and millimetre-wave devices

Digi-Key Corporation will globally distribute M/A-COM Technology Solutions (MACOM) products globally.

MACOM offers a wide RF, microwave and millimetre-wave products. The company serves diverse markets, including satellite, radar, wired and wireless networks, CATV, automotive, industrial, medical, and mobile devices. MACOM designs and manufactures standard and custom devices, integrated circuits, components, modules, and sub-systems for its customers .

“Wireless technology is finding more and more inroads into our daily lives,” says Mark Zack, Vice President, Global Semiconductor product at Digi-Key. “As more and more designers look to implement wireless technologies into their products, MACOM’s robust, reliable product offering and long-standing technology legacy will improve Digi-Key’s ability to continue removing barriers to entry into the wireless space and provide tremendous value for our customers around the world.”

MACOM possesses a broad portfolio of over 3000 products, which include diodes, GaAs MMICs, silicon and GaN transistors, and components that enable next-generation internet and modern battlefield applications. These products cover frequencies ranging from DC to 110 GHz.

“This agreement aligns perfectly with MACOM’s renewed focus on our core catalogue products. Digi-Key is recognised by design engineers worldwide for its exceptional service, and this partnership will allow us to leverage their broad customer reach,” says Jack Kennedy, Vice President, Global Sales at MACOM. “Having Digi-Key as an authorized global distributor offers MACOM the opportunity to address our customers’ needs by rapidly getting product into their hands for critical design cycles, thereby enabling improved time to market.

Controlling photons with InGaN quantum dots

By emitting photons from an indium gallium nitride quantum dot at the top of a GaN micropyramid, researchers have created a polarised light source. The device can be used in applications such as energy-saving computer screens and wiretap-proof communications

Polarised light - where all the light waves oscillate on the same plane - forms the foundation for technology such as LCD displays in computers and TV sets, and advanced quantum encryption.

Normally, this is created by normal unpolarised light passing through a filter that blocks the unwanted light waves. At least half of the light emitted, and thereby an equal amount of energy, is lost in the process.

A better method is to emit light that is polarised right at the source. This can be achieved with quantum dots - crystals of semiconductive material so small that they produce quantum mechanical phenomena. But until now, they have only achieved polarisation that is either entirely too weak or hard to control.

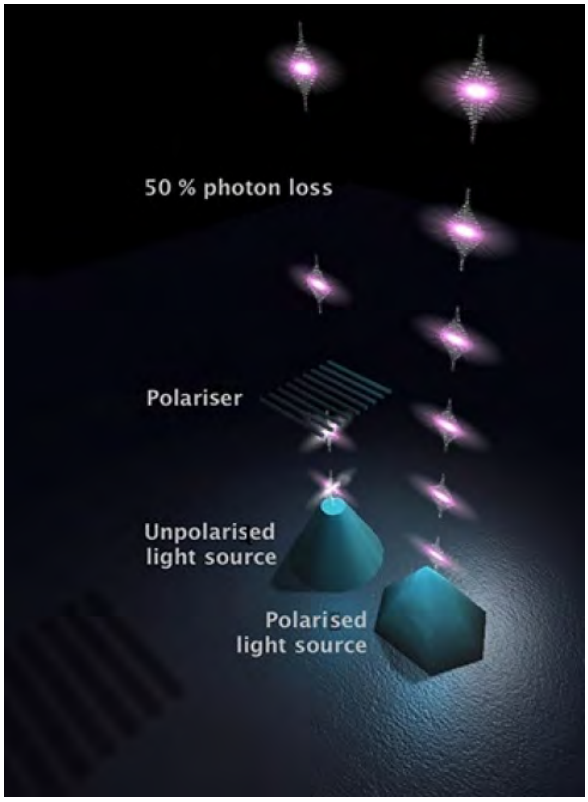
A semiconductive materials research group led by Per Olof Holtz, a professor at Linköping University, have now developed an alternative method.

The concept is based on InGaN QDs grown on top of elongated GaN hexagonal pyramids, by which the predefined elongation determines the polarisation vectors of the emitted photons from the QDs. This growth scheme should allow fabrication of ultra-compact arrays of photon emitters, with a controlled polarisation direction for each individual emitter.

With these, they have succeeded in creating light with a high degree of linear polarisation, on average 84 percent. The results are being published in the *Nature* periodical *Light: Science & Applications*.

"We're demonstrating a new way to generate polarised light directly, with a predetermined polarisation vector and with a degree of polarisation substantially higher than with the methods previously launched," Holtz says.

In experiments, quantum dots were used that emit violet light with a wavelength of 415 nm, but the photons can in principle take on any colour at all within the visible spectrum by varying the indium content.



Two ways of creating polarised light (Credit: Fredrik Karlsson, LiU)

"Our theoretical calculations point to the fact that an increased amount of indium in the quantum dots further improves the degree of polarisation," says reader Fredrik Karlsson, one of the authors of the article.

The micropyramid is constructed through crystalline growth, atom layer by atom layer, of the semiconductive material GaN. A couple of nanothin layers where the metal indium is also included are laid on top of this. From the asymmetrical quantum dot thus formed at the top, light particles are emitted with a well-defined wavelength.

The results of the research are opening up possibilities, for example for more energy-effective polarised LEDs in the light source for LCD screens. As the quantum dots can also emit one photon at a time, this is very promising technology for quantum encryption, a growing technology for wiretap-proof communications.

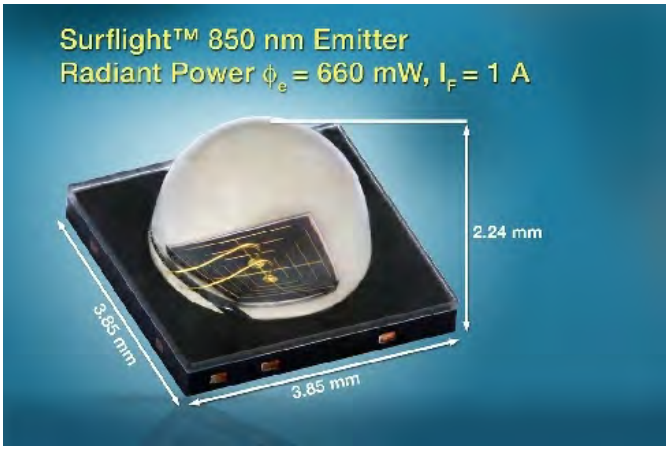
The work is described in detail in the article, "Direct generation of linearly polarised photon emission with designated orientations from site-controlled InGaN quantum dots," by A. Lundskog *et al* in*Science & Applications* (2014) 3, e139, published online on 31st January 2014. doi:10.1038/lsa.2014.20

The project has been conducted within Nano-N consortium funded by the Swedish Foundation for Strategic Research.

Vishay launches 850 nm IR GaAs based IR emitter

The gallium arsenide device features radiant intensity to 350 mW/sr at 1 A, optical power to 660 mW, and thermal resistivity down to 10 K/W

Vishay Intertechnology has broadened its optoelectronics portfolio with the release of a new 850 nm infrared (IR) emitter in a compact 3.85 mm by 3.85 mm by 2.24 mm top-view SMD package.



Based on SurfLight surface emitter chip technology and featuring an integrated lens, the VSMY98545 offers high drive current capability, high radiant intensity, and high optical power while providing low thermal resistivity.

The VSMY98545 features a 42 mm by 42 mm emitter chip, which supports a low thermal resistance of 10 K/W junction-to-pin, and enables high drive currents up to 1 A and pulses up to 5 A.

The emitter's integrated lens supports a +/- 45° angle of half intensity, resulting in ultra-high radiant intensity of 350 mW/sr at 1 A and 1600 mW/sr at 5 A (pulses). This is more than double the radiant intensity of devices without lenses.

With its extremely high drive current capabilities and optical power to 660 mW at 1 A, the VSMY98545 can replace multiple standard SMD devices, allowing designers to reduce the component count and improve performance in a wide variety of applications. The emitter is optimized for IR illumination in CCTV, gaming, and road cash systems, in addition to long-range proximity applications such as presence detection for wake-up functions in office equipment.

The device released today offers fast switching speeds down to 15 ns, low forward voltages down to 1.8 V at 1 A, and operating temperatures from -40 °C to +95 °C. The VSMY98545 ensures a shelf life of 168 hours and provides a moisture sensitivity level (MSL) of 3 in accordance with J-STD-020. Supporting lead -free reflow soldering, the device is RoHS-compliant, halogen-free, and Vishay Green.

Samples and production quantities of the new VSMY98545 are available now, with lead times of eight to ten weeks for larger orders.

Service Electric deploys Infinera InP transport network

The indium phosphide based PICs will be employed in Pennsylvania and New Jersey

Infinera has deployed its DTN platform across cable operator Service Electric Cable TV & Communications' new regional network serving customers in Central and North Eastern Pennsylvania and North Western New Jersey.

Service Electric selected the Infinera Intelligent Transport Network for the speed, simplicity and reliability that the Infinera DTN brings to its network.

Service Electric provides residential and commercial cable and telecommunications services, offering a full range of broadband services to its customers.

By deploying the Infinera DTN, Service Electric can quickly deliver services ranging from 155 megabits per second (Mb/s) to 100 gigabits per second (Gb/s). The platform's operational simplicity allows the existing engineering team to manage the regional network without the need to add additional engineering resources.

"We have a very busy engineering team, so we're looking for intelligent solutions that simplify network operations and accelerate new service turn-up. This allows us to focus on growing our business," says John M. Walson, President of Service Electric. "An Infinera Intelligent Network lets us do just that. With one-time optical layer engineering coupled with intelligent software that automates many provisioning operations that were previously manual, the Infinera solution allows our engineers to turn up services quickly. This gives us a competitive advantage with our customers."

"Cable and telecommunication operators like Service Electric see the value in an optical networking solution that is simple to operate and can deliver on services quickly," adds Mike Kelly, Vice President of Cable Sales at Infinera.

"The Infinera DTN, enabled by photonic integrated circuits and integrated digital switching, allows operators to add capacity to their network quickly without complicated engineering, and the DTN's reliability means MSO engineers can spend more time generating new revenue rather than fixing problems in the network."

Infinera's solutions for cable operators include the Infinera DTN, an Intelligent Transport platform for long-haul and metro core platform; the Infinera ATN metro edge platform designed to provide scalable optical transport for access and commercial service aggregation; and the Infinera DTN-X platform featuring 500 Gb/s long-haul super-channels. Infinera's Intelligent Transport Network solutions are widely deployed by major U.S. MSOs in national backbone, regional, and metro applications.

RF Electronics

RFMD and TriQuint to combine, creating a colossus in RF solutions

All-stock transaction creating new company with a revenue of more than $2 billion

RF Micro Devices, Inc, an innovator in the design and manufacture of high-performance radio frequency ("RF") solutions, and TriQuint Semiconductor, Inc , a premier RF solutions supplier and technology innovator, have announced a definitive merger agreement under which the companies will combine in an all-stock transaction. To reflect the nature of this transaction as a merger of equals, the new company ("NewCo") will have a new name and shared leadership team. The boards of directors of both RFMD and TriQuint have unanimously approved the transaction.

The merger will create new growth opportunities in three large global markets - mobile devices, network infrastructure and aerospace/defense - with scale advantages, innovative new products and a greatly improved operating model. RFMD and TriQuint together will offer the industry's broadest portfolio of critical enabling technologies to develop and commercialize tightly integrated solutions at record speeds. The combination will foster a new wave of exciting mobile devices that are broadly accessible and offer dramatically higher data throughput, to the benefit of carriers and consumers alike. The combination also creates a leader in infrastructure and defense (with approximately $500 million in annual revenue), with a broad portfolio of products and foundry services supporting applications including radar, next generation base stations, optical communications, and the Internet of Things.

With today's transaction, which is intended to qualify as a tax-free reorganization, TriQuint shareholders will receive 1.675 shares of NewCo and RFMD shareholders will receive 1 share of NewCo for each TriQuint or RFMD share held. At the closing of the transaction, the companies will execute a one-for-four reverse stock split resulting in approximately 145 million shares outstanding.

Former shareholders of RFMD and TriQuint will each own approximately 50 percent of the new company post-merger. The transaction represents an implied price of $9.73 for each TriQuint share, representing a 5.4% premium based on the closing price of $9.23 for TriQuint on February 21, 2014. The combination is expected to achieve at least $150 million in cost synergies; $75 million in annualized synergies exiting the first year after closing and an additional $75 million exiting the second year. The transaction is expected to be accretive to non-GAAP EPS in the first full fiscal year following the closing of the transaction.

"The world's demand for mobile data is growing exponentially," said RFMD CEO and President Bob Bruggeworth. "The combination of TriQuint and RFMD creates a new leader in RF solutions with expertise in mobile devices and complex infrastructure and global defense applications. With this merger of equals, we will bring under one roof all of the critical RF building blocks necessary to innovate at the heart of what makes mobile mobile - the crucial back-and-forth data flow between the mobile device and the network. We will harness this innovation for the benefit of all our customers - from mobile to infrastructure to defense."

"I believe this is an industry shaping event," said TriQuint CEO Ralph Quinsey. "Through this combination of RFMD and TriQuint we form a diversified market leader with a highly compatible combination of products and technologies and a world class team focused on innovation and superior financial results. The alignment of culture between the two companies and the well matched products, capabilities and technologies will create compelling new opportunities."

This transaction combines complementary product portfolios, featuring power amplifiers (PAs), power management integrated circuits (PMICs), antenna control solutions, switch-based products and premium filters - and leverages these to deliver the industry's most comprehensive portfolio of high-performance mobile solutions. It will also strengthen the combined company's service to the infrastructure and defense/aerospace industries and enable advanced gallium nitride (GaN) solutions for additional markets and applications.

The new company will have a shared leadership team. TriQuint CEO Ralph Quinsey will serve as non-executive Chairman, and RFMD CEO Bob Bruggeworth will serve as Chief Executive Officer. The board of directors will be made up of ten directors, with five directors from the existing board of each company. Eight of the ten directors will be independent. TriQuint CFO Steve Buhaly will serve as Chief Financial Officer and RFMD CFO Dean Priddy will serve as Executive Vice President of Administration, reporting to the CEO and responsible for integration and synergy value creation. Additional senior leaders of the combined company will include RFMD's Eric Creviston as President of mobile products, TriQuint's James Klein as President of infrastructure and defense products, TriQuint's Steven Grant as Corporate Vice President for Fab Technology & Manufacturing and RFMD's Jim Stilson as Corporate Vice President for Assembly/Test Technology & Manufacturing. Other

leaders will be named later this year.

The transaction is expected to close in the second half of calendar 2014 subject to approval by the shareholders of both companies, the receipt of regulatory approvals, and other customary closing conditions.

BofA Merrill Lynch is acting as exclusive financial advisor to RFMD. Goldman Sachs is acting as exclusive financial advisor to TriQuint. Perkins Coie is acting as counsel for TriQuint and Weil, Gotshal & Manges LLP and Womble Carlyle Sandridge & Rice, LLP are acting as counsel for RFMD.

Conference Call and Webcast Information

RFMD and TriQuint will host a conference call today that begins at 8:30 a.m. EST/5:30 a.m. PST. A live webcast of the conference call, as well as a related slide presentation, can be accessed at ir.rfmd.com or at invest.triquint.com. The call can also be accessed live over the phone by dialing 1-480-629-9866, access code 4671275.

Can RFaxis` silicon FEM devices kick GaAs?

Yes it can, according to Frost & Sullivan. The market research firm says RFaxis' cost effective technology is helping wireless devices achieve performance and quality that is comparable to a wired network

Based on its recent analysis of the market for radio frequency front-end module (RF FEM) solution for wireless communication, Frost & Sullivan honoured RFaxis, Inc. with the '2014 North American Frost & Sullivan Award for Technology Innovation Leadership'.

RFaxis leveraged its single-chip/single-die RF Front-end Integrated Circuit (RFeIC) architecture to develop unique RF front-end solutions for wireless communications.

These innovative solutions, which combine superior performance capabilities with affordability, also prove to be ideal alternatives to conventional gallium arsenide (GaAs) solutions.

RF front-end solutions are traditionally built by embedding active and passive multiple components on a substrate using GaAs. The hybrid integration of passive and active compounds forms a multi-chip RF FEM, resulting in a large package size and bigger footprint on the printed circuit board (PCB).

However, with the semiconductor industry for wireless communication moving from bulky, multiple integrated chips to leaner, single chips, RFaxis' RFeIC solutions are gaining prominence for being highly integrated on a single silicon-based chip.

Frost & Sullivan's research indicates that RFaxis has succeeded in developing the world's first single-chip/single-die integrated circuit architecture based purely on standard complementary metal oxide semiconductor (CMOS) technology.

And the firm syas its quality and performance are comparable with GaAs-based RF front-end solutions, while its cost structure, thermal conductivity and ruggedness are far superior.

"Apart from reducing the time to design and market, RF front-end level of integration offers device manufacturers a very simple solution that can be implemented as a plug and play," says Frost & Sullivan Sr. Research Analyst Swapnadeep Nayak. "RFaxis' technology helps OEMs reduce their product development cycles to as low as a few weeks, while competing solutions take months. It satisfies every performance criterion set forth by component manufacturers and original equipment manufacturers (OEMs)."

F&S says that unlike CMOS, GaAs is a niche domain, which does not have adequate foundry capacity to meet the global demand from the semiconductor industry and OEMs. Migrating to CMOS technology lowers the strain on the supply chain, which helps device manufacturers cope with demands from the industry.

RFaxis' technology offers substantial price reduction in comparison to incumbent solutions. It also helps system-on-chip (SoC) vendors and OEMs integrate the company's solutions with other modules.

The comparison of all RF Front-end solutions shows that RFaxis is among the few participants that integrate the key RF front-end components of power amplifiers, low noise amplifiers, and switches into a CMOS SoC.

Such a high degree of integration has a direct bearing on RF front-end innovations for the wireless local area network (WLAN), long term evolution (LTE/4G), and Machine-To-Machine communications markets.

RFaxis' technology powers a wide range of application segments that use wireless communication as a key platform, the main ones being broadband (gateways, set-top boxes, video streaming applications), mobile devices (smartphones), and the Internet of things (IoT).

RFaxis is also looking at the smart TV and remote control segments to transform them from mere devices to gadgets that perform functions, such as music and video streaming.

"The wireless application ecosystem is evolving with the advent of Zigbee, 4G, near field communication, and the IoT, and RFaxis' technology helps OEMs ease into this transition by helping wireless communication devices perform faster," notes Nayak. "Frost & Sullivan's benchmarking shows that RFaxis is efficiently extending the range of wireless communication applications through its RFeIC solutions without increasing the form factor or cost."

Every year, Frost & Sullivan presents this award to the company that has demonstrated uniqueness in developing and leveraging new technologies, which significantly impacts both the functionality and the customer value of the new products and applications. The award lauds the high R&D spend towards innovation, its relevance to the industry, and the positive impact on brand perception.

MACOM acquires Nitronex for $26 million

Nitronex's GaN-on-silicon adds to MACOM's process and product portfolio addressing RF applications

M/A-COM Technology Solutions Inc. (MACOM), a supplier of high performance analogue, RF, microwave and millimetre wave products, has acquired Nitronex, LLC, a specialist in the design and manufacture of GaN based RF solutions.

The acquisition of Nitronex is expected to provide MACOM with fundamental and innovative GaN-on-silicon epitaxial and pendeoepitaxial semiconductor process technology and materials for use in RF applications, establishing MACOM's growing GaN technology portfolio as one of the broadest in the industry.

Nitronex previously leveraged this technology to offer the industry's first GaN-on-silicon RF discrete devices and MMICs, providing a unique combination of GaN-based performance, ease of integration and a cost structure that can support high volume, mainstream markets.

The high device linearity, high output power and efficiency characteristics of GaN devices make GaN-on-silicon technology ideal for demanding high bandwidth communications such as CATV, broadband radio, wireless infrastructure, radar and ISM applications.

"GaN technology has been long viewed as the driver of the next generation of RF and Microwave applications," says John Croteau, President and CEO, MACOM. "With today's announcement, MACOM now provides what we believe to be the industry's largest portfolio of GaN devices. MACOM's broadened portfolio of GaN-on-silicon and GaN-on-SiC technologies offers customers the flexibility to utilise the best solution to solve their RF and Microwave design challenges."

"Nitronex is excited to join MACOM, a leader in high performance RF and microwave technology," says Greg Baker, President and CEO of Nitronex. "Today's announcement accelerates the deployment of GaN as a dislocating technology and furthers Nitronex's vision of bringing GaN-on-silicon to the fullest breadth of commercial and aerospace and defence applications possible. I believe MACOM's more than thirty years of experience in high performance RF power devices can help propel GaN-on-silicon to the next level of commercialisation, bringing it to a truly mainstream volume production technology."

MACOM purchased Nitronex from GaAs Labs, LLC for approximately $26 million in cash, subject to potential post-closing adjustments.

MACOM financed the transaction through a draw of additional indebtedness from its revolving credit facility. GaAs Labs, LLC is an affiliate of the majority stockholder of MACOM's parent company, M/A-COM Technology Solutions Holdings, Inc.

Nitronex selects Agilent software for high-power GaN design

The software will provide a complete GaN design flow that spans both device modelling and circuit simulation

Nitronex, a GaAs labs company and producer of GaN-on-silicon RF power devices, has selected Agilent's software for its GaN power device design.

The design flow uses Agilent EEsof EDA's IC-CAP model extraction software and Advanced Design System (ADS) circuit and system simulator - both platforms in RF and microwave design.

Gallium nitride has emerged as a semiconductor material of choice for designing RF power devices, providing a formidable combination of high bandwidth, efficiency and power.

In the case of Nitronex, whose GaN devices use silicon as a substrate, there is an added inherent cost advantage to its approach. Nonetheless, as with the development of any high-power device, designing for high levels of reliability, performance and yield requires

investing in leading modelling and simulation technology.

"Agilent's software platforms offer a clear advantage for our design process," says David Runton, vice president of engineering at Nitronex. "The usability and simulation advancements of ADS, combined with its superior device models and IC-CAP model extraction software, puts us in the best position to offer top-quality GaN parts to our customers. And, because Agilent's tools offer a complete design flow, our design process will be more streamlined."

"We appreciate Nitronex's decision to transition to Agilent simulation and modeling tools for their future GaN designs," said Charles Plott, marketing manager with Agilent EEsof EDA. "What is particularly gratifying is the positive acknowledgement about our usability advancements. We have gotten uniformly positive feedback from companies as they reengineer their design flows with the latest nonlinear modeling technologies and simulator advancements."

ADS delivers a host of usability features to improve designer productivity and efficiency for all applications it supports, as well as capabilities specifically applicable to GaN design. Support for Agilent's newly introduced artificial neural network-based model (extracted by IC-CAP device modelling software), for example, enables much more accurate FET modelling and simulation results for high-power GaN FET amplifiers.

Additionally, an electro-thermal simulator (based on a full 3-D thermal solver natively integrated into ADS) incorporates dynamic temperature effects to improve accuracy in "thermally aware" circuit simulation results.

IC-CAP features capabilities specifically geared toward high-frequency device modeling, including turnkey extraction of Agilent's neural networked-based model as well as the Angelov-GaN model. GaN models in particular need to be well suited to deal with the impact of trapping and thermal effects on the device electrical characteristics.

Peregrine RF front-end system takes on GaAs

The firm's Global 1 is claimed to be the first silicon based CMOS power amplifier to deliver gallium arsenide level performance for LTE devices

Peregrine Semiconductor, founder of RF SOI, is publicising the UltraCMOS Global 1, which the company says is the first reconfigurable RF front end (RFFE).

For the first time, 4G LTE platform providers and OEMs will be able to save time and money by creating a single SKU (stock keeping unit) design for global markets.

To support over forty frequency bands and a more than 5,000 fold increase in the number of possible operating states, a truly reconfigurable RFFE is now a requirement.

Peregrine says this level of reconfigurability is only feasible with a CMOS process.

Global 1 's entire system - multimode, multiband (MMMB) power amplifier (PA) ; post - PA switch, antenna switch, and antenna tuner - is based on Peregrine's UltraCMOS 10 technology platform.

This platform leverages twenty five years of RF expertise with proven performance demonstrated by more than two billion RF SOI units shipped.

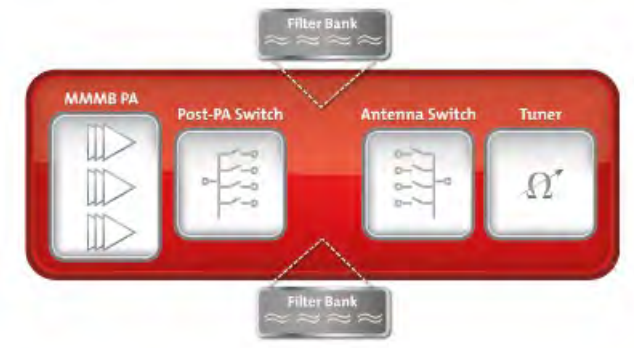
Also, Global 1 features the industry's first LTE CMOS PA with the same raw performance as the leading GaAs PAs and has a 33 percent efficiency increase over other CMOS PAs.

"For years RF engineers have been looking for an integrated, CMOS RF front - end offering that performs as well as GaAs for mobile devices," says Joe Madden, founder and principal analyst at Mobile Experts.

"Peregrine's UltraCMOS technology has demonstrated GaAs - level efficiency performance at high power, which could be a game - changer."

Global 1 RFFE System

On a single chip, Peregrine's Global 1 RFFE system delivers the scalability to easily support higher band counts through low - loss switching and tuneability high isolation to solve interoperability issues; simple, digitally - controlled adaptation across mode sand bands and, most importantly, PA performance equivalent to GaAs.



Peregrine's UltraCMOS Global 1, the first reconfigurable

RFFE system, includes a multimode, multiband power amplifier, post - PA switch, antenna switch and antenna tuner on a single chip

The UltraCMOS Global 1 system's reconfigurable RFFE delivers:

• 3 - path MMMB PA, post - PA switching, antenna switch and antenna tuner
• Support for envelope tracking
• Common RFFE MIPI interface

"Creating a global, single-SKU design for LTE devices is currently the toughest, unmet challenge in RF," says Jim Cable, CEO at Peregrine Semiconductor.Peregrine was founded with a vision for integration, and, after shipping billion switches and tuners, we are proud to announce a truly integrated RF front -end system that enables a single, global SKU."

UltraCMOS Global 1 PA Performance

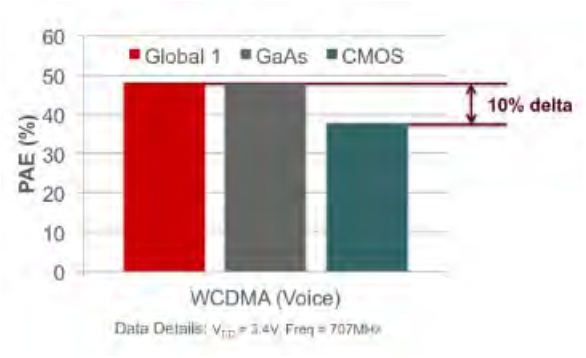
Before now no vendor has been able to deliver GaAs - level PA performance in a CMOS PA, which prevented CMOS PAs from competing in the performance - driven LTE handset market.

The Global 1 system integrates Peregrine's established, best - in - class RF switches and tuners seamlessly with the first CMOS PA to match the performance of GaAs PAs.

This level of performance is reached without enhancements from envelope tracking or digital predistortion, which is often used when benchmarking CMOS PAs with GaAs PAs.

A standard industry benchmark for PA performance is PAE (power - added efficiency) using a WCDMA (voice) waveform at an ACLR (adjacent channel leakage ratio) of - 38 dBc. Under these conditions, the performance of the UltraCMOS Global 1 PA approaches 50 percent PAE.

This is on par with the leading GaAs PAs and exceeds the performance of other CMOS PAs by 10 percentage points, which represents a 33 percent efficiency increase. Further, the UltraCMOS Global 1 PA maintains GaAs - equivalent PAE for LTE waveforms with varying resource - block allocations.



The UltraCMOS Global 1 power amplifier (PA) is the industry's first to match GaAs performance and exceed the performance of existing CMOS PAs by 10 percentage points, which represents a 33 - percent efficiency increase

While the UltraCMOS Global 1 PA reaches GaAs - competitive performance levels without the use of envelope tracking, the system natively supports all major envelope tracking solutions currently on the market. The PAE at saturated power (PSAT) provides a good indication on what PAE is possible using an envelope tracking odulator, however, the efficiency enhancements that envelope tracking brings are very band specific.

With an envelope tracker, the system efficiency of UltraCMOS Global 1 typically increases 10 percent age points, depending on band, Everyone According to Mobile Experts, the RFFE market is projected to grow from $6.1 billion in 2013 to $12.2 billion in 2018.

Much of this growth stems from demand in the LTE market and the impact the RFFE has on the overall performance in mobile devices. The benefits of Global 1 extend far beyond RF engineers to affect the entire wireless ecosystem:

• Platform providers can develop a single reference platform, reducing reference design development costs and validation time
• OEMs can design a single global SKU, cutting R&D costs, accelerating time to market, streamlining supply chains and improving inventory management.
• Consumers can enjoy longer battery life, better reception, faster data rates and wider roaming range.
• Wireless operators can reduce capital investments in their network with improved RFFE performance , resulting in better coverage and reductions in dropped calls.

Digi-Key to distribute MACOM GaAs and GaN products

The global electronic components distributor will supply MACOM's RF, microwave and millimetre-wave devices

Digi-Key Corporation will globally distribute M/A-COM Technology Solutions (MACOM) products globally.

MACOM offers a wide RF, microwave and millimetre-wave products. The company serves diverse markets, including satellite, radar, wired and wireless networks, CATV, automotive, industrial, medical, and mobile devices. MACOM designs and manufactures standard and custom devices, integrated circuits, components, modules, and sub-systems for its customers .

"Wireless technology is finding more and more inroads into our daily lives," says Mark Zack, Vice President, Global Semiconductor product at Digi-Key. "As more and more designers look to implement wireless technologies into their products, MACOM's robust, reliable product offering and long-standing technology legacy will improve Digi-Key's ability to continue removing barriers to entry into the wireless space and provide tremendous value for our customers around the world."

MACOM possesses a broad portfolio of over 3000 products, which include diodes, GaAs MMICs, silicon and GaN transistors, and components that enable next-generation internet and modern battlefield applications. These products cover frequencies ranging from DC to 110 GHz.

"This agreement aligns perfectly with MACOM's renewed focus on our core catalogue products. Digi-Key is recognised by design engineers worldwide for its exceptional service, and this partnership will allow us to leverage their broad customer reach," says Jack Kennedy, Vice President, Global Sales at MACOM. "Having Digi-Key as an authorized global distributor offers MACOM the opportunity to address our customers' needs by rapidly getting product into their hands for critical design cycles, thereby enabling improved time to market.

High pressure laser doping of GaN

To improve gallium nitride device performance for high-frequency RF applications, AppliCote is developing a high pressure laser doping process

Contact resistance and access resistance in deeply scaled FET devices greatly impact device performance at high frequency. This is of particular importance for GaN-based devices, which can achieve high power at high frequencies (>100 GHz).

Several processes have been developed to address these resistance issues, but these processes all have drawbacks.

For example, ion implantation can be used to increase the concentration of electrically active impurities in the source and drain regions of the device, but this process requires high temperatures for electrical activation, along with capping layers to prevent GaN decomposition.

In addition, implantation creates lattice damage that is difficult to remove via annealing and acts to compensate the dopants.

To improve GaN device performance for high-frequency RF applications, AppliCote is developing a high pressure (greater than 500 psi gas/vapour precursor) laser doping process.

The procedure will introduce electrically active *n*-type impurities into the source and drain regions of a GaN device to reduce contact resistance and decrease access resistance from the metal contact to the two dimensional electron gas (2DEG) in the device.

Low pressure (less than 60 psi gas/vapor precursor) laser doping process that has been successfully used and reported previously with numerous materials, including GaN, SiC, silicon/SiGe, and silicon-based photovoltaics.

Processing parameters for high pressure doping of silicon carbide have been developed (patent pending). Applicote plans to optimise processing conditions for doping GaN with silicon using a gaseous precursor and answer key questions about the electrical properties of the laser-doped GaN as well as process control and capabilities.

The high pressure laser doping process is a combination of a thermally driven process resulting from the interaction of the semiconductor with a high-power, short-duration laser pulse and a pressure driven process to increase dopant concentration to maximum solubility

levels at deep depths while mitigating surface damage.

The laser pulse results in an ultra-fast thermal ramp (1010 K/s) and impurity incorporation through decomposition of chemisorbed gas-phase source species and thermal diffusion of atoms into the crystalline lattice.

Impurity incorporation rate, diffusivity, and activation are all functions of the laser wavelength, power, and pulse time and precursor pressure.

Applicote has built a laser system and processing chamber for high pressure laser doping for rapid processing of substrates and simplification of the device fabrication process.

The technology will also be expanded to carbon doping of silicon wafers to create a surface region of SiC in silicon to accommodate GaN thin film deposition.

Prototype Laser Materials Synthesis Apparatus

AppliCote has its corporate headquarters in Lake Mary and the laser processing lab in Mount Dora, both in Florida.

Lasers

POET GaAs based laser reaches a new milestone

The gallium arsenide laser is claimed to take Moore's law to the next level

POET has achieved continuous-wave (cw) operation of its thyristor laser within its proprietary planar optoelectronic technology (POET) platform for monolithic fabrication of integrated electronic and optical devices on a single semiconductor wafer.

The company is also reporting significant progress on several other initiatives on its technical roadmap.

The firm has achieved the MS-5 milestone - the operation of its switching laser within the POET platform. This achievement has implications for on-chip and optical communications applications.

POET says this single demonstration is a big leap forward for an integrated circuit industry looking for ways to push complementary metal-oxide semiconductor (CMOS) processes past some challenging technical barriers.

Peter Copetti, Executive Chairman and interim CEO, notes,"This is the most definitive step yet in our drive to enhance POET's electronic and optical monolithic capability, beyond CMOS and silicon photonics."

Copetti adds, "While timeline variations are always to be expected for a company in development mode, our belief in Geoff Taylor and his team has never wavered. We would like to thank the entire technical team for its hard work and dedication."

Specifically, excellent switching operation was achieved with a laser threshold of 1-mA, just above a thyristor holding current of 0.5-mA, for a 10-micron diameter laser device, exhibiting a suppression ratio of 50 dB.

This enables optical short reach applications found in data-centre,server farms and high performance computing, thereby lowering system solution cost when compared to silicon photonics.

Facility Upgrades

In accordance with its planned maintenance scheduled for the POET facility, the company has completed its most recent wafer growth cycle.

In association with this, POET is upgrading its MBE system to make critical additions and replenish source materials.

One addition is a high-volume indium source to enable metamorphic growth on a GaAs substrate of the POET epitaxy with a wavelength of 1550nm.

This is expected to enable the production of long-wavelength lasers combined with high In-content field-effect transistor (FET) channels for superior high-speed transistor performance.

The company has previously announced that it realized submicron device operation from an initial 800-nm down to 200nm.

POET is trying to move towards the goal of 100nm feature sizes for the transistors within the POET platform, and has stabilised feature definition at the sub-200-nm level.

Short channel considerations are being addressed with new innovations,and the step of isolating source-drain and gate contacts with oxygen implantation is nearing completion.

III-V foundry capabilities hope to demonstrate greater than 20x speed improvement together with lower power consumption by 4x to 10x, depending on the application, compared to silicon at smaller nodes.

Although timelines are always subject to review depending on partner needs, the technical team sees no significant technical roadblocks ahead. POET anticipates completion of the 100 nm milestone by the end of April 2014.

Trying to optimise device parameters and yields, the company is focusing on establishing POET's technology design kits (TDKs). The TDKs comprise a comprehensive design rules and device parameter library for POET, and will enable customers and partners to implement the POET process into preferred foundries.

The TDKs will also help licensed designs in a POET device ecosystem to proliferate and help existing silicon library functions to migrate to POET technology-based circuitry in a minimum amount of time.

The company is reporting that with the help of select potential POET Development Alliance (PDA) partners, progress on this milestone is ahead of the schedule set by the former Special Strategic Committee.

Copetti notes, "It is gratifying to see our excitement shared by others, and we hope that excitement will be infectious as we head into the Global Semiconductor Forum. We have a relentless focus on securing our intellectual property and in forging ties to industry, and this positions POET Technologies in its drive to extend Moore's Law to the next level."

Rofin acquires FiLaser's assets

Part of the assets include FiLaser's unique laser cutting technology

Rofin-SINAR Technologies Inc. and FiLaser USA LLC. have entered into an Asset Purchase Agreement, under which Rofin will acquire the assets of FiLaser and its subsidiaries.

The transaction contains all intellectual property including trademarks, know-how, patents and patent applications of FiLaser. The transaction, which is subject to customary closing conditions, is expected to close in March 2014.

Rofin is a developer and manufacturer of laser sources and laser-based solutions while FiLaser USA LLC. specialises in developing and designing singulation processes for brittle materials,

"We are proud that FiLaser selected Rofin to market this technology. With the signing of the Asset Purchase Agreement, we are able to upgrade and complement our comprehensive ultra-short pulse laser offering with a specialised unique technology for the cutting of brittle materials, like glass and sapphire. The commercialization of this technology is an important step for the industry in improving the cutting performance of these materials and subsequently the wider use of laser technology," says Gunther Braun, President and CEO of Rofin. "We look forward to further developing and applying this technology to a broader range of materials."

Jeffrey Albelo, CEO and Chairman of FiLaser, commenting on the transaction, says, "Rofin is an ideal technology commercialisation vector, bringing scale, experience and integration prowess to bear on the problems of technology development and dissemination. We believe the nexus of FiLaser innovation and Rofin expertise in systems and lasers to be a winning combination. It enables optimal capture in the broadest market cross-section and greatly improves the adoption profile. We expect great things and we are excited to have our technology become a part of the Rofin technology portfolio."

Rofin-SINAR Technologies has its operational headquarters in Plymouth, Michigan, and Hamburg, Germany and maintains production facilities in the US, Germany, UK, Sweden, Finland, Switzerland, Singapore, and China.

FiLaser is headquartered in Portland, Oregon.

Physicists discover 'quantum droplet' in GaAs

A new quasiparticle by exciting gallium arsenide with an ultrafast red laser initially form excitons

JILA physicists used an ultrafast laser and help from German theorists to discover a new semiconductor quasiparticle - a handful of smaller particles that briefly

condense into a liquid-like droplet.

Quasiparticles are composites of smaller particles that can be created inside solid materials and act together in a predictable way. A simple example is the exciton, a pairing, due to electrostatic forces, of an electron and a so-called 'hole,' a place in the material's energy structure where an electron could be, but isn't.

The new quasiparticle, described in the February 26th 2014, issue of *Nature* and featured on the journal's cover, is a microscopic complex of electrons and holes in a new, unpaired arrangement.

The researchers call this a 'quantum droplet' because it has quantum characteristics such as well-ordered energy levels, but also has some of the characteristics of a liquid. It can have ripples, for example. It differs from a familiar liquid like water because the quantum droplet has a finite size, beyond which the association between electrons and holes disappears.

Although its lifetime is only a fleeting 25 picoseconds (trillionths of a second), the quantum droplet is stable enough for research on how light interacts with specialised forms of matter.

"Electron-hole droplets are known in semiconductors, but they usually contain thousands to millions of electrons and holes," says JILA physicist Steven Cundiff, who studies the properties of cutting-edge lasers and what they reveal about matter. "Here we are talking about droplets with around five electrons and five holes."

"Regarding practical benefits, nobody is going to build a quantum droplet widget. But this does have indirect benefits in terms of improving our understanding of how electrons interact in various situations, including in optoelectronic devices," he continues.

The JILA team created the new quasiparticle by exciting GaAs with an ultrafast red laser emitting about 100 million pulses per second. The pulses initially form excitons, which are known to travel around in semiconductors.

As laser pulse intensity increases, more electron-hole pairs are created, with quantum droplets developing when the exciton density reaches a certain level. At that point, the pairing disappears and a few electrons take up positions relative to a given hole. The negatively charged electrons and positively charged holes create a neutral droplet. The droplets are like bubbles held together briefly by pressure from the surrounding plasma.

Artist's conception of microscopic 'quantum droplet' discovered by JILA physicists in GaAs excited by an ultrafast red laser pulse. Each droplet consists of electrons and holes (representing absent electrons) arranged in a liquid-like pattern of rings. The surrounding area is plasma. The discovery adds to understanding of how electrons interact in optoelectronic devices (Credit: Baxley/JILA)

JILA's experimental data on energy levels of individual droplet rings agreed with theoretical calculations by co-authors at the University of Marburg in Germany. JILA researchers found they could tap into each energy level by tailoring the quantum properties of the laser pulses to match the particle correlations within the droplets.

The droplets seem stable enough for future systematic studies on interactions between light and highly correlated states of matter. In addition, quasiparticles, in general, can have exotic properties not found in their constituent parts, and thus, can play a role in controlling the behaviour of larger systems and devices.

JILA is a joint institute of the National Institute of Standards and Technology (NIST) and University of Colorado Boulder. Cundiff is a NIST physicist. The JILA research is supported by the National Science Foundation, NIST and the Alexander von Humboldt Foundation.

This work has been described in detail in the paper, "Quantum droplets of electrons and holes," by A.E. Almand-Hunter *et al* in *Nature*, 471 - 475, published online on February 26th, 2014.doi:10.1038/nature12994

This article has been adapted from a story by Laura Ost at NIST.

ASM stays in business with ALSI

ALSI has developed unique processes for dicing GaAs, high and ultra HB-LEDs, transistors and diodes

ASM Laser Separation International (ALSI) B.V. ("ASM ALSI") will continue the business of Advanced Laser Separation International (ALSI) N.V. ("ALSI") in Beuningen.

ASM ALSI intends to continue the business of ALSI as presently conducted including relationships with key customers, suppliers and other business partners.

ASM ALSI is a wholly owned subsidiary of ASM Pacific Technology Ltd (ASMPT), which is listed on the Hong Kong Stock Exchange and an assembly and packaging equipment supplier for the semiconductor and LED industries, and the world's third largest SMT equipment supplier.

As a subsidiary of the ASMPT group, ASM ALSI brings both the financial and technological strength to the business of ALSI that it needs to move to the next phase of expansion and development.

Richard Boulanger will continue as the managing director of ASM ALSI and all key employees of ALSI have expressed their commitment to continue their employment with ASM ALSI.

Customers, suppliers and other business partners of ALSI will be informed shortly in more detail.

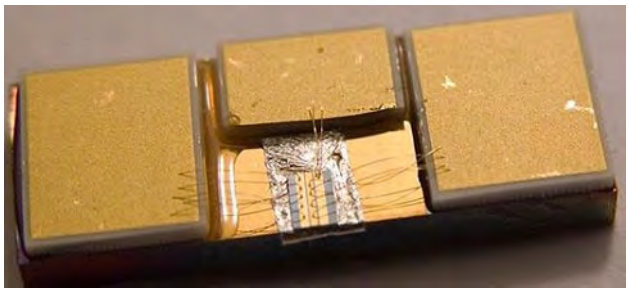
"We are very pleased to have ASM ALSI as a part of ASMPT. The multi-beam laser technology developed by ALSI offers customers unparalleled value. With the strong sales and service network of ASMPT, we can help to bring unique value to many customers at much faster pace", comments WK Lee, CEO of ASMPT.

Richard Boulanger also comments that, "We are excited to be part of the ASMPT organisation. We believe that ASMPT's excellent reputation and Global Sales and Service network will accelerate our Market Penetration especially for the Grooving Market as well as our other established markets. It will also increase our level of commitment and support to our customers. "

ALSI introduced the Multi Beam Laser Technology and has developed unique processes for dicing GaAs, Transistors and Diodes, High and Ultra High Brightness LEDs. The firm has now introduced the Matrix Grooving Process for the IC Market.

World's 'most powerful` terahertz laser chip built

The chips are based on III-V technology and include layers of GaAs



Researchers at the University of Leeds claim to have taken the lead in the race to build the world's most powerful terahertz laser chip.

A paper in the Institution of Engineering and Technology's (IET) journal *Electronics Letters* reports that the Leeds team has exceeded a 1 Watt output power from a quantum cascade terahertz laser.

The new record more than doubles landmarks set by the Massachusetts Institute of Technology (MIT) and subsequently by a team from Vienna last year.

Terahertz waves, which lie in the part of the electromagnetic spectrum between infrared and microwaves, can penetrate materials that block visible light and have a wide range of possible uses including chemical analysis, security scanning, medical imaging, and telecommunications.

Widely publicised potential applications include monitoring pharmaceutical products, the remote sensing of chemical signatures of explosives in unopened envelopes, and the non-invasive detection of cancers in the human body.

However, one of the main challenges for scientists and engineers is making the lasers powerful and compact enough to be useful.

Edmund Linfield, Professor of Terahertz Electronics in the University's School of Electronic and Electrical Engineering, explains, "Although it is possible to build large instruments that generate powerful beams of terahertz radiation, these instruments are only useful for a limited set of applications. We need terahertz lasers that not only offer high power but are also portable and low cost."

The quantum cascade terahertz lasers being developed by Leeds are only a few square millimetres in size.

In October 2013, Vienna University of Technology announced that its researchers had smashed the world record output power for quantum cascade terahertz lasers previously held by Massachusetts Institute of Technology (MIT). The Austrian team reported an output of 0.47 Watt from a single laser facet, nearly double the output power reported by the MIT team. The Leeds group has now achieved an output of more than 1 Watt from a single laser facet.

Linfield says, “The process of making these lasers is extraordinarily delicate. Layers of different semiconductors such as GaAs are built up one atomic monolayer at a time. We control the thickness and composition of each individual layer very accurately and build up a semiconductor material of between typically 1,000 and 2,000 layers. The record power of our new laser is due to the expertise that we have developed at Leeds in fabricating these layered semiconductors, together with our ability to engineer these materials subsequently into suitable and powerful laser devices.”

Giles Davies, Professor of Electronic and Photonic Engineering in the School of Electronic and Electrical Engineering, said: “The University of Leeds has been an international leader in terahertz engineering for many years. This work is a key step toward increasing the power of these lasers while keeping them compact and affordable enough to deliver the range of applications promised by terahertz technology.”

This work was mainly funded by the Engineering and Physical Sciences Research Council (EPSRC).

The full paper titled, «Terahertz quantum cascade lasers with >1 W output powers,» by Lianhe Li *et al* in*Electronics Letters* (2014) is available for download via the following link: DOI: 0.1049/el.2013.4035

Alfred Adams wins optoelectronics prize for no strain, no gain

One of the research discoveries made by the professor was that the electronic band structure of quantum well lasers were improved by growing the active layer in a strained condition

Alfred Adams, Distinguished Professor of Physics at the University of Surrey, has been awarded the Rank Prize for his research into the structure of semiconductor lasers.

The findings of this research, now forms the basis of many every-day technologies, from DVD and Blu-ray storage, to optical fibre communications and the Internet.

In 1986, Adams and his team proposed that the electronic band structure of quantum well lasers could be significantly improved by deliberately growing the active layer in a state of strain. The results of this work now dominate the entire semiconductor laser market, with approximately one billion produced each year, for a market valued at around $5B.

Adams says, “I feel greatly honoured to receive this prestigious award. In doing so, I would like to honour the efforts of the many engineers who have made such a difference to every-day life through so many ingenious applications of our research.”

The prize was jointly awarded to Adams’s co-researcher O’Reilly, now working at the Tyndall Institute, and to Eli Yablonovitch at Bell Communications Research and Gordon Osbourn at Sandia National Laboratories, for their independent work.

II-VI Laser extends laser diode portfolio

The product line-up includes high speed and high power VCSELs, expanded pulse range for seed lasers and an expanded wavelength range for stacks and fibre-coupled multi single-emitters

II-VI Laser Enterprise GmbH, a subsidiary of II-VI Incorporated, will debut new products from its High Power Laser Diode and VCSEL portfolio at Photonics West 2014.

These devices are suited for consumer, fibre laser, and medical applications.

The products include 25G VCSEL Chips, High Power VCSEL arrays, 14xx nm and 10xx nm High Power Stacks, and expansion of industry-standard multi single-emitter fibre laser pumps to 793 nm wavelengths for thulium pumping.

High speed multimode 850 nm VCSELs target next generation optical interconnects and enable new applications which require increased data rates of 25 Gb/s per channel. The addition of high power VCSELs complements its innovative product portfolio geared at high volume sensing and illumination applications in consumer electronics markets.

Arranged in a 2D array, the High Power VCSEL can reach up to 2W optical power for illumination of larger volumes required in sensing applications such as time-

of-flight.

The expansion of the BMU fibre-coupled multi single-emitter platform capability to 793nm wavelength range targets the Thulium fibre laser market, an area of increasing focus in industrial, medical and scientific applications. More than 25W from 105um fibre with wall-plug efficiency of up to 50% has been demonstrated from this high brightness fibre-coupled module at 793nm, making it ideal for pumping Thulium-doped fibre lasers and amplifiers as well as a host of emerging medical applications.

The expanded Seed Laser portfolio includes a new Fabry Perot (FP) laser diode module with ultra-broad band fibre Bragg grating (FBG) for high peak power pulsed Fibre Lasers and a Distributed Feedback (DFB) laser diode module designed for seeding of sub-nanosecond Fibre and Solid State lasers.

Other products on display at Photonics West will include the new family of 14xx nm and 10xx nm Stacks delivering higher power with industry-leading efficiency to further expand the application space in medical and industrial markets.

“With its strong heritage of over 30 years in semiconductor laser technology, II-VI Laser Enterprise once again manifests its position as global leader and innovator in semiconductor lasers,” says Director Sales & Marketing, Gunnar Stolze.

As a result of continuous innovation, II-VI Laser Enterprise representatives presented two technical papers during Photonics West.

These were, “High Power pump laser diodes for 2 um fibre laser,” and, “ High power laser diodes at 14xx nm wavelength range for industrial and medical applications”.

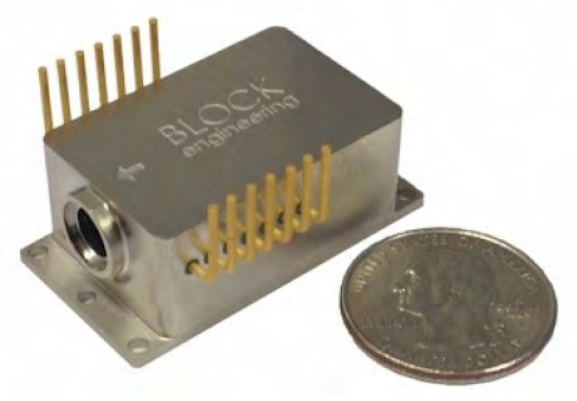
Block Engineering releases ultra-miniature QCL products

One of the III-V based laser systems is widely tuneable while the other can be used in a wireless mode

Block Engineering has released two ultra-miniaturised Quantum Cascade Laser (QCL) products, the Mini-QCL Module and the new LaserTune Infrared Source.

QCLs are fabricated using a number of III-V material systems. These include InGaAs/InAlAs, GaAs/AlGaAs, InGaAs/AlAsSb, InAs/AlSb and more recently Silicon/SiGe.

The Mini-QCL is a widely-tuneable QCL module for Original Equipment Manufacturers (OEMs), weighing only 75 grams (~2.5 oz).



Mini-QCL module

Block’s next-generation LaserTune has been miniaturised to a compact (16.5 × 12.7 × 11 cm), wirelessly-controllable system, while offering one of the widest contiguous tuning ranges available on the market (greater than 1000 cm-1).

LaserTune infrared source

Scott Riggi, VP of Sales, comments, “We are receiving tremendous interest in these new products from universities, corporate R&D labs, and a wide range of OEMs. Block has now introduced the world’s most compact, full-function QCL source with the widest contiguous spectral tuning range. The demand for these devices in gas sensing, metrology, and academic and corporate R&D applications is significant.”

Petros Kotidis, Block’s CEO adds, “These two new products are the result of Block’s innovation spirit, engineering strength, and optical packaging capabilities. They meet a strong market need for ultra-compact, ultra-widely tuneable sources for OEM integration and all-in-one laser sources.”

Kotidis adds, “These devices are now enabling new applications, which were not available to the past generations of QCLs, due to size, ruggedness and performance limitations. I look forward to the adoption of these new devices by our customers and the rapid growth of their applications.”

The Mini-QCL Module is available in spectral ranges greater than 250 cm-1 per module, and multiple modules can be combined by OEMs. The module can be used in a wide variety of real-time gas analysis applications requiring a mid-infrared laser source, including greenhouse gas monitoring, automotive combustion analysis, oil and gas exploration, and air quality monitoring.

The module is also designed to be integrated into a variety of spectroscopic instruments, including products used in the fields of Photoacoustic Spectroscopy (PAS), Cavity Ring-Down Spectroscopy (CRDS), Infrared Microscopy, and Atomic Force Microscopy (AFM).

The New LaserTune Infrared Source has been significantly reduced in size, while leading the industry in contiguous tuning range. The 2 x 4 mm collimated beam can now be programmed to operate in several modes with a manual step, programmable step, and programmable sweep.

The LaserTune offers fast scan capability at 25 cm-1 per msec, and the source can be programmed to emit pulses from 20 to 500 nsec, while maintaining a duty-cycle up to ~30 percent. Computer control of the LaserTune is via Wireless or Ethernet/HDMI with analogue and digital control for monitoring and controlling the laser wavelength.

Block will be demonstrating the products at SPIE’s Photonics West Conference (Booth #5333) and the BiOS Conference (Booth #8507) in San Francisco.

Solar

Chinese partnership to fuel NJIT›s solar research

The New Jersey’s science and technology university will concentrate on CdTe and CIGS technology

Earlier this month, NJIT formalised an agreement with Chinese partners that will advance the university’s research on thin-film solar cells, an alternative energy technology with the potential to make buildings and other infrastructure substantially more energy-efficient.

With more than $650,000 from the Shanghai-based China National Building Materials Company (CNBM), one of the largest gypsum, cement, and fibre glass producers in the world, NJIT will renovate its solar cell research laboratory and build prototype equipment that will enable manufacturers to produce thin-film cells more cost effectively.

The university’s CNBM New Energy Materials Research Centre, directed by physics Ken Chin, is focused on thin-film cells based on CIGS and CdTe, which are both potentially lower-cost alternatives to silicon, the industry standard, because they use raw materials more sparingly, take less net energy to produce, and occupy less space on buildings. Compounds such as CdTe and silicon function as the active semiconductor in a solar cell, absorbing sunlight and converting it to electricity.

The CNBM Centre has already developed important insights into the physics of the photoelectric behavior of these materials, which suggests that new manufacturing conditions could produce much higher cell efficiencies.

“Cadmium telluride is a promising photovoltaic material, but to date, with the exception of a single company, it has been difficult to produce and deploy on a manufacturing scale,” says Alan Delahoy, research professor and the Centre’s general manager. “In terms of the market, the hurdle is making it competitive with crystalline silicon modules. But we see no reason why we can’t meet key efficiency targets by solving some basic scientific questions - and that’s what we aim to do.”

With its new funding, the solar team is building a machine, for example, that will permit manufacturers to deposit thin layers of a transparent conductive material such as zinc oxide on a photovoltaic plate without oxidising the surface of the source metal in the process.

“Conventional technology performs reactive sputtering to form metal oxides for thin-film solar cells, transistors, and sensors, but this process is notoriously difficult to control,” Delahoy says, adding, “Process control is a big challenge in thin-film production. We are trying to come up with better manufacturing methods.”

The research team is also building sensitive equipment that will allow manufacturers to better detect defects in semiconductors.

CNBM is eager to speed development of inexpensive power production that can be seamlessly incorporated into a range of building materials.

“If just the rooftops of the world’s commercial buildings were equipped with current generation solar panels,

it would satisfy ten percent of the global energy need. Imagine if every surface of civil infrastructure and private housing could be generating power," said Donald Sebastian, senior vice president for research and development at NJIT.

Amtech bags $10 million for solar manufacturing

The firm has received its second orders from solar technology stalwarts in Korea and Taiwan for PECVD tools

Amtech Systems, a supplier of production and automation systems and related supplies for the manufacture of solar cells, semiconductors, and sapphire and silicon wafers, has received approximately $10 million in new solar orders.

These include orders for its diffusion and PECVD systems from respected solar technology manufacturers in Korea and Taiwan.

The orders are expected to ship within the next six months.

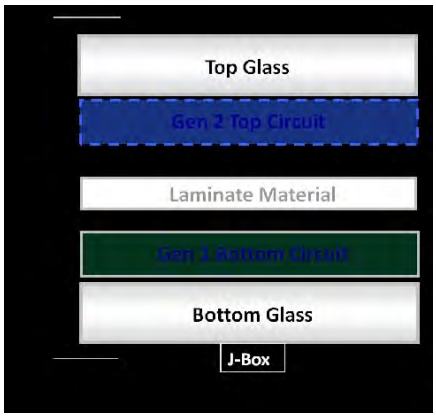
Fokko Pentinga, Chief Executive Officer of Amtech, comments, "We are very pleased to see this new demand for our products from solar technology leaders in Asia. These industry leaders reflect the increasing demand for solar technology solutions and a renewed market interest in adding new, highly productive capacity to meet the goal of higher solar cell efficiency at a lower total cost of ownership."

He adds, "We continue to have discussions with both current and potential new customers about our leading-edge technology solutions including our ion implant system, N-type and PECVD technologies. We are proud of securing the second PECVD production order, and believe our new PECVD system alone has the potential to more than double our served available market."

Amtech Systems, Inc. manufactures capital equipment, including silicon wafer handling automation, thermal processing and ion implant equipment and related consumables used in fabricating solar cells, LED and semiconductor devices.

Stion CIGS hits the 23.2 percent efficiency level

The firm has used its proprietary 'Simply Better' tandem technology to improve solar cell efficiency



Stacked Tandem Graphic

Stion has produced a 23.2 percent efficiency thin-film cell based on its proprietary tandem junction technology.

Stion says it has already scaled this technology at or above 20.0 percent efficiency on a prototype module (20 cm x 20 cm) and expects to soon scale to monolithic modules (65 cm x 165 cm) in the 20 to 22 percent efficiency range.

A pioneer in tandem module technology, Stion says it is the first to demonstrate fully integrated thin film devices at such high conversion efficiencies using scalable commercial processes. The firm will continue to implement the key technical innovations behind the 23.2 percent cell on its pilot production line in San Jose, California in preparation for the commercialisation of thin-film modules with over 20 percent efficiency.

Stacked tandem

"Achieving 23.2 percent cell efficiency and 20 percent mini-module efficiency on this state-of-the-art technology clearly demonstrates Stion's commitment to technology

differentiation and its deep IP portfolio," says Howard Lee, Stion's Chief Technology Officer, Founder and Sr. Vice President of Technology. "Showing initial results of 20 percent+ is a strong validation of scalability, and our ability to provide 'Simply Better' solutions to our customers using this technology. We expect the technology to keep improving with production experience"

Stion's approach to CIGS leverages proprietary materials and device expertise along with a robust, high-volume manufacturing process based on readily available, standardised equipment. Combining the simplicity of thin-film manufacturing with ultra high performance products greater than 20 percent efficiency is yet Stion is striving to be Simply Better than the competition.

HelioVolt seeking investment

In order to maximise value in its CIGS technology, the company intends to consider a range of alternatives, including investments, joint ventures or an M&A transaction that fits its strategic objectives

HelioVolt's Board of Directors has authorised the evaluation of strategic alternatives for the company's CIGS photovoltaic development and manufacturing business.

The company has suspended manufacturing operations to align its short-term cost structure with the objective of preserving maximum value in its intellectual property and demonstration facility while a suitable alternative is identified. HelioVolt will reduce personnel over the next sixty days as appropriate to support its evolving strategy.

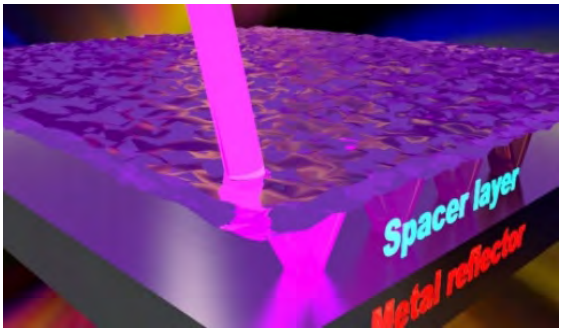
B.J. Stanbery, the firm's founder and Chief Science Officer, says, "We are initiating this process because our strategic partner, SK Group, for reasons related to their business strategy, has informed us that they will no longer pursue their prior global solar PV goals. While we continue to highly value the relationship with SK and have made tremendous technical progress in partnership with them, we are disappointed by their decision at a moment when we believe the solar market is poised for exceptional growth."

Dong Kim, HelioVolt's Executive Chairman and President of the SK PV Task Force, adds, "HelioVolt's technology and strength of its commercial ready manufacturing process have been greatly improved, having achieved new performance levels and reduced cost of ownership, potentially becoming a world leader. We are devoted to continue developing relationships with potential partners/ investors who will pursue the manufacturing initiative with HelioVolt technology."

A cavity that renders an optical nanocavity

Researchers say an optical 'nanocavity' could boost light absorption in semiconductors and improve solar cells, cameras and more

Scientists at the University of Buffalo say a new advancement could lead to major breakthroughs in energy-harvesting and conversion, security and other areas that will benefit humankind. Associated with unhappy visits to the dentist, "cavity" means something else in the branch of physics known as optics. Put simply, an optical cavity is an arrangement of mirrors that allows beams of light to circulate in closed paths. These cavities help us build things like lasers and optical fibre used for communications. Now, an international research team have pushed the concept further by developing an optical 'nanocavity' that boosts the amount of light that ultrathin semiconductors absorb. The advancement could lead to, among other things, more powerful photovoltaic cells and faster video cameras; it also could be useful for splitting water using energy from light, which could aid in the development of hydrogen fuel. The team, comprised of faculty and students from the University at Buffalo and two Chinese universities, presented its findings February 24th in the journal*Advanced Materials*.



A rendering shows a beam of light interacting with an optical nanocavity. The nanocavity boosts light absorption in ultrathin semiconductors. (Credit: Advanced Materials)

"We're just scratching the surface, but the preliminary work that we've done is very promising," says Qiaoqiang Gan, PhD, lead author and UB assistant professor of electrical engineering. "This advancement could lead to major breakthroughs in energy-harvesting and conversion, security and other areas that will benefit humankind." The most common semiconductor material, silicon, is used to make microchips for cellular phones, computers and other electronic devices.

Industry has kept pace with the demand for smaller, thinner and more powerful optoelectronic devices, in part, by shrinking the size of the semiconductors used

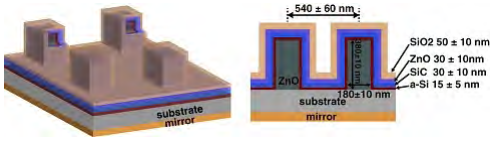
in these devices. The problem, however, is that these ultrathin semiconductors do not absorb light as well as conventional bulk semiconductors. Therefore, there is an intrinsic trade off between the ultrathin semiconductors' optical absorption capacity and their ability to generate electricity. As a result, researchers worldwide are trying to find ways to boost the amount of light that ultrathin semiconductors can absorb.

Harvard University researchers recently had varying degrees of success by combining thin films of germanium, another common semiconductor, on a gold surface. "While the results are impressive, gold is among the most expensive metals," says Suhua Jiang, associate professor of materials science at Fudan University in China. "We illustrated a nanocavity, made with aluminium or other whitish metals and alloys that are far less expensive, can be used to increase the amount of light that semiconducting materials absorb."

The nanocavity consists of, from bottom to top: aluminium, aluminium oxide and germanium. In the experiment, light passed through the germanium, which is 1.5 to 3 nanometres thick, and circulated in a closed path through the aluminium oxide and aluminium. The absorption rate peaked at 90 percent, with germanium absorbing roughly 80 percent of the blue-green light and aluminium absorbing the rest. This is ideal, says Haomin Song, PhD candidate in electrical engineering at UB and the paper's first author, because the bulk of the light stays within the semiconducting material. "The nanocavity has many potential applications. For example, it could help boost the amount of light that solar cells are able to harvest; it could be implanted on camera sensors, such as those used for security purposes that require a high-speed response. It also has properties that could be useful for photocatalytic water splitting, which could help make hydrogen fuel a reality," Song says. Before any of that happens, however, more research must be done, especially as it relates to how the semiconductor would turn the light into power as opposed to heat. Gan's research group is collaborating with Alexander Cartwright, PhD, UB professor of electrical engineering and vice president for research and economic development, and Mark Swihart, PhD, UB professor of chemical and biological engineering, to develop ultrathin energy-harvesting devices. Gan is also working with Hao Zeng, PhD, UB associate professor of physics, to study its effect on photocatalysis. The National Science Foundation supported the research. The paper, called "Nanocavity enhancement for ultra-thin film optical absorber," by Haomin Song *et al* is available via the following link:
DOI: 10.1002/adma.201305793

Slashing costs in thin film solar cell manufacturing

Scientists have designed onion-like structures to match light-trapping efficiency with the absorption efficiency of the semiconductor materials in thin film CdTe and CIGS solar cells



Researchers from North Carolina State University have developed a 'superabsorbing' design that may significantly improve the light absorption efficiency of thin film solar cells and drive down manufacturing costs.

The superabsorbing design could decrease the thickness of the semiconductor materials used in thin film solar cells by more than one order of magnitude without compromising the capability of solar light absorption.

"State-of-the-art thin film solar cells require an amorphous silicon layer that is about 100 nm thick to capture the majority of the available solar energy," says Linyou Cao, an assistant professor of materials science and engineering at NC State and senior author of a paper describing the work. "The structure we're proposing can absorb 90 percent of available solar energy using only a 10 nm thick layer of amorphous silicon."

"The same is true for other materials. For example, you need a CdTe layer that is one micron thick to absorb solar energy, but our design can achieve the same results with a 50 nm thick layer of CdTe. Our design can also enable a 30 nm thick layer of copper indium gallium selenide to fully absorb solar light. That's a huge advance."

Cao notes that the deposition of semiconductor materials stands as a major bottleneck for improving manufacturing productivity and lowering the cost of thin film solar cells. "A decrease in the thickness of semiconductor materials by one order of magnitude would mean a substantial improvement in manufacturing productivity and reduction in cost," Cao says, because the cells would use less material and the thin films could be deposited more quickly.

In cross-section, the new design looks like a rectangular onion. The light-absorbing semiconductor material coats a rectangular core. The semiconductor, in turn, is coated by three layers of anti-reflective coating that do not

absorb light.

To develop the design, the researchers began by examining the maximum light absorption efficiency of semiconductor materials using light-trapping techniques. They found that maximising solar absorption requires a design in which the light-trapping efficiency for solar light is equal to the intrinsic absorption efficiency of the semiconductor materials.

In other words, in order to maximise solar absorption, you need to match the amount of solar light trapped inside the structure and the amount of solar light that could be absorbed. The researchers then designed the onion-like structures to match their light-trapping efficiency with the absorption efficiency of the semiconductor materials in thin film solar cells.

“We first theoretically predicted the maximum solar light absorption efficiency in given semiconductor materials, and then proposed a design that could be readily fabricated to achieve the predicted maximum. We developed a new model to do this work, because we felt that existing models were not able to find the upper limit for the solar absorption of real semiconductor materials,” Cao says.

“And if this works the way we think it will, it would fundamentally solve light-absorption efficiency problems for thin film solar cells.The superabsorbing structure is designed for the convenience of fabrication, and we are looking for partners to produce and test this design,” Cao adds. “The structure should be very easy to produce with standard thin film deposition and nanolithography techniques. We are happy to work with industry partners to implement this design in the production of next-generation solar cells.

The paper, “Semiconductor Solar Superabsorbers,” by Yiling Yu *et al* was published in the journal*Scientific Reports*.

DOI: 10.1038/srep04107

TSMC CIGS branch out in the U.S.

Aimed at the residential and commercial solar markets Centrosolar will provide the territory covered by the solar energy markets in the United States, Canada, Mexico, Virgin Islands and Puerto Rico

Centrosolar America and TSMC Solar, a subsidiary of TSMC, have come to an agreement for the deployment of TSMC Solar’s CIGS solar modules across North America.

The agreement names Centrosolar America as the exclusive provider of the TSMC Solar CIGS technology in residential and commercial solar markets. TSMC Solar and Centrosolar America may also collaborate on utility-scale projects.

Centrosolar America will distribute CIGS solar modules from TSMC Solar, whose CIGS (copper, indium, gallium, selenium) technology is cost competitive with silicon based solar modules, and differentiates itself through several key attributes.

Most importantly, the CIGS modules yield more kWh’s per Watt installed over the life of the system due to a lower temperature coefficient, increased power rating due to the “Light Soaking effect” once exposed to light, and less power loss in shaded conditions due to the CIGS cell configuration.

These high performance attributes of the CIGS modules are especially important in high temperature regions, such as the Sun Belt in the United States and in Mexico and the Caribbean. In addition, the CIGS modules have an all black, sleek appearance that is aesthetically pleasing to homeowners.

“With its heritage of manufacturing excellence and as a world leader in CIGS-based solar technology, TSMC Solar is now changing the landscape of the North American solar energy market,” says Ram Akella, Centrosolar America’s Managing Director. “Our robust network of installers and distributors today delivers the most cutting-edge, turn-key solutions on the market and is ideally positioned to bring TSMC Solar’s new high performance CIGS technology to homeowners and commercial projects on a broad scale.”

“For Centrosolar America, this partnership with TSMC Solar means expanded opportunities in serving the larger scale commercial and utility-scale markets and new ways to provide our installers with the latest technology,

products and service for their customers. It means more choices in solar for the end-users and it challenges the mainstream industry to take solar to the next level," adds Akella.

"Just as TSMC has for twenty-five years now, TSMC Solar stands for outstanding customer service as well as advanced technology products that set new standards. With its great relationships with installers and widely recognized excellence in customer service, Centrosolar America is a natural fit for us as we bring our high-performance CIGS solar technology to North American markets," says Steve McKenery, Vice President & General Manager of TSMC Solar North America.

Emcore wins contract to support NASA's Mars mission

The company's III-V triple-junction solar cells will be used in the InSight spacecraft

Emcore has been awarded a contract by ATK to design and manufacture solar panels for NASA's InSight Mars Lander.

The mission, managed by the Jet Propulsion Laboratory (JPL), is planned for launch in March of 2016.

Solar panels populated with Emcore's most advanced ZTJ solar cells will power the InSight spacecraft which will be built and operated by Lockheed Martin Space Systems Company in Denver.

ATK will integrate Emcore's solar panels into its UltraFlex solar arrays for the final flight configuration of the spacecraft.

InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) is a NASA Discovery Program mission that will place a single geophysical lander on Mars to study its deep interior.

Furthermore, InSight will serve as a terrestrial planet explorer that will open a window into the processes that shaped the rocky planets of the inner solar system (including Earth) more than four billion years ago.

"Missions of this magnitude require extremely high reliability and proven performance," says David Messner, Vice President and General Manager of Solar Arrays and Deployables for ATK's Space Components division. "We are pleased to be partnering with Emcore again, this time to support the exploration of the Martian surface for Lockheed Martin and NASA's Jet Propulsion Laboratory as part of the exciting Mars InSight program."

"This contract with ATK is a very important award for Emcore, and we are honored once again to contribute to NASA's next mission to Mars," commentsBrad Clevenger, Executive Vice President and General Manager of Emcore's Photovoltaics Division. "Emcore has partnered with ATK on many successful programs and has supported several high-profile NASA-JPL missions including the Mars Science Laboratory (MSL) that carried the rover 'Curiosity' to Mars."

"Emcore is in the process of delivering solar panels for several other NASA missions including the Green Propellant Infusion Mission (GPIM) with ATK," adds Navid Fatemi, Vice President of Business Development for Emcore Photovoltaics. "We greatly value our long-standing business relationship with ATK and look forward to another successful partnership with ATK on NASA's Insight Mars Lander mission."

First Solar honours top suppliers of 2013

The CdTe solar cell manufacturer has awarded four companies with achievement awards

First Solar has announced recipients of the company's 2013 NOVA award for outstanding performance by suppliers.

The suppliers - SMA Solar Technology AG, OMCO Solar, Airgas USA, LLC and Air Liquide Malaysia Sdn. Bhd. - were recognised for providing enduring value to First Solar's manufacturing and EPC project activities.

SMA Solar Technology AG was recognised for its continued partnership with First Solar on a number of key strategic initiatives, including third party sales support, around the world, while maintaining quality and controlling costs.

OMCO Solar was honoured for demonstrating considerable manufacturing flexibility that accommodated First Solar's dynamic EPC project schedules in North America.

Airgas USA, LLC was recognised for ensuring continued, uninterrupted supply of manufacturing materials to First Solar's Perrysburg production facility, as well as personal protection equipment and safety equipment, while remaining open to creative approaches to managing inventory and reducing costs.

Air Liquide Malaysia Sdn. Bhd. (ALM) was awarded for delivering an expanded nitrogen generation system in support of new manufacturing processes at First Solar's production facility in Kulim, Malaysia, and for supporting First Solar's requirements at competitive rates.

"Our suppliers play a critical role in fulfilling our mission to create enduring value by enabling a world powered by clean, affordable solar electricity," said Shellie Molina, First Solar's Vice President of Global Supply Chain. "We appreciate the exceptional efforts of these NOVA award recipients and the value they provide through the highest standards of quality, cost and performance in both the manufacturing and EPC environments."

First Solar estimates that its business operations support approximately 33,000 supply chain jobs on a global basis. The company established the NOVA Award in 2011 to honour suppliers who significantly support its mission.

Avancis raises the bar with 16.6 percent efficiency CIS module

NREL has certified the firm's cadmium free thin-film PV module

Avancis has achieved a new efficiency world record for encapsulated thin-film modules.

On a 30 x 30 cm² cadmium free CIS solar module, the company has achieved an international peak value of 16.6 percent, which was independently confirmed by the U.S. Energy Department's National Renewable Energy Laboratory (NREL), the laboratory of the U.S. for research and development for renewable energy and energy efficiency.

Avancis increased its last externally certified efficiency record of 2011 and heads again the international efficiency ranking of encapsulated CIS thin-film modules. The aperture efficiency of 16.6 percent of the champion module has been certified by NREL in January 2014 and will be listed in the official record efficiency table of the journal *Progress in Photovoltaics: Research and Applications*released in the next edition (*Solar Efficiency Tables, Table II: Confirmed terrestrial module efficiencies*).

Together with the recently published efficiency of ZSW´s 20.8 percent efficiency on a laboratory cell, the result demonstrates the extraordinary potential of the CIS based thin-film technologies.

"The increased efficiency shows the enormous potential of our CIS production process," comments Jörg Palm, Head of Process Development at Avancis. "A transfer of the pilot process to the production would lead to an impressive module performance of nearly 160 Wp of the approximately 1 m² sized PowerMax modules. The very good homogeneity of the CIS absorber properties based on production dimensions of 158 x 66 cm² were demonstrated by the minor deviation of 0.15 % absolute between different 30 x 30 cm² modules from the same full-size absorber."

The 30 x 30 cm² sized champion module is taken by a mass-produced CIS absorber of the second Avancis factory in Torgau, and was further processed from the buffer processing in the research and development centre in Munich.

The improvement in efficiency is based on the optimisation of the buffer layer with respect to InxSy bandgap, band matching, and in particular transmission in a short wavelength range. In addition, the transmittance and the sheet resistance of the sputtered ZnO:Al front contact was optimized and the dead area between the series-connected cells was reduced by the use of picosecond laser process

POET Technologies closes $5 million private placement

The proceeds will fund the company's internal and third party development efforts necessary to complete the milestones required to enable the monetisation of the POET Technology

POET Technologies Inc. has announced the closing of its non-brokered private placement financing of 7,692,307 Units at a price of Canadian $0.65 per unit for proceeds of Canadian $5 million.

Each unit consists of one common share and one common share purchase warrant. Each warrant allows the holder to acquire one additional common share of POET for a period of two years at an exercise price of Canadian $1.00 per share.

All of the securities issued pursuant to the private placement are subject to a hold period which expires on June 13th, 2014. No commission was payable with respect to this financing.

The proceeds will be used to fund the company's internal and third party development efforts necessary to complete the milestones required to enable the monetisation of the POET Technology.

The proceeds will also be used to cover general and administrative expenses, and working capital. The Canadian $5 million dollar placement strengthens POET's balance sheet to enable it to continue implementing its monetisation strategy to increase shareholder value.

Following the closing of the private placement there are currently 142,800,040 shares issued and outstanding.

UK universities awarded £2 million for solar cell research

The project aims to replace gallium, indium, cadmium and tellurium used in the manufacture of photovoltaic solar cells, while also implementing processes compatible with large-scale manufacturing

A University of Bristol-led research project which aims to develop new active materials for photovoltaic solar cells based on abundant and low cost elements has been awarded £2 million funding by the Engineering and Physical Sciences Research Council (EPSRC).

The study 'Photovoltaic Technology based on Earth Abundant Materials (PVTEAM)', led by David Fermin, a professor in Bristol's School of Chemistry, is one of four research projects to be awarded a total of £10.3 million by the EPSRC.

Each project aims to find safer, more sustainable alternatives to many of the raw materials used by manufacturing industries.

The Bristol-led research aims to replace key elements - such as gallium, indium, cadmium and tellurium - used in the manufacture of photovoltaic solar cells, while also implementing processes compatible with large-scale manufacturing. As these elements have low abundance, high costs and high toxicity, finding alternatives to them represents an extraordinary opportunity.

Fermin saiys, "The aim of this programme is to lay the foundations of sustainable thin-film photovoltaic technology based on Earth-abundant materials and scalable manufacturing processes.This will be achieved by developing processes and production technologies for materials and material systems to a level they can be taken up by manufacturing industries.

"PVTEAM will specify a carefully selected range of chemical compounds (chalcogenides and oxides) as substitutes to proven commercial materials. Using a multi-level screening approach, we will incorporate the

best performing candidates into established solar cell architectures."

The consortium involves five universities (Bristol, Bath, Northumbria, Swansea and Loughborough) with state-of-the-art infrastructure for material development and characterisation as well as for device fabrication, testing and integration into photovoltaic modules.

Material processing will be based on facilities available at the Sustainable Product Engineering Centre (SPECIFIC), which will be in charge of designing scale-up strategies and preparing techno-economic assessment.

The PVTEAM industrial partners, Tata Steel, Pilkington NSG and Johnson Matthey, have a worldwide footprint on materials for the construction, coating and chemical industries.

The consortium also includes SMEs, M-Solve and Semimetrics, which will provide means for the exploitation of new PVTEAM technologies in module fabrication and metrology.

Ascent Solar completes $10 million stock financing

The CIGS cell manufacturer has completed financing with Ironridge Technology

Ascent Solar Technologies, Inc. has completed the $5 million second closing of its Series B preferred stock purchase agreement with institutional investor Ironridge Technology Co., a division of Ironridge Global IV, Ltd.

The company received the first $5 million from Ironridge in November 2013, and has now received the second $5 million.

In both closings, the company issued Ironridge shares of its Series B-1 Preferred Stock, which is convertible into shares of common stock at a fixed conversion price of $1.15 per common share.

John C. Kirkland, Ironridge Global Partners' Managing Director says, "We are pleased to close on the second $5 million tranche earlier than anticipated, and to help facilitate the expansion of the EnerPlex brand through strengthening Ascent Solar's balance sheet."

Ascent intends to use the proceeds of the offering to fund continuing operations and accelerated expansion of both traditional and kiosk centric retail channels for its EnerPlex products, aggressive brand building, as well as the launch of additional EnerPlex products and product lines in 2014. There are no restrictions on use of proceeds.

A shelf registration statement (File No. 333-178821) relating to the securities being offered has been filed with and declared effective by the Securities and Exchange Commission. A prospectus supplement relating to the offering has been filed by the Company with the SEC.

Eternal Sun and Solliance to develop unique solar testing system

he project aims to gain new insights in the behaviour of all types of solar cells

A Dutch consortium, consisting of Eternal Sun, Hielkema Testequipment, Rera Solutions and Solliance partners ECN and TNO will develop a climate chamber with AAA-class accuracy simulated sunlight to simultaneously test performance and degradation of all types of solar cells and mini-modules.

This unique combination is able to gather information which is at the moment unattainable. The equipment is expected to become commercially available in the first half of 2015.

The new hybrid test setup will be based on an existing model, which has already been in use by TNO for three years. The combination of climate chamber and solar simulator is used for research on the performance and degradation of CIGS cells at the new Solliance facility at the High Tech Campus in Eindhoven.

The new hybrid test setup is a combination of a modified climate chamber, a multi cell IV-measurement system and a large area solar simulator. This simulator uses an array of lamps to produce AAA-class (less than 2 percent accurate) sunlight which is used to provide nearly flawless performance and degradation measurements of all types of solar cells and mini-modules.

The ultimate objective of the joint project is to gain new insights in the behaviour of all types of solar cells and mini-modules. Because the new hybrid test setup is able to simultaneously measure performance and degradation the combination is able to gather data which was previously unattainable.

This new data enables new research, focused on the performance of cells and mini-modules during the degradation process. The hybrid test setup enables Solliance to perform most existing IEC-tests as well as

new developed test procedures, with the use of one single test setup, and enables them to gain new insights into the behaviour of all types of PV cells and mini-modules.

Stefan Roest, CTO and co-founder of Eternal Sun says, 'We are excited to start the cooperation with Solliance and to be able to develop such a unique piece of equipment. To be able to work closely together with experienced partners is always a pleasure and I am confident that this new test system will be interesting for all solar research facilities around the globe.'

Mirjam Theelen, researcher at Solliance comments, 'The existing test setup has been very successfully used to learn more about the degradation behavior of new types of solar cells. There was a lot of interest from other research institutes for this setup, and we are very content with the fact that Dutch companies will bring it to the market in cooperation with us.

POET restructures senior management and Connecticut University license

The firm aims to be first to market a practical III-V compound semiconductor solution in the industry's race to sustain Moore's Law beyond the constraints of traditional silicon

POET Technologies Inc. has announced changes to its executive team and board.

Peter Copetti has been named Executive Chairman and interim CEO. Copetti previously served as Executive Director and Chair of the Special Strategic Committee (SSC), which was dissolved, following its final report to POET's Board of Directors.

Leon M. Pierhal has stepped aside as CEO and will continue his role as President and member of the Board.

Also, Mark Benadiba has stepped down as Executive Chairman of the Board and will remain a member of the Board, as Vice Chairman.

An enthusiastic Peter Copetti, incoming Executive Chairman and interim CEO comments, "I am delighted to assume leadership of the Company's operational responsibility and strategic vision. I take the fiduciary duties associated with these appointments seriously, and intend to continue to provide superior returns and value to shareholders. On behalf of the Board, I would like thank Mark and Leon for their commitment and contributions, and will continue to work with both of them in progressing POET's story to the next phase, which is expected to culminate in the monetisation of POET's proprietary platform and processes."

Peter Copetti adds, "Currently, POET is at an advanced stage in its 16-year development history. We are determined to be first to market with a practical compound semiconductor solution in the industry's race to sustain Moore's Law beyond the constraints of traditional silicon."

"POET intends to go to market with the world's first completely integrated optical and electrical device operating on a single die, and to fulfill its promise of vastly superior processing speed and energy utilisation in a patented production process that can ultimately be retrofitted to conventional fabs," concludes Copetti.

Leon M. Pierhal, President comments, "Semiconductors, computer technology and telecommunications were all, at one time, emerging industries in my forty-plus years in the technology industry. As a co-founder of POET, I'm immensely proud of my participation throughout the organisation's development life cycle. In this time, I steered the company through infancy, and shepherded POET safely through turbulent change. POET has since evolved from its origins as pure R&D, to a publicly-traded going concern trading on two markets in Canada and the U.S., to where it stands today - at an inflection point, where monetization of the POET platform is on the horizon, with fully-integrated optical-electronic chips leading the way for the semiconductor industry's next generation chip technology."

Pierhal continues, "Our position firm, I've decided to step aside as CEO and stay on as President and a member of the Board. This change in role allows me to spend time with family, and tend to overdue personal commitments that had been put aside, due to the arduous demands needed to bring POET to where it is today. Having worked closely with Mr. Peter Copetti over the past eighteen months, I am confident in Peter's ability to serve as CEO, and look forward to continuing to work together. I firmly believe Peter will deliver significant value on behalf of all stakeholders, and play a pivotal role in bringing the Company's technology to market."

Mark Benadiba, Vice Chairman, notes, "I want to personally express my gratitude to our Board and shareholders for the support they have given me through my tenure as Chairman. Of special note is that, without Peter and his tremendous efforts, we would not have accomplished the objectives that we have to date. I am certain that his leadership will serve our shareholders well going forward. Thank you, all."

The company also wishes to announce that it has entered into a term sheet with the University of Connecticut to restructure its license agreement of April 8th, 2003. The parties confirmed that the licenses granted pursuant to the License Agreement are in full force and are irrevocable.

While the maintenance fee provisions of the License Agreement remain unchained, the parties agreed to restructure the payment provisions by reducing the royalty payment to three percent of amounts received from unaffiliated third parties in respect of the exploitation of the Intellectual Property defined in the License Agreement.

In consideration for the favourable restructuring of the royalty terms, the Company will provide the University 2,000,000 common shares, subject to approval by the TSX Venture Exchange; trading of these shares is restricted until May 31st, 2016. The restructuring is subject to the final execution of the formal amendment to the License Agreement.

Copetti states, “I am extremely pleased with the University of Connecticut’s vote of confidence in POET, exhibited by their taking an equity stake in the Company as an alternative to a higher potential royalty revenue stream. At the same time, their decision will greatly enhance the Company’s ability to monetise the POET technology and create shareholder value.”

The company remains on track with its technology roadmap, and will shortly be providing updates to all stakeholders on progress and achieved milestones to date.

POET Technologies is the developer of the POET platform for monolithic fabrication of integrated circuit devices containing both electronic and optical elements on a single semiconductor wafer. With head office in Toronto, Ontario, Canada, and operations in Storrs, CT, the Company, through ODIS Inc., a U.S. company, designs III-V semiconductor devices for military, industrial and commercial applications, including infrared sensor arrays and ultra-low-power random access memory.

Siva Power CIGS cells approach 19 percent efficiency

Former NREL director Charlie Gay has joined Siva Power’s CIGS PV team

Siva Power has achieved near record efficiency with its CIGS panel technology.

The firm’s product has achieved nearly 19 percent efficiency in a record time of just ten months.

In addition, the company welcomes leading solar energy expert, Charlie Gay, Ph.D., to its Technical Advisory Board.

Gay joins Rommel Noufi, Ph.D., John Benner, and Markus Beck, Ph.D. to support Siva Power as it creates a profitable path to sub-$0.40 per watt solar power and unprecedented production scale.

Siva Power repositioned itself for success in February 2013 by transitioning to CIGS thin-film technology. In December 2013, the National Renewable Energy Laboratory (NREL) certified Siva Power as achieving a laboratory efficiency of 18.8 percent - less than a year after the company shifted its technology focus.

In achieving 18.8 percent efficiency, Siva Power has nearly equalled accredited international research institutes such as NREL, the Swiss Federal Laboratory for Materials Science and Technology (EMPA) and ZSW Centre for Solar Energy and Hydrogen Research, all of which have engaged in research and development (R&D) on CIGS for upwards of 20 years.

Siva Power also surpasses the majority of solar companies using CIGS technology, many of which have taken more than five years to achieve this degree of panel efficiency. Much of this success is directly attributable to the deposition approach that Siva Power has selected.

All CIGS efficiency records over the past two decades have been achieved using three-stage co-evaporation. This is the method that Siva Power has elected to scale to high-volume manufacturing.

“The Siva Power team’s rate of progress in demonstrating these high efficiencies is unprecedented and is further proof that our technology, combined with an unrivaled manufacturing plan, is the most viable pathway to a profitable and sustainable solar industry,” says Brad Mattson, Siva Power CEO. “This efficiency milestone speaks to our team’s expertise, and we welcome Charlie’s knowledge and experience as a critical component toward helping us achieve even more.”

With more than 30 years of solar industry experience,. Gay is an internationally recognised pioneer in photovoltaics (PV). In 2013, Gay was elected to the U.S. National Academy of Engineering, one of the highest professional honours accorded engineers. At present, Gay is co-founder and president of Greenstar

Foundation, an organisation dedicated to enabling microenterprise development in rural communities.

Gay began the early part of his career working for ARCO Solar where he forged the transition of single crystalline silicon from R&D to mass production. In 1994, he was elected director of NREL where he managed an annual budget of more than $235 million, with a staff of more than 1,000 employees. After his tenure at NREL, he served as president of ASE Americas.

From 2001 to 2005, Gay served as chairman of the SunPower Advisory Board. He then joined Applied Materials in 2006 as corporate vice president and general manager of the Solar Business Group. He was named president of Applied Solar and chairman of the Applied Solar Council in 2009.

“I am honoured to join such an experienced team with Beck, Noufi, and Benner,” says Gay. “Collectively, they represent one of the most experienced groups ever assembled for CIGS technology and high volume manufacturing.”

Novel solar cell technology handles the blues

A new technology enables the capture of high-energy photons more efficiently in CIS solar cells

Getting the blues is rarely a desirable experience - unless you’re a solar cell, that is.

Scientists have together developed a new, inexpensive material that has the potential to capture and convert solar energy - particularly from the bluer part of the spectrum - much more efficiently than ever before.

The researchers are from the U.S. Department of Energy’s Argonne National Laboratory and the University of Texas at Austin.

Most simple solar cells handle the bluish hues of the electromagnetic spectrum inefficiently. This is because blue photons - incoming particles of light that strike the solar cell - actually have excess energy that a conventional solar cell can’t capture

“Photons of different energies kick electrons up by different amounts,” says Brian Korgel, a professor at the University of Texas. “Some photons come in with more energy than the cell is optimised to handle, and so a lot of that energy is lost as heat.”

Because of this limitation, scientists had originally believed that simple solar cells would never be able to convert more than about 34 percent of incoming solar radiation to electricity.

However, about a decade ago, researchers saw the potential for a single high-energy photon to stimulate multiple ‘excitons’ (pairs of an electron and a positively-charged partner called a ‘hole’) instead of just one. “This was a very exciting discovery, but we were still sceptical that we could get the electrons out of the material,” Korgel says.

In their study, Korgel and his team used specialised spectroscopic equipment at Argonne’s Centre for Nanoscale Materials to look at multi-exciton generation in copper indium selenide (CIS), a material closely related to another more commonly produced thin film that holds the record for the most efficient thin-film semiconductor.”

This is one of the first studies done of multiple exciton generation in such a familiar and inexpensive material,” notes Argonne nanoscientist Richard Schaller. “Argonne’s spectroscopic techniques played a critical role in the detection of the multi-excitons,”

Korgel notes. “These kinds of measurements can’t be made many places.”

In order to deposit thin films of the nanocrystalline material, the researchers used a process known as ‘photonic curing’, which involves the split-second heating up and cooling down of the top layer of the material. This curing process not only prevents the melting of the glass that contains the nanocrystals, but also vaporises organic molecules that inhibit multiple exciton extraction.

Although the study mostly proves that the efficiency boost provided by multiple exciton extraction is possible in mass-producible materials, the major hurdle will be to incorporate these materials into actual real-world devices.

“The holy grail of our research is not necessarily to boost efficiencies as high as they can theoretically go, but rather to combine increases in efficiency to the kind of large-scale roll-to-roll printing or processing technologies

that will help us drive down costs," Korgel explains.

A paper based on the study appeared in the paper, *Journal of Physical Chemistry Letters*. The study was supported by grants from the Department of Energy's Office of Science and the National Science Foundation.

PTIP to inaugurate CIGS pilot plant in South Africa

Singulus supplied the technology and support for the key production processes

In the presence of numerous honorary guests from Germany and South Africa including high-ranking politicians, business and technical partners, Photovoltaic Technology Intellectual Property (Pty) Limited (PTiP) will officially launch the successful commissioning of its pilot production line for the manufacturing of CIGS thin-film solar modules.

Singulus Technologies supplied the engineering technology and support for the key production processes.

PTiP, a spin-off from the University of Johannesburg (UJ), has already been working on the development of CIGS solar modules for the past 20 years. The demonstration plant in the Techno Park near Stellenbosch was established on the back of the critical success demonstrated in the UJ research laboratories.

This facility will serve as a state-of-the-art research and development facility for commercial-scale and market ready 1200 mm x 600 mm CIGS modules. The commercial development of the PTiP process is in the limelight of the South African government.

The Industrial Development Corporation (IDC) is a strategic shareholder and financially support of the expansion by PTiP in Techno Park. PTiP received additional financial support from the "Technology Innovation Agency" (TIA), an initiative of Department of Science and Technology. With the new CIGS line, the development of modules can be improved with particular regard to the efficiency and the special demands of the African market.

The project also attained particular interest in the course of the German-South African Science Initiative.

Vivian Alberts, CEO of PTiP, comments, "The commissioning and official opening of this CIGS pilot facility in South Africa confirms the goals of the South African government to support and promote alternative and renewable energies, based on locally developed IP and skills. It is an important step for a successful energy policy in our country."

Alberts adds, "The immediate goal is to set-up a commercially viable production plant for CIGS thin-film modules in South Africa in order to supply products with high local content to existing and future PV projects in South Africa. The European Investment Bank already announced its support for the establishment of a PTiP production plant and the mass production of PV modules. With the core production equipment and support from our partner, Singulus, we are able to industrially and efficiently implement our developed process."

Singulus has been working with the scientists from the University of Johannesburg for the past 3 years and in the course of the cooperation already delivered the first laboratory systems in 2011. -Ing. Stefan Rinck, CEO of the Singulus Technologies AG, remarks, "With the vacuum coating, the selenisation as well as two work steps in the wet-chemical area, in total we supplied four key process steps for a CIGS line. With our partner PTiP, we intend to continue to successfully implement the additional expansion stages as well."

Solar cells and modules can be categorised in terms of

the specific production processes and used materials, for example, crystalline silicon solar cells and CIGS thin-film modules.

The CIGS thin-film solar technology utilizes large glass substrates as the basic substrate material, on which a very thin photo-active layer with a thickness of approx. 1.5 to 2.5 µm is applied. This absorber layer consists of a compound semiconductor including the elements copper, gallium and indium with selenium and sulphur in a so-called chalkcpyrite structure.

In contrast to monocrystalline or polycrystalline solar cells, thin-film modules only marginally lose performance amid low light or very high temperatures. This results in the fact that thin-film solar cells produce electricity earlier in the morning hours and later in the evening hours. Furthermore, thin-film solar modules can be used as a design feature for the front or the roof of buildings due to its homogenous surface and better visual appearance.

Singulus Technologies focuses on the market of CIGS solar cells with photoactive layers made of compound semiconductors. These thin-film cells have achieved laboratory efficiency levels of around 20 percent so far. The efficiency of modules is in a range from 13 percent to 15 percent, depending on the module size.

Power Electronics

Cree releases power SiC Schottky diodes

The firm says its CPW5 Z-Rec diodes extend benefits of silicon carbide into Megawatt power systems market, improving efficiency and reducing costs

Cree has launched its new CPW5 Z-Rec high-power SiC Schottky diodes.

The firm says this is the industry's first commercially available family of 50 Amp SiC rectifiers.

Designed to deliver the cost reduction, high efficiency, system simplicity and improved reliability of SiC technology to high power systems these diodes have been designed to address demanding applications.

These include solar / PV inverters, industrial power supplies, induction heating, battery charging stations, wind turbine converters and traction inverters and work from 50kW to over 1MW;

Developed to facilitate the direct matching of 50 Amp diodes to 50 Amp MOSFETs or IGBTs, Cree(R) CPW5 Schottky diodes reduce system complexity and cost by enabling the replacement of multiple low-voltage, low-current SiC Schottky diodes, or silicon PiN diodes, with a single CPW5 rectifier.

Additional cost savings can be achieved through reduced maximum voltage ratings and the elimination of snubber circuitry due to the diminished voltage overshoot during switching in SiC.

"Cree's CPW5 family of SiC Schottky diodes are a critical component in our high performance power modules and power electronic systems," says Ty McNutt, director of business development, APEI, Inc. "The low forward voltage drop, fast switching speed and extended temperature capability allow us to push power density and efficiency across many applications, such as high power motor drives and solar inverters."

Cree CPW5 diodes enable a new generation of high-current Si/SiC IGBT modules. Hybrid Si/SiC IGBT modules can deliver up to a 43 percent reduction in switching losses over conventional modules, while also reducing voltage- and current-overshoot, switching dead time and cooling requirements.

As an added benefit, design engineers can use the same gate driver design and circuits used with conventional modules, allowing easy and immediate implementation. Cree CPW5 diodes also provide a peak forward surge resistance greater than 500 Amps repetitive and 2000 Amps non-repetitive, delivering increased reliability under the harshest electrical conditions.

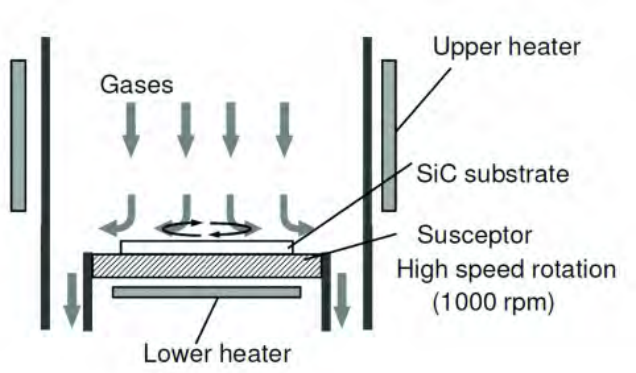
"As the sole distributor of Cree SiC-based power products in wafer and die form, SemiDice is excited to offer the CPW5 family of Z-Rec Schottky diodes," says Dan Cormack, CEO of SemiDice, Inc. "We are seeing increased customer demand for 50 Amp Schottky diodes and we know that as a global leader in the manufacture of advanced SiC diodes, Cree will deliver the quality and performance that our customers expect to help them minimise system cost and size."

The CPW5 family of Z-Rec Schottky diodes includes 1700V/50A, 1200V/50A, 650V/50A and 650V/30A combinations.

The CPW5 diodes are available immediately in bare die form from SemiDice.

Accelerating SiC growth and throughput

Novel reactor enables rapid growth of high-quality 150 mm SiC epiwafers



Although the SiC reactor is similar to those used for silicon epitaxy, the hot zone features a higher number of heaters: As well as the two-zone lower heater, there are additional upper heaters. Resistance heaters are used throughout, and precise control of the radial temperature uniformity across the entire wafer is possible with a lower heater system featuring inside and outside heaters

A Japanese team claims to have set a new benchmark for high throughput of high-quality epiwafers by developing a novel 150 mm SiC reactor.

The high-performance tool, which features high-speed wafer rotation and is capable of growth rates of

40-50 µm/hour, was developed through collaboration between five institutions: the Central Research Institute of Electric Power Industry (CRIEPI), Denso, NuFlare Technology, Toyota Motor Corporation and Toyota Central R&D Labs. In addition to the high growth rate – conventional reactors are limited to 30 µm/hour or less, according to reports from academia – strengths of the Japanese reactor include its capability to produce epiwafers that combine a low defect density with excellent thickness and doping uniformity.

Team-member Hiroaki Fujibayashi, who is affiliated to CRIEPI and Denso, believes that in order for a successful SiC device market to develop, there must to be a low-cost, 150 mm growth technology. And it must deliver a high-throughput of wafers with a low defect density and high uniformity.

“Therefore, I consider that the high quality and high throughput of a 6-inch SiC epitaxial growth process, such as that of our technology, can contribute to growth of the SiC power device market.”

The engineering team refer to their single-wafer tool as a ‘dual reactor system’. Thanks to its design, a throughput of 4 wafers/hour is possible, assuming a growth time per wafer of 15 minutes. Although a multi-wafer reactor has the potential for even higher throughput, there are several good reasons for preferring a single-wafer tool, according to Fujibayashi. He argues that single-wafer reactors are smaller, and this leads to a shorter heating-cooling time and reduced maintenance costs.

What’s more, he points out that the development of reactors accommodating even larger wafers is much easier with a single-wafer platform. With this type of tool, moving from a 150 mm wafer to a 200 mm wafer requires an increase in holder diameter of 50 mm; but with a multi-wafer reactor, the holder diameter would have to increase by 100 mm for an identical increase in wafer size.

High-speed wafer rotation is common for the epitaxy of silicon and III-Vs, where it provides high growth rates and enhanced uniformity. But, up until now, it has not been applied to SiC, due to the far higher growth temperatures – they are typically 1600 °C.

The team has determined the roles of rotation speed and pressure on growth rates. It has carried out a series of experiments involving deposition of SiC on 4H SiC substrates with a 4° off-cut silicon face. Rotating at 50 revolutions-per-minute (rpm), changes in pressure had little impact on growth rate. But when rotation was cranked up to 1000 rpm, changes in pressure from just below 100 mbar to almost 1000 mbar more than double growth rates to around 50 µm/hour.

At higher pressures, improvements in thickness uniformity with increasing rotation speed are magnified: At 500 mbar, uniformity can be around 0.25 percent at 1000 rpm, compared to 1.5 percent at 50 rpm, when uniformity is defined in terms of the standard deviation divided by the mean.

Really high pressures are not recommended, however. Simulations suggest that at 800 mbar a swirl of gas near the edge of the chamber can be generated, which could lead to particles that contaminate the wafer.

Employing a system pressure of 267 mbarand a rotation speed of 1000 rpm, engineers deposited a 9.3 µm film of

4H SiC on a 3-inch wafer at a growth rate of 37 µm/hour. Total morphological defects in this epiwafer were just 0.2 cm-2, while the root-mean-square roughness of the film was just 0.18 nm.

Turning to a 150 mm substrate and depositing a slightly thicker film at an identical pressure produced thickness and doping uniformities of 2.8 percent and 5.2 percent

(uniformities are defined in terms of the standard deviation divided by the mean, and calculated using a 6 mm edge exclusion).

H. Fujibayashi *et. al.*

Appl. Phys. Express 7 015502 (2014)

Nitronex selects Agilent software for high-power GaN design

The software will provide a complete GaN design flow that spans both device modelling and circuit simulation

Nitronex, a GaAs labs company and producer of GaN-on-silicon RF power devices, has selected Agilent's software for its GaN power device design.

The design flow uses Agilent EEsof EDA's IC-CAP model extraction software and Advanced Design System (ADS) circuit and system simulator - both platforms in RF and microwave design.

Gallium nitride has emerged as a semiconductor material of choice for designing RF power devices, providing a formidable combination of high bandwidth, efficiency and power.

In the case of Nitronex, whose GaN devices use silicon as a substrate, there is an added inherent cost advantage to its approach. Nonetheless, as with the development of any high-power device, designing for high levels of reliability, performance and yield requires investing in leading modelling and simulation technology.

"Agilent's software platforms offer a clear advantage for our design process," says David Runton, vice president of engineering at Nitronex. "The usability and simulation advancements of ADS, combined with its superior device models and IC-CAP model extraction software, puts us in the best position to offer top-quality GaN parts to our customers. And, because Agilent's tools offer a complete design flow, our design process will be more streamlined."

"We appreciate Nitronex's decision to transition to Agilent simulation and modeling tools for their future GaN designs," said Charles Plott, marketing manager with Agilent EEsof EDA. "What is particularly gratifying is the positive acknowledgement about our usability advancements. We have gotten uniformly positive feedback from companies as they reengineer their design flows with the latest nonlinear modeling technologies and simulator advancements."

ADS delivers a host of usability features to improve designer productivity and efficiency for all applications it supports, as well as capabilities specifically applicable to GaN design. Support for Agilent's newly introduced artificial neural network-based model (extracted by IC-CAP device modelling software), for example, enables much more accurate FET modelling and simulation results for high-power GaN FET amplifiers.

Additionally, an electro-thermal simulator (based on a full 3-D thermal solver natively integrated into ADS) incorporates dynamic temperature effects to improve accuracy in "thermally aware" circuit simulation results.

IC-CAP features capabilities specifically geared toward high-frequency device modeling, including turnkey extraction of Agilent's neural networked-based model as well as the Angelov-GaN model. GaN models in particular need to be well suited to deal with the impact of trapping and thermal effects on the device electrical characteristics.

POET restructures senior management and Connecticut University license

The firm aims to be first to market a practical III-V compound semiconductor solution in the industry's race to sustain Moore's Law beyond the constraints of traditional silicon

POET Technologies Inc. has announced changes to its executive team and board.

Peter Copetti has been named Executive Chairman and interim CEO. Copetti previously served as Executive Director and Chair of the Special Strategic Committee (SSC), which was dissolved, following its final report to POET's Board of Directors.

Leon M. Pierhal has stepped aside as CEO and will continue his role as President and member of the Board.

Also, Mark Benadiba has stepped down as Executive Chairman of the Board and will remain a member of the Board, as Vice Chairman.

An enthusiastic Peter Copetti, incoming Executive Chairman and interim CEO comments, "I am delighted to assume leadership of the Company's operational responsibility and strategic vision. I take the fiduciary duties associated with these appointments seriously, and intend to continue to provide superior returns and

value to shareholders. On behalf of the Board, I would like thank Mark and Leon for their commitment and contributions, and will continue to work with both of them in progressing POET's story to the next phase, which is expected to culminate in the monetisation of POET's proprietary platform and processes."

Peter Copetti adds, "Currently, POET is at an advanced stage in its 16-year development history. We are determined to be first to market with a practical compound semiconductor solution in the industry's race to sustain Moore's Law beyond the constraints of traditional silicon."

"POET intends to go to market with the world's first completely integrated optical and electrical device operating on a single die, and to fulfill its promise of vastly superior processing speed and energy utilisation in a patented production process that can ultimately be retrofitted to conventional fabs," concludes Copetti.

Leon M. Pierhal, President comments, "Semiconductors, computer technology and telecommunications were all, at one time, emerging industries in my forty-plus years in the technology industry. As a co-founder of POET, I'm immensely proud of my participation throughout the organisation's development life cycle. In this time, I steered the company through infancy, and shepherded POET safely through turbulent change. POET has since evolved from its origins as pure R&D, to a publicly-traded going concern trading on two markets in Canada and the U.S., to where it stands today - at an inflection point, where monetization of the POET platform is on the horizon, with fully-integrated optical-electronic chips leading the way for the semiconductor industry's next generation chip technology."

Pierhal continues, "Our position firm, I've decided to step aside as CEO and stay on as President and a member of the Board. This change in role allows me to spend time with family, and tend to overdue personal commitments that had been put aside, due to the arduous demands needed to bring POET to where it is today. Having worked closely with Mr. Peter Copetti over the past eighteen months, I am confident in Peter's ability to serve as CEO, and look forward to continuing to work together. I firmly believe Peter will deliver significant value on behalf of all stakeholders, and play a pivotal role in bringing the Company's technology to market."

Mark Benadiba, Vice Chairman, notes, "I want to personally express my gratitude to our Board and shareholders for the support they have given me through my tenure as Chairman. Of special note is that, without Peter and his tremendous efforts, we would not have accomplished the objectives that we have to date. I am certain that his leadership will serve our shareholders well going forward. Thank you, all."

The company also wishes to announce that it has entered into a term sheet with the University of Connecticut to restructure its license agreement of April 8th, 2003. The parties confirmed that the licenses granted pursuant to the License Agreement are in full force and are irrevocable.

While the maintenance fee provisions of the License Agreement remain unchained, the parties agreed to restructure the payment provisions by reducing the royalty payment to three percent of amounts received from unaffiliated third parties in respect of the exploitation of the Intellectual Property defined in the License Agreement.

In consideration for the favourable restructuring of the royalty terms, the Company will provide the University 2,000,000 common shares, subject to approval by the TSX Venture Exchange; trading of these shares is restricted until May 31st, 2016. The restructuring is subject to the final execution of the formal amendment to the License Agreement.

Copetti states, "I am extremely pleased with the University of Connecticut's vote of confidence in POET, exhibited by their taking an equity stake in the Company as an alternative to a higher potential royalty revenue stream. At the same time, their decision will greatly enhance the Company's ability to monetise the POET technology and create shareholder value."

The company remains on track with its technology roadmap, and will shortly be providing updates to all stakeholders on progress and achieved milestones to date.

POET Technologies is the developer of the POET platform for monolithic fabrication of integrated circuit devices containing both electronic and optical elements on a single semiconductor wafer. With head office in Toronto, Ontario, Canada, and operations in Storrs, CT, the Company, through ODIS Inc., a U.S. company, designs III-V semiconductor devices for military, industrial and commercial applications, including infrared sensor arrays and ultra-low-power random access memory.

EpiGaN honoured for revenue and growth

The company has been recognised by Trends Magazine for its progress in gallium nitride on silicon technology

EpiGaN, a provider of III-nitride epitaxial material solutions, was awarded the 'Trends Gazelle Starter 2014 'in the Province of Limburg by Trends Magazine.

The annual award recognises EpiGaN to have fostered positive momentum in revenue and employee growth in a three year time span.

“EpiGaN has experienced positive revenue and cash flow since its inception in 2010,” says Marianne Germain, co-founder and CEO of EpiGaN.

She continues, “We are honoured by this award to be recognised by Trends Magazine for our stellar growth over the past few years. It is the dedication of our team that has enabled us to maintain consistent growth by shipping products to customers worldwide from our facility in Hasselt.”

The company now has ten employees and is planning to grow the organisation further in 2014 to support its manufacturing expansion.

EpiGaN has a strong technical foundation with leading-edge semiconductor material products. Its GaN - on -silicon wafers are being used to create high voltage power and high frequency RF devices that in turn are being used to save energy in consumer electronics, industrial power supplies, AC drives, cellular base stations, cable TV infrastructure and other things.

The company has its cleanroom manufacturing facilities locally in Hasselt, Belgium located in the triangle Aachen, Eindhoven and Leuven . EpiGaN is one of the few Flemish companies that does not outsource manufacturing of high tech products, making it a valuable contributor to the local economy.

High pressure laser doping of GaN

To improve gallium nitride device performance for high-frequency RF applications, AppliCote is developing a high pressure laser doping process

Contact resistance and access resistance in deeply scaled FET devices greatly impact device performance at high frequency. This is of particular importance for GaN-based devices, which can achieve high power at high frequencies (>100 GHz).

Several processes have been developed to address these resistance issues, but these processes all have drawbacks.

For example, ion implantation can be used to increase the concentration of electrically active impurities in the source and drain regions of the device, but this process requires high temperatures for electrical activation, along with capping layers to prevent GaN decomposition.

In addition, implantation creates lattice damage that is difficult to remove via annealing and acts to compensate the dopants.

To improve GaN device performance for high-frequency RF applications, AppliCote is developing a high pressure (greater than 500 psi gas/vapour precursor) laser doping process.

The procedure will introduce electrically active *n*-type impurities into the source and drain regions of a GaN device to reduce contact resistance and decrease access resistance from the metal contact to the two dimensional electron gas (2DEG) in the device.

Low pressure (less than 60 psi gas/vapor precursor) laser doping process that has been successfully used and reported previously with numerous materials, including GaN, SiC, silicon/SiGe, and silicon-based photovoltaics.

Processing parameters for high pressure doping of silicon carbide have been developed (patent pending). Applicote plans to optimise processing conditions for doping GaN with silicon using a gaseous precursor and answer key questions about the electrical properties of the laser-doped GaN as well as process control and capabilities.

The high pressure laser doping process is a combination of a thermally driven process resulting from the interaction of the semiconductor with a high-power, short-duration laser pulse and a pressure driven process to increase dopant concentration to maximum solubility levels at deep depths while mitigating surface damage.

The laser pulse results in an ultra-fast thermal ramp (1010 K/s) and impurity incorporation through decomposition of chemisorbed gas-phase source species and thermal diffusion of atoms into the crystalline lattice.

Impurity incorporation rate, diffusivity, and activation are all functions of the laser wavelength, power, and pulse time and precursor pressure.

Applicote has built a laser system and processing chamber for high pressure laser doping for rapid processing of substrates and simplification of the device fabrication process.

The technology will also be expanded to carbon doping of silicon wafers to create a surface region of SiC in silicon to accommodate GaN thin film deposition.

Prototype Laser Materials Synthesis Apparatus

AppliCote has its corporate headquarters in Lake Mary and the laser processing lab in Mount Dora, both in Florida.

Equipment and Materials

Sapphire market to fire up

The highlighting features of sapphire are high efficiency, good thermal and electric properties, and longer life. The material is best suited for LEDs, power electronics devices and display covers for consumer electronics

The global sapphire market by substrate is expected to reach $3.01 billion by 2020 at a CAGR of 12.31 percent, where as the Global Sapphire Technology Market for devices is expected to reach $6.17 billion by 2020 at a CAGR of 12.24 percent.

So says the report, “Sapphire Technology Market by Growth Technologies (Substrate Wafer (Si-on-Sapphire, SiC-on-Sapphire, GaN-on-Sapphire, and Others), Devices, Applications, and Geography - Analysis & Forecast to 2013 - 2020,” from marketsandmarkets.com.

The analyst says sapphire is gaining attention due to an effective cost matrix and leads to a longer life cycle with greater reliability.

The Sapphire Technology Market is expected to captivate essentials for new entrants as well as winning opportunities for the established players

The Americas has been identified as the fastest growing region, with U.S leading the way. Europe also has a very promising market with Germany and the U.K. while the ROW also impetus to the growth.

The competitive landscape of the market presents a very interesting picture, where a large number of small players have become a force to reckon with. The market is witnessing a large scale collaboration and partnership across the value chain with number of tier-one players around the globe.

Major players in this Sapphire Technology Market include: GT Advanced Technology (U.S.), Rubicon Technology (U.S.), Namiki Precision Jewel Co. Ltd (Japan), Monocrystal Inc. (Russia), and DK Aztec Co. Ltd (Korea).

New shares from Aixtron stock options to be traded under separate ISIN

New shares resulting from exercised options will be traded on the Frankfurt Stock Exchange under a separate ISIN

Aixtron SE, has a number of stock option programs in place that grant employees the right to purchase Aixtron shares under certain conditions.

Under the terms of the stock option plan 2007, stock options can currently be exercised. New shares resulting from exercised options are not entitled to a dividend for fiscal year 2013 and will therefore be traded on the Frankfurt Stock Exchange under the separate ISIN DE000A1YDC08 until and including the day of the Annual General Meeting 2014 on May 14th, 2014.

Aixtron’s Executive and Supervisory Boards will propose to the shareholders’ meeting that the 2013 loss should be carried forward.

Craic develops thin film thickness software for sub-micron sampling

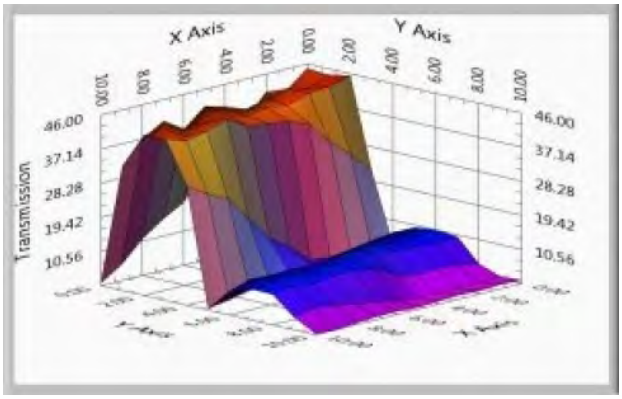
The company’s FilmPro software is used with Craic Technologies’ microspectrometers to measure the thickness of thin films of microspot areas in both reflectance and transmission

Craic Technologies, an innovator of UV-visible-NIR microanalysis solutions, is introducing Craic FilmPro film thickness measurement software.

This software package is designed to plug-in to Craic

Technology's microspectrophotometers and their controlling Lambdafire software. Craic FilmPro allows the user to measure the thickness of thin films rapidly and non-destructively.

Able to analyse films of many materials on both transparent and opaque substrates, Craic FilmPro enables the user to determine thin film thickness on everything from semiconductors, MEMS devices, disk drives to flat panel displays. The software can be used in many different fields and in everything from research to industrial settings.



Film Thickness Mapping

"Many of our customers want to measure the thickness of thin films of smaller and smaller sampling areas for rapid quality control of their products. Craic FilmPro is a plug-in module that can be added to a Craic Technologies microspectrophotometer to enable this capability. This software was built in response to customer requests for a powerful, flexible film thickness tool that can measure sub-micron areas on both transparent and opaque substrates.Craic Technologies microspectrophotometers equipped with Craic FilmPro meets those needs" says Paul Martin, President.

The complete Craic Technologies microspot film thickness solution combines an advanced microspectrophotometer with the sophisticated Craic FilmPro software. This software is a plug-in module to Craic Technologies Lambdafire instrument control software.

It enables the user to measure film thickness by either transmission or reflectance of many types of materials and substrates.

Due to the flexibility of the Craic Technologies design, sampling areas can range from over 100 microns across to less than a micron. Designed for both research and the production environment, it incorporates a number of easily modified processing recipes, the ability to create new film recipes and sophisticated tools for analysing data.

With the addition of spectral mapping from Craic Technologies, the firm says film thickness maps of entire devices can be created.

Rudolph reports record installations for semiconductor software

Increasing demand for productivity information has been driven by needs for better yields in LEDs and compound semiconductor manufacturing

Rudolph Technologies says it has completed record installations in Q4 2013 of its fab-wide yield management software (YMS) products, Discover Enterprise and Genesis Enterprise.

These packages are used by semiconductor manufacturers to obtain process yield and equipment productivity information.

In addition to traditional semiconductor manufacturing, Discover Enterprise Software was installed at a multi-billion dollar OEM in multiple labs, replacing the incumbent technology.

Rudolph attributes the rise in adoption to the industry's growing need for productivity data as it seeks to increase the yields of new, increasingly complex manufacturing processes.

The data necessary to generate productivity information comes from many different sources throughout the fab: inspection and metrology systems, tool sensors, tool recipes, electrical tests, and the fab environment.

As the complexity and cost of manufacturing processes increase, the value of faster, better analysis to support critical manufacturing decisions grows too, so customers are demanding robust yield management systems that can analyse large, complex data sets quickly and effectively.

Rudolph's fully-integrated YMS solutions are designed to analyse data from disparate sources and multiple sites to maximise productivity across the entire value chain.

"Improving quality and yield as well as tool productivity were the paramount reasons we selected Rudolph's YMS solutions," says Philip O'Leary, Six Sigma Master Black Belt, Murata Electronics Oy, a designer and manufacturer of silicon capacitive sensors: accelerometers, gyroscopes, combined sensors and inclinometres.

He adds, “The development of better processes and tool productivity will have direct, positive impact on our yield, and ultimately, create a better product for our customers. The ease of installation was remarkable and the product demonstrated immediate value. In addition, the scalability of the software will facilitate our future expansion plans.”

Mike Plisinski, vice president and general manager of Rudolph’s Data Analysis and Review Business Unit, comments, “The integration of our yield management system technologies, Discover Enterprise and Genesis, provides customers with a system designed for storage and alignment of a wide array of data types as well as patented analytics to transform that data into valuable information to help our customers optimise their process, improve equipment productivity, and more rapidly bring new technologies to market.”

Discover Enterprise is a real-time manufacturing monitoring and in-line yield management system that provides the foundation of a fully-integrated database and analytical routines that help semiconductor, LED, compound semiconductors, automotive, FPD, HDD and other related manufacturers improve yield, productivity and profitability in their manufacturing lines.

It integrates and analyses data from all inspection, metrology, process, and test systems in the fab and across the supply chain to provide a complete report of fab-wide yield problems, turning raw data into actionable information separating random from systematic yield loss. Process engineers use this information to optimise process tool performance (fleet management) and quickly identify and correct the causes of yield excursions.

Genesis Enterprise is an offline yield management system that provides data mining, genealogy (unit tracking) and correlation of all data types across the supply chain. The system is designed to maximise factory efficiency and automate the drill down process identifying causes of yield loss.

It can be integrated directly with the Discover Enterprise database or be used offline for yield analysis and data mining connecting to raw data files and 3rd party systems. Analysis algorithms identify domain-specific issues, such as wafer processing sequence problems, commonality of effects, product characterisation and systematic versus random yield loss.

Genesis software handles data from any source: parametric, defect, memory, design, or assembly and packaging; and integrates all-surface defect analysis, fault detection, and run-to-run process control to help users achieve maximum efficiency.

5N Plus takes on Richard Perron as CFO

The 5N Plus, a producer of specialty metal and chemical products, has taken on Richard Perron as Chief Financial Officer of the company, effective March 17th, 2014. Perron succeeds David Langlois who will be leaving 5N Plus to pursue other interests. Richard Perron has nearly twenty years of international experience as a finance professional. From 2006 to the present, Perron has held progressively senior roles and has gained valuable experience within Arcelor Mittal and more recently as the Chief Financial Officer (CFO) and Strategy Manager of Long Carbon Americas, one of Arcelor Mittal’s most important business units.

In this role, he was responsible for all countries of the Americas generating a total of $11 billion in annual sales, with 17,900 employees and more than twenty-five key operations and plants among countries like Canada, USA, Mexico, Costa Rica, Trinidad and Tobago, Brazil and Argentina. From 1999 to 2006, he served as Director, Finance and Control and Perron has a B.Com. degree in Accounting from Concordia University, an M.Sc. in Administration, Management and Accounting, and an M.B.A. from the University of Sherbrooke.

He is a certified public accountant (CPA) in the USA (IL & DE) and a chartered professional accountant in the Province of Quebec, Canada.

“His broad in-depth knowledge of the market, strong leadership skills and hands-on approach will greatly contribute to help us execute our growth strategy, which calls for both organic and acquisition related initiatives,” says L’Ecuyer, president & CEO of 5N Plus.

ASM stays in business with ALSI

ALSI has developed unique processes for dicing GaAs, high and ultra HB-LEDs, transistors and diodes

ASM Laser Separation International (ALSI) B.V. (“ASM ALSI”) will continue the business of Advanced Laser Separation International (ALSI) N.V. (“ALSI”) in Beuningen.

ASM ALSI intends to continue the business of ALSI as presently conducted including relationships with key customers, suppliers and other business partners.

ASM ALSI is a wholly owned subsidiary of ASM Pacific Technology Ltd (ASMPT), which is listed on the Hong

Kong Stock Exchange and an assembly and packaging equipment supplier for the semiconductor and LED industries, and the world's third largest SMT equipment supplier.

As a subsidiary of the ASMPT group, ASM ALSI brings both the financial and technological strength to the business of ALSI that it needs to move to the next phase of expansion and development.

Richard Boulanger will continue as the managing director of ASM ALSI and all key employees of ALSI have expressed their commitment to continue their employment with ASM ALSI.

Customers, suppliers and other business partners of ALSI will be informed shortly in more detail.

"We are very pleased to have ASM ALSI as a part of ASMPT. The multi-beam laser technology developed by ALSI offers customers unparalleled value. With the strong sales and service network of ASMPT, we can help to bring unique value to many customers at much faster pace", comments WK Lee, CEO of ASMPT.

Richard Boulanger also comments that, "We are excited to be part of the ASMPT organisation. We believe that ASMPT's excellent reputation and Global Sales and Service network will accelerate our Market Penetration especially for the Grooving Market as well as our other established markets. It will also increase our level of commitment and support to our customers. "

ALSI introduced the Multi Beam Laser Technology and has developed unique processes for dicing GaAs, Transistors and Diodes, High and Ultra High Brightness LEDs. The firm has now introduced the Matrix Grooving Process for the IC Market.

Optoelectronics boosted by multi-million pound order

A cluster system order received by Oxford Instruments will improve the energy efficiency performance of electronic and optoelectronic devices

Oxford Instruments has recently received a multi-million pound order for a complex deposition and analysis cluster system from the James Watt Nanofabrication Centre at the University of Glasgow.

The system will enable development to improve the energy efficiency performance of electronic and optoelectronic devices for a large range of applications.

Through its Plasma Technology and Omicron Nanoscience businesses, the Oxford Instruments Nanotechnology Tools business sector was able to provide the broad range of technologies necessary for this 'Powerhouse' multi-chamber and multi-function system.

This Oxford Instruments four chamber cluster system combines the following: Plasma Technology's FlexAL Atomic Layer Deposition tool used for depositing very thin films of metals, oxides and nitrides using both thermal and inductively coupled plasma (ICP) ALD processes, a PlasmaPro System100 ICP for etching of compound semiconductor materials and a PlasmaPro System100 ICP for High-Density PECVD deposition system providing for low damage, low temperature thin films; plus the Omicron Nanoscience NanoSAM LAB, for surface sensitive chemical analysis and high resolution imaging of small (micro and nano) structures by Scanning Auger Microscopy) and Scanning Electron Microscopy.

These systems will be combined in a unique configuration, and under vacuum, allowing device manufacturing and characterisation measurements to be performed on device interfaces and surfaces without exposure to atmosphere. This is a very exciting development for Oxford Instruments.

They will be used in projects that will develop applications and improve the efficiencies of electronic and optoelectronic devices, and aid in the reduction of ICT energy consumption and carbon emissions.

Projects include ''Silicon compatible GaN power electronics'' developing energy efficient power electronics, and ''Scalable solar thermoelectrics and photovoltaics'' where the objective is to dramatically reduce the cost of large scale exploitation of solar energy and in so-doing massively decrease the carbon dioxide emissions associated with electrical and thermal power generation.

Douglas Paul, Director of the James Watt Nanofabrication Centre at Glasgow, comments, "We chose Oxford Instruments systems for a number of reasons: our long and successful collaboration history, Oxford Instruments was the manufacturer who could integrate an analysis chamber with sub-10 nm

resolution for chemical analysis (essential for many nanodevices), and also because of the very strong third-party recommendations we received about the capability of their ALD system. We are looking forward to the extensive research opportunities this system will enable."

Mark Sefton, Sector Head for Oxford Instruments Nanotechnology Tools adds, "This substantial order from a leading British research institute is great news for us. Our group of businesses offers the research community the opportunity to integrate a range of our high technology fabrication and analysis tools, rather than having to approach multiple suppliers. Longer term benefits are that our dedicated process, service and support team will be able to offer Glasgow University the cohesive process applications and system support on the entire system that they will require."

Oerlikon takes pump engineering into a new dimension

New turbo molecular vacuum technology for the analytical and R&D markets can be used in the MOCVD growth of III-V semiconductors

Oerlikon says its new pumps of the TURBOVAC i product line offer high performance for widely differing requirements. Through their additional compression stage, the TURBOVAC 350 i and 450 i are suited for ultra-high vacuum applications and for integration within compact pump system solutions.

Offering a pumping speed for light gases which is claimed to be up to 60 percent above that of comparative products, and a compression level which the company says is approximately a hundred times higher compared to products of the previous generation, these pumps were designed especially for processes with small backing pumps.

The TURBOVAC T 350 i and T 450 i designed with classic rotorshave technology and have a high gas throughput, fast run-up time and insensitivity to particulates and are optimised for process applications and high gas loads.

TURBOVAC 350i *TURBOVAC 450i*

The TURBOVAC 350-400 i Multi Inlet pumps have been developed to meet the requirements of analytical instrumentation by offering a high degree of flexibility and allowing the customisation of the number, height and

position of the vacuum connections.

Additionally, there is the option of adapting the pump housing or customszing the pump to a specific vacuum chamber.

“With the best ratio between performance and size in the ISO 100- and 160-range, our new turbo molecular pumps offer an innovative concept. Rotors and Holweck stages have been optimised. The result is excellent vacuum performance and a previously unattainable pumping speed. This accelerates pumping especially in connection with light gases,” says Martin Füllenbach, about the new line of turbo molecular pumps.

The maintenance and oil-free hybrid bearings with lifetime lubrication make regular maintenance by way of oil changes superfluous. The bearing system ensures low vibration and low noise operation - thereby being less demanding with respect to applications which are sensitive to vibrations. The ceramics ball bearings are replaceable on-site should this be required.

TURBOVAC multi-inlet

The thermal design of the TURBOVAC i ensures optimum cooling of the bearings. To protect the bearings against critical gases or particles, all pumps have been equipped with a purge gas connection. Oerlikon says this increases the service life of the pump and system uptime.

The TURBOVAC i family offers numerous options for fulfilling a wide range of different requirements. Both the TURBOVAC 350 i and also the 450 i are available with an additional interstage port allowing pumping down of an additional chamber.

In order to keep installation, operation and maintenance as simple as possible, the TURBOVAC i is equipped with a rotatable vacuum flange connection, integrated drive electronics with direct 24/48 V DC supply as well as a flexible communication interface with USB, RS 485 and digital I/O ports.

Additional interface options are available upon request.

A flexible and comprehensive range of accessories supplements the new product line. It comprises among other things cost-effective power supplies for 100 V to 240 V mains supplies (either on-board or stand-alone), adjustable air or water cooling units, heating jackets, venting and purge gas accessories (actively controlled, passive) as well as installation and mounting kits which assist commissioning.

Edwards’ big vacuum pump enhances performance

State-of-the-art technology improves gas flow capability and high temperature management to prevent powder deposition

Edwards Limited, a manufacturer of sophisticated vacuum products and abatement systems used in MOCVD manufacturing, has introduced the STP-iXA4506.

This is a large-capacity turbomolecular pump (TMP), designed to deliver significant savings for cost-sensitive manufacturers of semiconductors, flat panel displays, LEDs and solar panels.

STP-iXA4506

“The new STP-iXA4506 turbo pump is the all-in-one solution with improved pumping performance,” states Shinichi Yoshino, TMP Product Marketing Manager, Edwards.“It pairs Edwards’ latest rotor design with the well-established, highly reliable, on-board controller of the iXA series, to maximise the allowable gas throughput and, hence, minimise the number of pumps required for high-flow processes, particularly in solar and flat panel applications.”

Yoshino continues, “The fully-integrated controller

eliminates the need and cost of cables and a separate controller rack, resulting in a compact package that is fast and easy to install in a variety of applications. And, like all of our magnetically-levitated turbo pumps, the absence of mechanical bearings practically eliminates the cost of periodic maintenance."

The pump's high speed (4300 l/s N2) and throughput (up to 4300 sccm N2), combined with its ability to efficiently pump both light and heavy gases, make the STP-iXA4506 ideal for a wide range of large-volume, high-flow applications, including semiconductor etch, LCD etch, glass coating, solar PVD and coating PVD.

Its tightly-integrated design includes a completely sealed electronic module for robust, reliable operation in the most demanding factory environments. When needed, a thermal management system can be added to reduce the accumulation of deposits and particulates from process byproducts.

Edwards is a developer and manufacturer of sophisticated vacuum products, abatement systems and related value-added services. These are integral to manufacturing processes for semiconductors, flat panel displays, LEDs and solar cells; are used within an increasingly diverse range of industrial processes including power, glass and other coating applications, steel and other metallurgy, pharmaceutical and chemical; and for both scientific instruments and a wide range of R&D applications.

Samco to purchase ninety percent of issued shares of UCP

UCP, manufactures and sells precision plasma cleaning systems for semiconductor production

Samco Inc., a provider of plasma etching and CVD solutions to compound semiconductors device manufacturers, has made an agreement with Büchel Holding to purchase ninety percent of the issued shares of UCP Processing Ltd.

UCP, a wholly-owned subsidiary of Büchel, is located in Liechtenstein and manufactures and sells precision plasma cleaning systems for semiconductor production.

1. The Purpose of the Stock Purchase

Samco has been primarily engaged in the manufacture and sales of process equipment for compound semiconductor production, especially catering to applications such as LED and power devices. Samco has been focused on expansion of its product sales internationally, and currently has direct sales and service offices in the United States, China, Taiwan, South Korea, Singapore, and Vietnam.
Furthermore, Samco has been seeking the opportunity to establish sales and/or service offices in Europe. The acquisition of UCP will lead to the establishment of a Samco office at UCP's location in Liechtenstein, in the central part of continental Europe, and will give Samco better access to customers in Germany, France, and Italy, three important European markets.

Additionally, Samco foresees a positive synergy effect in the acquisition, as both Samco and UCP have abundant experience in the manufacture and sales of plasma cleaning systems. After the acquisition of UCP, Samco plans to sell its products (e.g. plasma etching and CVD systems) using UCP's existing sales network in Europe.

2. UCP Company Information

1. Company Name: UCP Processing Ltd.
2. Head Office: Industriering 10, LI-9491 Ruggell, Liechtenstein
3. Establishment: October 8, 2003 (became independent from Balzers & Leybold AG)
4. Main Office: Same as Head Office
5. Main Business: Manufacture and sales of plasma cleaning systems for semiconductor production
6. Capital: 1,155,000 CHF
7. Number of Directors and Employees: Less than ten (10), as of Janmber 2013
8. Sales Revenue in 2013: 2,043,000 CHF

3. Details about Stock Purchase

1. Amount of Shares to be Purchased: 9.45 shares ninety percent of the issued shares of UCP
2. Method of Payment for Shares: Cash
3. Fundraising: Imprest Fund
4. Method of Acquiring Shares: Through purchase of shares from Büchel, which possesses a hundred (100) percent of the UCP shares
5. Purchase Schedule: Contract to be finalised by April 30th, 2014.

4. Details about Büchel

1. Company Name: Büchel Holdings
2. Head Office: Industriering 10, LI-9491 Ruggell, Liechtenstein
3. CEO: Büchel Herbert

5. The Effect on Samco Sales Revenue

Samco will publish details about the effect of this UCP acquisition on sales revenue if it is necessary in accordance with the relevant law.

Evatec enhances GaAs PVD processing capabilities in U.S.

The company has delivered multiple RADIANCE cluster sputter tools to a major US GaAs fab supplying products to the RF industry

Evatec is shipping tools to support expansion of the fab's 6" GaAs production requirements to an undisclosed U.S. company.

The system enables implementation of new bump metallisation and high fill ratio barrier layer processes leading to significant cost savings.

Pictured below is a typical RADIANCE cluster tool with twin cassette stations, central handler with dual arm robot connected to three process modules- a batch process module with five sputter sources, a single process module with one large cathode , and a single process module configured with three smaller sources for co-deposition.

Evatec RADIANCE tool

Evatec says it was chosen for their high throughput and superior process stability leading to increased yield and reliability performance.

RADIANCE itself is a sputter tool, which can be configured for multiple technologies on a single platform.

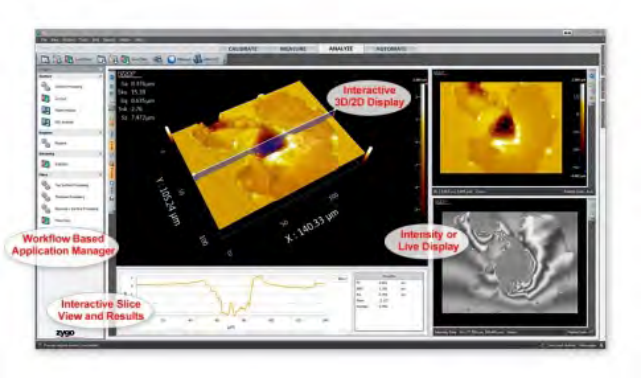
Single process modules can be configured for PVD, PECVD or ICP etch, whilst a 6 process position 'BATCH' module can be equipped for sputter and etch processes, allowing for *in-situ*processes on the same platform.

The RADIANCE flexibility combined with process knobs such as substrate rotation, target to substrate distance and in situ metrology capabilities such as optical monitoring makes the tool an ideal choice for development and production facilities across a wide range of market applications from compound semiconductors to optoelectronic applications.

Evatec delivers complete process solutions for thin film deposition and etch to the semiconductor, MEMS, optical and optoelectronic industries around the globe. With a technology portfolio including enhanced evaporation and sputtering, Evatec engineers are able to offer practical production advice from R&D to mass production.

Zygo 3D optical profiler enhances surface metrology

The tool can be used to view the surface morphology on III-V based wafers



Zygo Corporation is launching the NewView 8000 series of 3D optical profilers.

This latest generation in the NewView product family, the NewView 8000 systems provide rapid, precise, quantitative, and interactive surface metrology.

The modular platform has been designed to meet the metrology and budgetary requirements of a wide range of applications in scientific research, product and process development, and volume manufacturing.

NewView 8000 optical surface profiler

The two models of NewView 8000 series of benchtop profilers, each configured for different performance requirements, are based on non-contact optical technology and powered by Zygo's Mx software.

The NewView 8000 profilers provide hundreds of surface results and analyses, including the latest ISO 25178 area surface texture parameters for quantitative analysis. In addition, the systems offer exceptional surface visualization via optimised optical design and advanced surface detection algorithms.

The user is now able to truly "see" surfaces through real time interactive analysis with 2D and 3D plotting technology. The integrated isolation and workflow-based Windows® style interface of the NewView 8000 series simplify installation and provide enhanced ease-of-use.

The NewView 8000 systems offer a wide range of application capabilities that include the metrology of roughness, flatness, angles, steps, and more, for applications ranging from precision-machined automotive components to patterned semiconductor wafers, to microfluidics and MEMS.

Specialised software modules - for measurement in the presence of transparent films, and for 2D vision analysis - are available for expanded functionality. Advances in both hardware and software enable the use of ZYGO proprietary SureScan acquisition technology, to produce extremely precise measurements even in noisy and vibrating environments.

"The NewView profilers have always been strong performers for ZYGO. The improvements integrated into the NewView 8000 series result in more data, more quickly, for our customers. We're excited to bring this new benchtop optical profiler family to market and look forward to the expanded application opportunities its enhanced capabilities enable for our customers," comments Tony Allan, Zygo Corporation Chief Operating Officer.

Zygo is launching the NewView 8000 series of profilers at the SPIE Photonics West 2014 exhibition in San Francisco, California.

Entegris to acquire ATMI for $1.15 billion

The transaction combines two preeminent suppliers of critical technology to the compound semiconductor Industry

Entegris is to acquire ATMI for a total equity value of approximately $1.15 billion on a fully-diluted basis, or approximately $850 million net of cash acquired, including the net cash proceeds from the sale of ATMI's LifeSciences business of $170 million.

Under the terms of the merger agreement, ATMI shareholders will receive $34.00 in cash, without interest or dividends, for each share of ATMI common stock they hold at the time of closing. The companies anticipate closing the transaction in the second quarter of 2014.

The price represents a premium of 26.3 percent to ATMI's closing price of $26.93 on February 3rd, 2014. The transaction is expected to yield approximately $30 million in annualised cost synergies. Entegris expects to fund the all-cash transaction with a combination of existing cash balances and additional committed debt financing, and expects it to be immediately accretive to non-GAAP earnings per share (EPS).

The combination brings together two key suppliers in the semiconductor industry to create a technology leader in advanced process materials, contamination control and wafer handling.

By leveraging ATMI's market-leading critical products, global infrastructure and expertise in key processes, Entegris will have an even stronger platform to serve the demanding technology needs of the world's largest semiconductor makers and other electronics companies.

The transaction will also provide a broader set of growth opportunities, and the company will sustain its investments in R&D, infrastructure and metrology to support that growth.

Bertrand Loy, President and Chief Executive Officer of Entegris says, "ATMI's microelectronics business is an excellent fit with Entegris and provides us with a

premium portfolio of products that will enable us to create enhanced value. ATMI and Entegris share a long and successful history of solving some of the most difficult yield challenges facing the industry."

Loy continues, "Together, we will be uniquely positioned with innovative yield-enhancing solutions to address the increasing complexity and cost of new semiconductor processes. Upon closing, approximately 80 percent of our product sales will be unit-driven and focused on the most rapidly growing and critical areas of the semiconductor fab. We are excited about the opportunities ahead and look forward to quickly realising the significant benefits of this transaction for our shareholders, customers and employees."

Doug Neugold, President and Chief Executive Officer of ATMI, comments, "Throughout this process, our goal has been to enter into a transaction that not only maximises shareholder value, but also places our business with the right partner for our valued customers and employees. We are pleased to merge our microelectronics business into Entegris. Entegris' global platform and complementary products represents a great opportunity for ATMI stakeholders, including our shareholders, who will receive an immediate premium for their investment."

Financial Benefits

The combination is expected to generate annualized cost synergies of approximately $30 million, achieved through identified operational efficiencies and overhead consolidation. The combined company will have an efficient balance sheet, benefitting from the deployment of excess cash and the addition of attractive debt financing.

The transaction is expected to be immediately accretive to non-GAAP EPS with the potential for significant earnings leverage as the combined company's cash flow generation enables the repayment of debt.

Closing Conditions

The transaction is subject to regulatory approvals of both U.S. and international regulators, including expiration or termination of the applicable waiting period under the Hart-Scott-Rodino Antitrust Act, as well as other customary closing conditions. The transaction is also subject to approval by ATMI shareholders.

The transaction is also conditioned on the closing of ATMI's previously announced sale of its LifeSciences business, which is expected in the first quarter of 2014.

Entegris and ATMI hosted a joint conference call which can be accessed via telephone by dialling (800) 585-8367 or (404) 537-3406 and using the passcode #59322873, or by accessinghttp://investor.entegris.com/events.cfm.

Entegris provides a wide range of products for purifying, protecting and transporting critical materials used in processing and manufacturing in semiconductor and other high-tech industries.

ATMI, Inc. is a global provider of specialty semiconductor materials, and safe, high-purity materials handling and delivery solutions designed to increase process efficiencies for the microelectronics, life sciences, and other industries.

IQE reveals industry's first 150mm InSb substrates

The indium antimonide substrates are suited for use in MWIR focal plane infrared detectors

IQE is, this week, presenting a series of invited papers on recent key developments in advanced photonic technologies at optoelectronics event, Photonics West.

One of the papers announces what IQE says is an industry first; the commercial growth and characterisation of 6" diameter InSb substrates that are suitable for use in the fabrication of MWIR focal plane infrared detectors.

Mid-wavelength infrared (MWIR), also called intermediate infrared (IIR) devices, are in the 3 to 8 µm range.

Growth and characterisation of 6" InSb substrates for use in large area infrared imaging applications

In addition to the 150mm InSb announcement, IQE will establish a strong presence at Photonics West with the presentation of a further two invited papers by the Group's infrared division:

GaSb-based photodetectors covering short-wave to long-wave IR grown by MBE

Molecular beam epitaxial (MBE) growth of GaSb-based photodetector structures spanning the short-wave to long wave IR spectral range. Barrier-type nBn detectors, grown on 4-inch GaSb or 6-inch GaAs.

Multi-wafer growth of GaInAs photodetectors on 4" InP by MOCVD for SWIR imaging applications

Growth of InP/GaInAs photodetectors on 4" InP by MOCVD.

Disordered crystals: A replacement for classic nitrides?

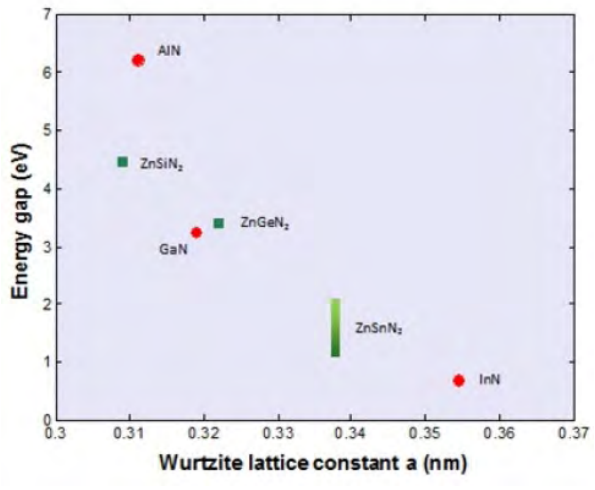
The race is on to identify the band gap energy and carrier mobility of the new semiconductor ZnSnN2

Recently, the European Commission has flagged the supply of both gallium and indium as "at risk," recommending that market conditions be closely monitored to avoid production bottlenecks.

Enter theorist Walter Lambrecht, who pointed out that there is an interesting family of semiconductors composed of zinc, silicon, germanium, tin and nitrogen which is analogous to the pervasive (Al,Ga,In) nitride family – and completely gallium and indium free.

Intriguingly, ZnSiN2 and ZnSnN2 fit into the category of what many are calling "earth abundant element semiconductors," a reference to the relatively low crustal abundance of gallium and indium.

Ultraviolet band gap ZnSiN2 has been synthesised previously, but the lower-energy tin-based family member (critical for photovoltaics and visible wavelength devices) has only recently been reported. In 2013, three groups, each using a different technique, obtained crystalline samples of ZnSnN2. These were Case Western Reserve University, the California Institute of Technology, and the University at Buffalo.



The race is now on to identify intrinsic properties such as band gap energy and carrier mobility of this new semiconductor. Surprisingly, the collaboration (Buffalo, London, and Liverpool) has observed experimental evidence for disorder-induced reduction of the band gap. This was predicted by density functional theory calculations to span from 1.1 to 2.1 eV.

The phenomenon occurs as the sub-lattice containing zinc and tin atoms is variously "scrambled" while the host material remains single crystalline. This could enable a radically new approach to band gap tuning for optoelectronic devices: through controlled disorder in a crystalline material via growth conditions, not alloying, as postulated three decades previously.

This work was conducted in conjunction with Steve Durbin at Western Michigan University and the University at Buffalo, David Scanlon at University College London and Tim Veal at the University of Liverpool.

The work is described in detail in the papers,

" Growth, disorder, and physical properties of ZnSnN2," by N. Feldberg *et al* in *Applied Physics Letters,*103, 042109 (2013). doi: 10.1063/1.4816438

and

"Growth of ZnSnN2 by Molecular Beam Epitaxy," by N. Feldberg *et al* in *Journal of Electronic Materials*.DOI: 10.1007/s11664-013-2962-8

Showa Denko boosts ammonia production capacity in China

The company is strengthening its supply of gases for LED semiconductor production

Showa Denko (SDK) has increased the production capacity for high-purity ammonia at its manufacturing subsidiary in Zhejiang Province, China, from 1,000 t/y to 2,000 t/y. The expanded facility started operation this month.

Zhejiang Quzhou Juhua Showa Electronic Chemical Materials Co., Ltd. Site

High-purity ammonia is used for nitride film deposition

in the manufacturing processes of liquid crystal display (LCD) panels and LEDs. While LEDs are used for general lighting and backlight for LCDs, the LED market in China is growing for such new applications as landscape lighting and large screens, in addition to general lighting.

Thus, SDK has strengthened its supply system to meet the growing demand for high-purity ammonia in East Asia, where electronics production sites are integrated.

SDK is operating three high-purity ammonia plants, one each in Japan, Taiwan, and China. Following the capacity expansion in China, SDK now has a total high-purity ammonia production capacity of 6,000 tons a year.

SDK's high-purity ammonia production sites and their capacities, as of January 31st 2014 include:

1. Japan: SDK's Kawasaki Plant (Kawasaki City) 1,500 t/y
2. Taiwan: Taiwan Showa Chemicals Manufacturing Co., Ltd. (Tainan City) 2,500 t/y
3. China: Zhejiang Quzhou Juhua Showa Electronic Chemical Materials Co., Ltd. (Quzhou City, Zhejiang Province) 2,000 t/y

Under its consolidated business plan PEGASUS Phase II, SDK classifies the semiconductor-processing high-purity gas business as a "Growth" business. SDK will aim to further globalise the business this year, strengthening the production/distribution system in Asia and expanding sales.

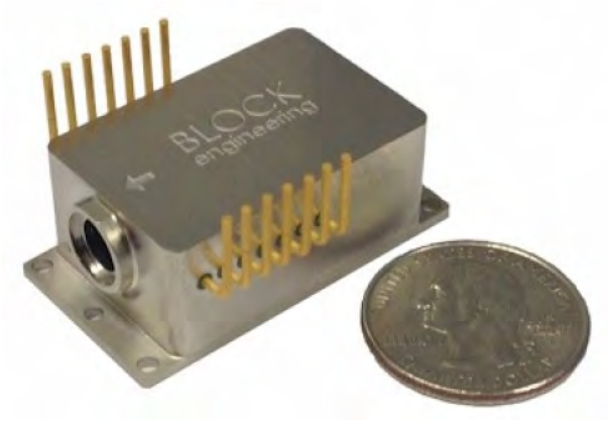
Block Engineering releases ultra-miniature QCL products

One of the III-V based laser systems is widely tuneable while the other can be used in a wireless mode

Block Engineering has released two ultra-miniaturised Quantum Cascade Laser (QCL) products, the Mini-QCL Module and the new LaserTune Infrared Source.

QCLs are fabricated using a number of III-V material systems. These include InGaAs/InAlAs, GaAs/AlGaAs, InGaAs/AlAsSb, InAs/AlSb and more recently Silicon/SiGe.

The Mini-QCL is a widely-tuneable QCL module for Original Equipment Manufacturers (OEMs), weighing only 75 grams (~2.5 oz).



Mini-QCL module

Block's next-generation LaserTune has been miniaturised to a compact (16.5 × 12.7 × 11 cm), wirelessly-controllable system, while offering one of the widest contiguous tuning ranges available on the market (greater than 1000 cm-1).

LaserTune infrared source

Scott Riggi, VP of Sales, comments, "We are receiving tremendous interest in these new products from universities, corporate R&D labs, and a wide range of OEMs. Block has now introduced the world's most compact, full-function QCL source with the widest contiguous spectral tuning range. The demand for these devices in gas sensing, metrology, and academic and corporate R&D applications is significant."

Petros Kotidis, Block's CEO adds, "These two new products are the result of Block's innovation spirit, engineering strength, and optical packaging capabilities. They meet a strong market need for ultra-compact, ultra-widely tuneable sources for OEM integration and all-in-one laser sources."

Kotidis adds, “These devices are now enabling new applications, which were not available to the past generations of QCLs, due to size, ruggedness and performance limitations. I look forward to the adoption of these new devices by our customers and the rapid growth of their applications.”

The Mini-QCL Module is available in spectral ranges greater than 250 cm-1 per module, and multiple modules can be combined by OEMs. The module can be used in a wide variety of real-time gas analysis applications requiring a mid-infrared laser source, including greenhouse gas monitoring, automotive combustion analysis, oil and gas exploration, and air quality monitoring.

The module is also designed to be integrated into a variety of spectroscopic instruments, including products used in the fields of Photoacoustic Spectroscopy (PAS), Cavity Ring-Down Spectroscopy (CRDS), Infrared Microscopy, and Atomic Force Microscopy (AFM).

The New LaserTune Infrared Source has been significantly reduced in size, while leading the industry in contiguous tuning range. The 2 x 4 mm collimated beam can now be programmed to operate in several modes with a manual step, programmable step, and programmable sweep.

The LaserTune offers fast scan capability at 25 cm-1 per msec, and the source can be programmed to emit pulses from 20 to 500 nsec, while maintaining a duty-cycle up to ~30 percent. Computer control of the LaserTune is via Wireless or Ethernet/HDMI with analogue and digital control for monitoring and controlling the laser wavelength.

Block will be demonstrating the products at SPIE’s Photonics West Conference (Booth #5333) and the BiOS Conference (Booth #8507) in San Francisco.

Oerlikon Leybold Vacuum moves to Cologne logistics centre

The new building is supplying production facilities with goods and controlling international goods flows from OLV to customers and worldwide subsidiaries

Oerlikon Leybold Vacuum (OLV), one of the largest high-tech vendors for vacuum pumps and systems, at the beginning of this year, moved into its new, modern lean logistics centre at the Cologne site.

OLV logistics centre in Cologne

Vacuum pumps are employed in compound semiconductor MOCVD manufacturing.

Designed by planning company Dr. Schönheit + Partner, the building was erected by construction company Günther GmbH & Co. KG from Netphen, Germany. This new building is the logistics hub supplying production facilities with goods and controlling international goods flows from Oerlikon Leybold Vacuum to customers and worldwide subsidiaries.

Placed at the centre of the surrounding production facilities, this new building offers some technical novelties cutting the length of internal pathways and the warehousing time for incoming materials thereby also reducing the door-to-door time of the products.

Within a construction period of just under one year, 13,000 tonnes of concrete and 570 tonnes of reinforcing steel were used creating an enclosed space of 59,000 cubic metres.

The three-storey building comprises a basement with technical plant room and sprinkler tank. Located on the ground floor is the entire warehouse with automatic small-parts warehouse, narrow-aisle warehouse, and large pallet warehouse as well as functional areas like foyer with waiting area, and areas for picking and provisioning with different building heights. The administration is accommodated on the top floor with a floor space of over 450 square metres.

OLV warehouse in Cologne

The erection of the building included a peculiarity: the former riverbed of the Rhine had left in this area sandy soil so that the soil conditions required thorough and diligent preparations for the foundations.

Moreover, old foundations and basements were found in this area which now had to be bypassed by pile foundations and which had to be prepared for accommodating the construction of the building itself and the floor slab.

Two hundred and twenty eight large drilled piles were driven up to 17 metres deep into the soil and are now carrying the building and the new 70 cm thick floor slab which is now bearing the load of the 16 metre high storage racks. In order to ensure high turnover speeds of the forklifts in the narrow-aisle warehouse, the flatness of the floor slab had to meet exceptionally high requirements.

“This project was professionally and logistically highly demanding for us, but owing to our long- standing experience in the erection of turnkey industrial and commercial buildings as well as our competent staff, we were able to manage the project once more to the full satisfaction of our usually long-standing clients”, explains Siebel, executive director of the construction company Günther GmbH & Co. KG.

In spite of the rather adverse weather conditions during the relatively harsh winter of 2012/2013, Günther was able to meet all deadlines without delay so that we were able to move into the building in November starting up operations there.

“We are highly satisfied with the architectural planning and the realisation of this concept. In spite of running operations, the restricted space and increased traffic on the factory premises everything worked out without a hitch. We are now in a position to optimally implement our future oriented logistics visions,” says Martin Füllenbach, CEO of Oerlikon Leybold Vacuum GmbH.

Mark Gabriel, Oerlikon Vacuum Project Manager adds, “Also the cooperation and the consistent solution-oriented efforts from the construction company Güther were highly positive and characterised by a high degree of openness. We would like to thank both partners for their excellent support in the implementation of our aim of being able to move to this building in time”.

Total floor space including outdoor areas and incoming goods space is 3,900 m2 and investment in the two digit million range, warehousing area 1904 m2, functional area 1224 m2, administrative floor space 478 m2, building height up to 20 metres.

Sensors Unlimited to reveal two InGaAs cameras

One of the cameras is claimed to be the world’s fastest 2048 pixel linescan camera. Both devices are designed specifically for spectral-domain optical coherence

UTC Aerospace Systems / Sensors Unlimited Inc. (SUI) will demonstrate what they say is the world’s fastest 2048-pixel Linescan Camera at >145,000 A-lines per second at BIOS and Photonics West.

The SUI GL2048R camera, joins the 76,000 lps GL2048L enabling OEMs and researchers to maximise speed or minimise cost for their Spectral Domain OCT systems (SD-OCT).

GL2048 pixel linescan camera. Tomography at 1.05 and 1.31 microns

The GL2048R and L cameras deliver the high-resolution and high-speed needed for SD-OCT, whether to minimise eye motion artefacts or to scan larger volumes with minimum patient discomfort.

Compact and slim, the GL2048 cameras feature InGaAs photodiode arrays of 2048 pixels with 210 µm height and 10 µm width.

The cameras are ideal for SD-OCT at 1.04 µm for retina diagnostics, 1.31 µm for corneal and cardiovascular imaging, or 1.55 µm for deepest imaging in non-medical OCT applications.

The GL2048L model has been shipping for a year to researchers and OEMs, and with its line rate range from 100 lps is also being used for silicon ingot photoluminescence inspection.

SWIR snapshot Mil-rugged high sensitivity high-definition InGaAs camera

The new Sensors Unlimited GA1280JSX-12.5 snapshot camera is the third megapixel-class InGaAs commercial camera put into production by UTAS since 2011 and will be demonstrated at the show booth.

Featuring SUI's unique extended sensitivity pixel design, now in a 12.5 µm pixel pitch, the new camera is ideal for high-definition imaging in varying conditions from low-level light to daylight, and through low-density obscurants.

The light-weight and compact size enables easy integration into aerial, mobile and hand-held surveillance or hyperspectral systems.

What's more, the camera employs on-board Automatic Gain Control (AGC) and built-in non-uniformity corrections (NUCs), allowing it to address the challenges of high-dynamic-range urban night imaging without blooming.

Camera Link digital output provides for plug-and-play video with 12-bit images for digital image processing or transmission.

UTAS / Sensors Unlimited will be showcasing these cameras at booth #8622 at BIOS and #622 at Photonics West and will also be able to describe companion HD models, the GA1280J-15 and the GA1280JS-12.5 cameras, which can be used for high-definition microscope inspection of integrated circuits and MEMs devices.

Also being demonstrated will be the Sensors Unlimited SU640HSX, the very sensitive InGaAs camera for pilot or driver vision enhancement, laser detection, wide area surveillance, imaging through low-density fog, dust or smoke, video-rate nano-tube imaging, photoluminescence and weak electroluminescence, and other low- light applications.

Providing both analogue EIA-170 video and 12-bit digital video out, the camera uses patented image enhancement and automatic gain control algorithms to produce clear usable video over a very wide range of lighting conditions.

Developed in 2008, these algorithms have ensured the SU640HSX continues imaging long after competitor's have packed up their cameras and gone home.

Novel Devices

Relativity shakes a magnet

Using GaMnAs, researchers have demonstrated a new principle for magnetic recording

The research group of Jairo Sinova, a professor at the Institute of Physics at Johannes Gutenberg University Mainz (JGU), in collaboration with researchers from Prague, Cambridge, and Nottingham, have predicted and discovered a new physical phenomenon.

They have found a way that allows you to manipulate the state of a magnet by electric signals.

Current technologies for writing, storing, and reading information are either charge-based or spin-based.

Semiconductor flash or random access memories are prime examples among the large variety of charge-based devices. They utilise the possibility offered by semiconductors to easily electrically manipulate and detect their electronic charge states representing the 'zeros' and 'ones".

The downside is that weak perturbations such as impurities, temperature change, or radiation can lead to uncontrolled charge redistributions and, as a consequence, to data loss. Spin-based devices operate on an entirely distinct principle.

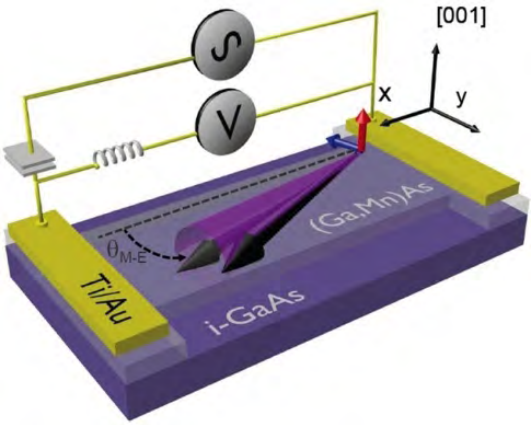
In some materials, like iron, electron spins generate magnetism and the position of the north and south pole of the magnet can be used to store the zeros and ones. This technology is behind memory applications ranging from kilobyte magnetic stripe cards to terabyte computer hard disks. Since they are based on spin, the devices are much more robust against charge perturbations.

However, the drawback of current magnetic memories is that in order to reverse the north and south poles of the magnet, i.e., flip the zero to one or vice versa, the magnetic bit has to be coupled to an electro-magnet or to another permanent magnet. If instead one could

flip the poles by an electric signal without involving another magnet, a new generation of memories can be envisaged combining the merits of both charge and spin-based devices.

In order the shake a magnet electrically without involving an electro-magnet or another permanent magnet one has to step out of the realm of classical physics and enter the relativistic quantum mechanics. Einstein's relativity allows electrons subject to electric current to order their spins so they become magnetic.

The researchers took a permanent magnet GaMnAs and by applying an electric current inside the permanent magnet they created a new internal magnetic cloud, which was able to manipulate the surrounding permanent magnet. The work has been published in the journal *Nature Nanotechnology.*



Electrically shaken GaMnAs magnet (Credit of Jairo Sinova)

The observed phenomenon is closely related to the relativistic intrinsic spin Hall effect which Jörg Wunderlich, Jairo Sinova, and Tomas Jungwirth discovered in 2004 following a prediction of Sinova and co-workers in 2003. Since then it has become a text-book demonstration of how electric currents can magnetise any material.

"Ten years ago we predicted and discovered how electric currents can generate pure spin-currents through the intrinsic structure of materials. Now we have shown how this effect can be reversed to manipulate magnets by the current-induced polarisation. These new phenomena are a major topic of research today since they can lead to new generation of memory devices. Besides our on-going collaborations, this research direction couples very well with on-going experimental research here in Mainz. Being part of this world-leading research and working with superb colleagues is an immense privilege and I am very excited about the future," says Sinova.

This work has been described in the paper, "An antidumping spin-orbit torque originating from the Berry curvature", Nature Nanotechnology, by Kurebayashi, H., Sinova, J. *et al*.
DOI:10.1038/nnano.2014.15

III-Vs and silicon unite to quicken heart treatment

Scientists have created a transformative device using GaN, GaAs and silicon which is aimed at delivering treatment or predict an impending heart attack before a patient shows any physical symptoms

Using an inexpensive 3-D printer, biomedical engineers have developed a custom-fitted, implantable device with embedded sensors that could transform treatment and prediction of cardiac disorders.

Igor Efimov at the School of Engineering & Applied Science at Washington University in St. Louis and an international team of biomedical engineers and materials scientists have created a 3-D elastic membrane. This is made of a soft, flexible, silicon material that is precisely shaped to match the heart's epicardium, or the outer layer of the wall of the heart.

Pictured in the image above are Igor Efimov, the Lucy & Stanley Lopata Distinguished Professor of Biomedical Engineering working with Sarah Gutbrod, PhD candidate in biomedical engineering, in Efimov's lab in Whitaker Hall.

Efimov and a team of researchers are developing a custom-fitted, implantable device that can deliver treatment or predict an impending heart attack before a patient shows any physical symptoms.

Current technology is two-dimensional and cannot cover the full surface of the epicardium or maintain reliable contact for continual use without sutures or adhesives.

The team can then print tiny sensors onto the membrane that can precisely measure temperature, mechanical strain and pH, among other markers, or deliver a pulse of electricity in cases of arrhythmia. Those sensors could assist physicians with determining the health of the heart, deliver treatment or predict an impending heart attack before a patient exhibits any physical signs.

The findings were published online in *Nature Communications* last week.

"Each heart is a different shape, and current devices are one-size-fits-all and don't at all conform to the geometry

of a patient's heart," says Efimov. "With this application, we image the patient's heart through MRI or CT scan, then computationally extract the image to build a 3-D model that we can print on a 3-D printer. We then mold the shape of the membrane that will constitute the base of the device deployed on the surface of the heart."

Ultimately, the membrane could be used to treat diseases of the ventricles in the lower chambers of the heart or could be inserted inside the heart to treat a variety of disorders, including atrial fibrillation, which affects three million to five million patients in the United States.

"Currently, medical devices to treat heart rhythm diseases are essentially based on two electrodes inserted through the veins and deployed inside the chambers," says Efimov, also a professor of radiology and of cell biology and physiology at the School of Medicine. "Contact with the tissue is only at one or two points, and it is at a very low resolution. What we want to create is an approach that will allow you to have numerous points of contact and to correct the problem with high-definition diagnostics and high-definition therapy."

Co-leading the team with Efimov is John Rogers, the Swanlund Chair and professor of materials science and engineering and director of the F. Seitz Materials Research Laboratory at the University of Illinois at Urbana-Champaign.

Rogers, who developed the transfer printing technique, developed the sensors using semiconductor materials including GaAs, GaN and silicon, along with metals, metal oxides and polymers.

Recently, Google announced its scientists had developed a type of contact lens embedded with sensors that could monitor glucose levels in patients with diabetes. Efimov says the membrane his team has developed is a similar idea, though much more sophisticated.

An example of the 3-D elastic membrane being developed by Efimov and his team

"Because this is implantable, it will allow physicians to monitor vital functions in different organs and intervene when necessary to provide therapy," he adds. "In the case of heart rhythm disorders, it could be used to stimulate cardiac muscle or the brain, or in renal disorders, it would monitor ionic concentrations of calcium, potassium and sodium."

Efimov says the membrane could even hold a sensor to measure troponin, a protein expressed in heart cells and a hallmark of a heart attack. Analysis for troponin is standard of care for patients with suspected heart attacks due to a test developed by Jack Ladenson, the Oree M. Carroll and Lillian B. Ladenson Professor of Clinical Chemistry in Pathology and Immunology and professor of clinical chemistry in medicine at the School of Medicine.

Ultimately, such devices will be combined with ventricular assist devices, Efimov says.

"This is just the beginning," he says. "Previous devices have shown huge promise and have saved millions of lives. Now we can take the next step and tackle some arrhythmia issues that we don't know how to treat."

This work has been described in detail in the paper, "3D multifunctional integumentary membranes for Spatiotemporal cardiac measurements and stimulation across the entire epicardium," by Xu L et al in Nature Communications, **5** (3329). doi:10.1038/ncomms4329

Funding for this research was provided by the National Institutes of Health R01 HL115415, R01 HL114395 and R21 HL112278; the Frederick Seitz Materials Research Laboratory and Centre for Microanalysis of Materials at the University of Illinois at Urbana-Champaign.

This article was adapted from one written by Beth Miller at the University of Washington.

Physicists discover 'quantum droplet' in GaAs

A new quasiparticle by exciting gallium arsenide with an ultrafast red laser initially form excitons

JILA physicists used an ultrafast laser and help from German theorists to discover a new semiconductor quasiparticle - a handful of smaller particles that briefly condense into a liquid-like droplet.

Quasiparticles are composites of smaller particles that can be created inside solid materials and act together in a predictable way. A simple example is the exciton, a pairing, due to electrostatic forces, of an electron and a so-called 'hole,' a place in the material's energy structure

where an electron could be, but isn't.

The new quasiparticle, described in the February 26th 2014, issue of *Nature* and featured on the journal's cover, is a microscopic complex of electrons and holes in a new, unpaired arrangement.

The researchers call this a 'quantum droplet' because it has quantum characteristics such as well-ordered energy levels, but also has some of the characteristics of a liquid. It can have ripples, for example. It differs from a familiar liquid like water because the quantum droplet has a finite size, beyond which the association between electrons and holes disappears.

Although its lifetime is only a fleeting 25 picoseconds (trillionths of a second), the quantum droplet is stable enough for research on how light interacts with specialised forms of matter.

"Electron-hole droplets are known in semiconductors, but they usually contain thousands to millions of electrons and holes," says JILA physicist Steven Cundiff, who studies the properties of cutting-edge lasers and what they reveal about matter. "Here we are talking about droplets with around five electrons and five holes."

"Regarding practical benefits, nobody is going to build a quantum droplet widget. But this does have indirect benefits in terms of improving our understanding of how electrons interact in various situations, including in optoelectronic devices," he continues.

The JILA team created the new quasiparticle by exciting GaAs with an ultrafast red laser emitting about 100 million pulses per second. The pulses initially form excitons, which are known to travel around in semiconductors.

As laser pulse intensity increases, more electron-hole pairs are created, with quantum droplets developing when the exciton density reaches a certain level. At that point, the pairing disappears and a few electrons take up positions relative to a given hole. The negatively charged electrons and positively charged holes create a neutral droplet. The droplets are like bubbles held together briefly by pressure from the surrounding plasma.

Artist's conception of microscopic 'quantum droplet' discovered by JILA physicists in GaAs excited by an ultrafast red laser pulse. Each droplet consists of electrons and holes (representing absent electrons) arranged in a liquid-like pattern of rings. The surrounding area is plasma. The discovery adds to understanding of how electrons interact in optoelectronic devices (Credit: Baxley/JILA)

JILA's experimental data on energy levels of individual droplet rings agreed with theoretical calculations by co-authors at the University of Marburg in Germany. JILA researchers found they could tap into each energy level by tailoring the quantum properties of the laser pulses to match the particle correlations within the droplets.

The droplets seem stable enough for future systematic studies on interactions between light and highly correlated states of matter. In addition, quasiparticles, in general, can have exotic properties not found in their constituent parts, and thus, can play a role in controlling the behaviour of larger systems and devices.

JILA is a joint institute of the National Institute of Standards and Technology (NIST) and University of Colorado Boulder. Cundiff is a NIST physicist. The JILA research is supported by the National Science Foundation, NIST and the Alexander von Humboldt Foundation.

This work has been described in detail in the paper, "Quantum droplets of electrons and holes," by A.E. Almand-Hunter *et al* in *Nature*, 471 - 475, published online on February 26th, 2014.doi:10.1038/nature12994

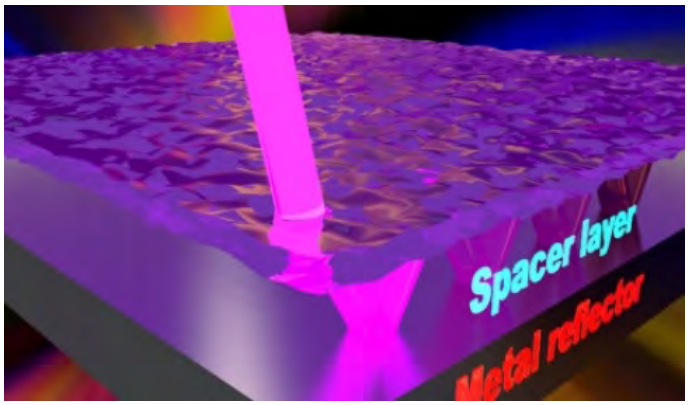
This article has been adapted from a story by Laura Ost at NIST.

A cavity that renders an optical nanocavity

Researchers say an optical 'nanocavity' could boost light absorption in semiconductors and improve solar cells, cameras and more

Scientists at the University of Buffalo say a new advancement could lead to major breakthroughs in energy-harvesting and conversion, security and other areas that will benefit humankind. Associated with unhappy visits to the dentist, "cavity" means something else in the branch of physics known as optics. Put simply, an optical cavity is an arrangement of mirrors that allows beams of light to circulate in closed paths. These cavities help us build things like lasers and optical fibre used for communications. Now, an international research team

have pushed the concept further by developing an optical 'nanocavity' that boosts the amount of light that ultrathin semiconductors absorb. The advancement could lead to, among other things, more powerful photovoltaic cells and faster video cameras; it also could be useful for splitting water using energy from light, which could aid in the development of hydrogen fuel. The team, comprised of faculty and students from the University at Buffalo and two Chinese universities, presented its findings February 24th in the journal*Advanced Materials*.



A rendering shows a beam of light interacting with an optical nanocavity. The nanocavity boosts light absorption in ultrathin semiconductors. (Credit: Advanced Materials)

"We're just scratching the surface, but the preliminary work that we've done is very promising," says Qiaoqiang Gan, PhD, lead author and UB assistant professor of electrical engineering. "This advancement could lead to major breakthroughs in energy-harvesting and conversion, security and other areas that will benefit humankind." The most common semiconductor material, silicon, is used to make microchips for cellular phones, computers and other electronic devices. Industry has kept pace with the demand for smaller, thinner and more powerful optoelectronic devices, in part, by shrinking the size of the semiconductors used in these devices. The problem, however, is that these ultrathin semiconductors do not absorb light as well as conventional bulk semiconductors.

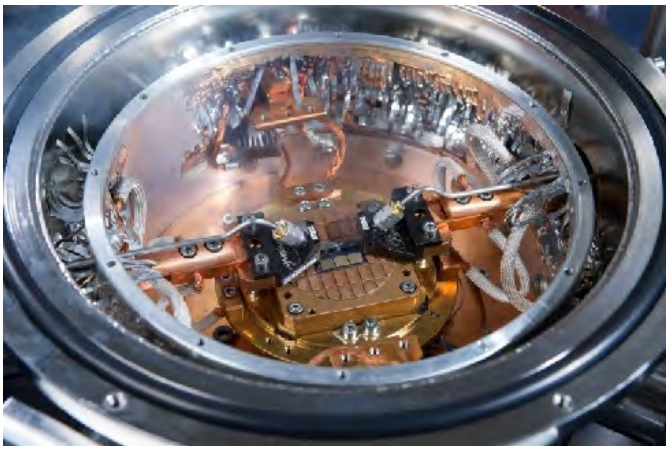
Therefore, there is an intrinsic trade off between the ultrathin semiconductors' optical absorption capacity and their ability to generate electricity. As a result, researchers worldwide are trying to find ways to boost the amount of light that ultrathin semiconductors can absorb. Harvard University researchers recently had varying degrees of success by combining thin films of germanium, another common semiconductor, on a gold surface. "While the results are impressive, gold is among the most expensive metals," says Suhua Jiang, associate professor of materials science at Fudan University in China. "We illustrated a nanocavity, made with aluminium or other whitish metals and alloys that are far less expensive, can be used to increase the amount of light that semiconducting materials absorb."

The nanocavity consists of, from bottom to top: aluminium, aluminium oxide and germanium. In the experiment, light passed through the germanium, which is 1.5 to 3 nanometres thick, and circulated in a closed path through the aluminium oxide and aluminium. The absorption rate peaked at 90 percent, with germanium absorbing roughly 80 percent of the blue-green light and aluminium absorbing the rest. This is ideal, says Haomin Song, PhD candidate in electrical engineering at UB and the paper's first author, because the bulk of the light stays within the semiconducting material. "The nanocavity has many potential applications. For example, it could help boost the amount of light that solar cells are able to harvest; it could be implanted on camera sensors, such as those used for security purposes that require a high-speed response. It also has properties that could be useful for photocatalytic water splitting, which could help make hydrogen fuel a reality," Song says.

Before any of that happens, however, more research must be done, especially as it relates to how the semiconductor would turn the light into power as opposed to heat. Gan's research group is collaborating with Alexander Cartwright, PhD, UB professor of electrical engineering and vice president for research and economic development, and Mark Swihart, PhD, UB professor of chemical and biological engineering, to develop ultrathin energy-harvesting devices. Gan is also working with Hao Zeng, PhD, UB associate professor of physics, to study its effect on photocatalysis. The National Science Foundation supported the research. The paper, called "Nanocavity enhancement for ultra-thin film optical absorber," by Haomin Song *et a*l is available via the following link: DOI: 10.1002/adma.201305793

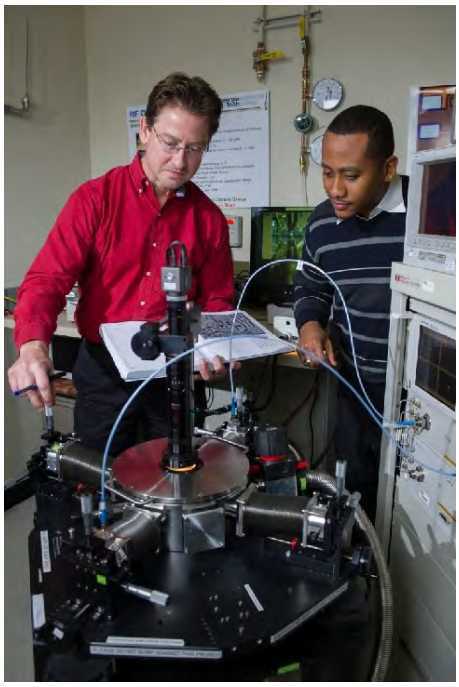
SiGe chip sets new speed record

The silicon-germanium technology could be used in cold-temperature applications such as in outer space, where temperatures can be extremely low
A research collaboration consisting of IHP-Innovations for High Performance Microelectronics in Germany and the Georgia Institute of Technology has demonstrated what it claims is the world's fastest silicon-based device to date. The investigators operated a silicon-germanium (SiGe) transistor at 798 gigahertz (GHz) fMAX, exceeding the previous speed record for SiGe chips by about 200 GHz.



High-speed SiGe chips and measurements probes can be seen inside a cryogenic probe station in the laboratory of John Cressler and co-workers at the Georgia Institute of Technology (Georgia Tech Photo: Rob Felt)

Although these operating speeds were achieved at extremely cold temperatures, the research suggests that record speeds at room temperature aren't far off, says John D. Cressler, a professor who led the research for Georgia Tech. Information about the research was published in February 2014, by*IEEE Electron Device Letters*. "The transistor we tested was a conservative design, and the results indicate that there is significant potential to achieve similar speeds at room temperature - which would enable potentially world changing progress in high data rate wireless and wired communications, as well as signal processing, imaging, sensing and radar applications," says Cressler, who hold the Schlumberger Chair in electronics in the Georgia Tech School of Electrical and Computer Engineering. He adds, "Moreover, I believe that these results also indicate that the goal of breaking the so called 'terahertz barrier' - meaning, achieving terahertz speeds in a robust and manufacturable SiGe transistor - is within reach." Cressler further says the tested transistor itself could be practical as is for certain cold-temperature applications. In particular, it could be used in its present form for demanding electronics applications in outer space, where temperatures can be extremely low.



John Cressler (left) and graduate student Adilson Cardoso work at a cryogenic probe station at Georgia Tech. (Georgia Tech Photo: Rob Felt)

IHP, a research centre funded by the German government, designed and fabricated the device, a heterojunction bipolar transistor (HBT) made from a nanoscale SiGe alloy embedded within a silicon transistor. Cressler and his Georgia Tech team, including graduate students Partha S. Chakraborty, Adilson Cordoso and Brian R. Wier, performed the exacting work of analysing, testing and evaluating the novel transistor. "The record low temperature results show the potential for further increasing the transistor speed toward terahertz (THz) at room temperature.

This could help enable applications of silicon-based technologies in areas in which compound semiconductor technologies are dominant today. At IHP, B. Heinemann, H. Rücker, and A. Fox supported by the whole technology team working to develop the next THz transistor generation," according to Bernd Tillack, who is leading the technology department at IHP in Frankfurt (Oder), Germany. Silicon, a material used in the manufacture of most modern microchips, is not competitive with other materials when it comes to the extremely high performance levels needed for certain types of emerging wireless and wired communications, signal processing, radar and other applications. Certain highly specialised and costly materials - such as InP, GaAs and GaN - presently dominate these highly demanding application areas.

But silicon-germanium changes this situation. In SiGe technology, small amounts of germanium are introduced into silicon wafers at the atomic scale during the standard manufacturing process, boosting performance

substantially. The result is cutting-edge silicon germanium devices such as the IHP Microelectronics 800 GHz transistor. Such designs combine SiGe›s extremely high performance with silicon›s traditional advantages - low cost, high yield, smaller size and high levels of integration and manufacturability - making silicon with added germanium highly competitive with the other materials. Cressler and his team demonstrated the 800 GHz transistor speed at 4.3 Kelvins (-268oC). This transistor has a breakdown voltage of 1.7 V, a value which is adequate for most intended applications.

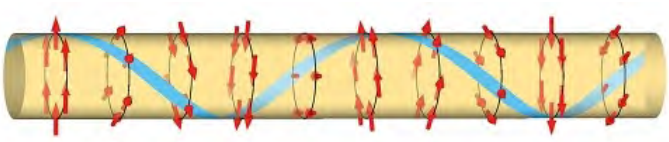
The 800 GHz transistor was manufactured using IHP's 130 nm BiCMOS process, which has a cost advantage compared with today's highly-scaled CMOS technologies. This 130 nm SiGe BiCMOS process is offered by IHP in a multi-project wafer foundry service. The Georgia Tech team used liquid helium to achieve the extremely low cryogenic temperatures of 4.3 Kelvins in achieving the observed 798 GHz speeds. «When we tested the IHP 800 GHz transistor at room temperature during our evaluation, it operated at 417 GHz,» Cressler notes. «At that speed, it›s already faster than 98 percent of all the transistors available right now.» This work is described in detail in the paper, «A 0.8 THz *fMAX* SiGe HBT Operating at 4.3 K" by P.S. Chakraborty *et al*in IEEE Electron Device Letters, 35 (2), p 151 - 153. DOI: 10.1109/LED.2013.2295214

Helical spin order in GaAs quantum wires

Researchers have examined the electron and nuclear spin order in gallium arsenide nanowires at temperatures of 0.1 kelvin

Physicists at the University of Basel have observed a spontaneous magnetic order of electron and nuclear spins in a GaAs quantum wire at temperatures of 0.1 kelvin.

In the past, this was possible only at much lower temperatures, typically in the microkelvin range. The coupling of nuclei and electrons creates a new state of matter whereby a nuclear spin order arises at a much higher temperature. The results are consistent with a theoretical model developed in Basel a few years ago, as reported by the researchers in the scientific journal *Physical Review Letters*.



Helical order: The spins of the electrons and nuclei (red arrows) take the form of a helix rotating along the axis of the quantum wire. The blue ribbon is a guide to the eye for the helix. (Illustration: B. Braunecker, P. Simon, and D. Loss, Phys. Rev. B 80, 165119 (2009))

The researchers, led by r Dominik Zumbühl a professor at the University of Basel's Department of Physics, used quantum wires made from GaAs. These are one-dimensional structures in which the electrons can move in only one spatial direction.

At temperatures above 10 kelvin, the quantum wires exhibited universal, quantised conductance, suggesting that the electron spins were not ordered.

However, when the researchers used liquid helium to cool the wires to a temperature below 100 millikelvin (0.1 kelvin), the electronic measurements showed a drop in conductance by a factor of two, which would suggest a collective orientation of the electron spin. This state also remained constant when the researchers cooled the sample to even lower temperatures, down to 10 millikelvin.

Electron-nuclear spin coupling

The results are exceptional because this is the first time that nuclear spin order has been measured at temperatures as high as 0.1 kelvin. Previously, spontaneous nuclear spin order was observed only at much lower temperatures, typically below 1 microkelvin; i.e. five orders of magnitude lower in temperature.

The reason why nuclear spin order is possible already at 0.1 kelvin is that the nuclei of the gallium and arsenic atoms in these quantum wires couple to the electrons, which themselves act back on the nuclear spins, which again interact with the electrons, and so on.

This feedback mechanism strongly amplifies the interaction between the magnetic moments, thus creating the combined nuclear and electron spin magnetism. This order is further stabilised by the fact that the electrons in such quantum wires have strong mutual interactions, bumping into each other like railcars on a single track.

Helical electron and nuclear spin order

Interestingly, in the ordered state, the spins of the electrons and nuclei do not all point in the same direction. Instead, they take the form of a helix rotating along the quantum wire. This helical arrangement is predicted by a theoretical model described by Professor Daniel Loss and collaborators at the University of Basel in 2009. According to this model, the conductance drops by a factor of two in the presence of a nuclear spin helix. All other existing theories are incompatible with the data

from this experiment.

A step closer to the development of quantum computers

The results of the experiment are important for fundamental research, but are also interesting for the development of quantum computers based on electron spin as a unit of information (proposed by Daniel Loss and David P. DiVincenzo in 1997).

In order for electron spins to be used for computation, they must be kept stable for a long period. However, the difficulty of controlling nuclear spins presents a major source of error for the stability of electron spins.

The work of the Basel physicists opens up new avenues for mitigating these disruptive nuclear spin fluctuations: with the nuclear spin order achieved in the experiment, it may be possible to generate much more stable units of information in the quantum wires.

In addition, the nuclear spins can be controlled with electronic fields, which was not previously possible. By applying a voltage, the electrons are expelled from the semiconductor, which dissolves the electron-nucleus coupling and the helical order.

The work was conducted by an international team led by Professor Dominik Zumbühl from the University of Basel's Department of Physics; the team received support in the measurements from Harvard University (Professor Amir Yacoby). The nanowires originated from Princeton University (Loren N. Pfeiffer and Ken West).

The research was co-funded by the European Research Council, the Swiss National Science Foundation, the Basel Centre for Quantum Computing and Quantum Coherence (Basel QC2 Centre), the Swiss Nanoscience Institute and the NCCR Quantum Science & Technology (QSIT).

The work is described in detail in the paper, " Possible Evidence for Helical Nuclear Spin Order in GaAs Quantum Wires," by C. P. Scheller *et al, Physical Review Letters*, published 10th February 2014. doi: 10.1103/PhysRevLett.112.066801.

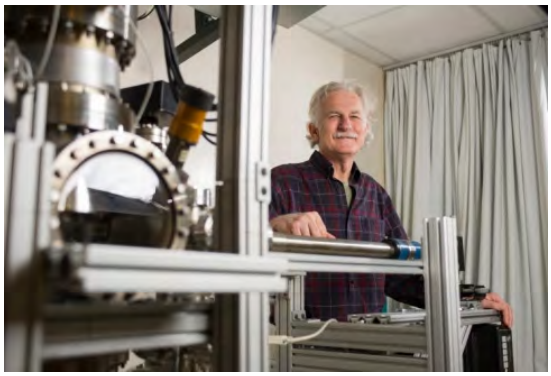
Graphene on SiC could revolutionise electronics

Ballistic transport in graphene could result in a new class of room temperature coherent electronic devices which would be very different from what we make today in silicon

Using electrons more like photons could provide the foundation for a new type of electronic device that would capitalise on the ability of graphene to carry electrons with almost no resistance even at room temperature.

This is a property known as ballistic transport.

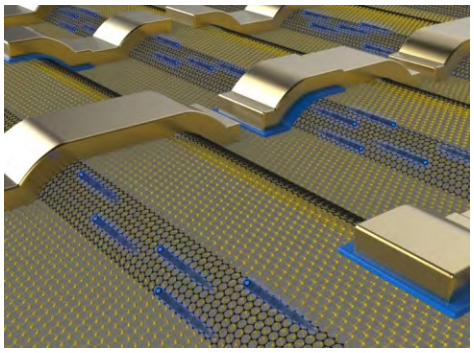
Research reported this week shows that electrical resistance in nanoribbons of epitaxial graphene changes in discrete steps following quantum mechanical principles. The research shows that the graphene nanoribbons act more like optical waveguides or quantum dots, allowing electrons to flow smoothly along the edges of the material.



Walt de Heer, a Regent's professor in the School of Physics at the Georgia Institute of Technology, poses with equipment used to measure the properties of graphene nanoribbons. De Heer and collaborators from three other institutions have reported ballistic transport properties in graphene nanoribbons that are about 40 nm wide. (Georgia Tech Photo: Rob Felt)

In ordinary conductors such as copper, resistance increases in proportion to the length as electrons encounter more and more impurities while moving through the conductor.

The ballistic transport properties, similar to those observed in cylindrical carbon nanotubes, exceed theoretical conductance predictions for graphene by a factor of ten. The properties were measured in graphene nanoribbons approximately 40 nm wide that had been grown on the edges of three-dimensional structures etched into SiC wafers.



Conceptual drawing of an electronic circuit comprised of interconnected graphene nanoribbons (black atoms) that are epitaxially grown on steps etched in silicon carbide (yellow atoms). Electrons (blue) travel ballistically along the ribbon and then from one ribbon to the next via the metal contacts. Electron flow is modulated by electrostatic gates. (Image courtesy of John Hankinson)

"This work shows that we can control graphene electrons in very different ways because the properties are really exceptional," says Walt de Heer, a Regent's professor in the School of Physics at the Georgia Institute of Technology. "This could result in a new class of coherent electronic devices based on room temperature ballistic transport in graphene. Such devices would be very different from what we make today in silicon."

The research, which was supported by the National Science Foundation, the Air Force Office of Scientific Research and the W.M. Keck Foundation, was reported February 5th in the journal *Nature*.

The research was done through a collaboration of scientists from Georgia Tech in the United States, Leibniz Universität Hannover in Germany, the Centre National de la Recherche Scientifique (CNRS) in France and Oak Ridge National Laboratory - supported by the Department of Energy - in the United States.

For nearly a decade, researchers have been trying to use the unique properties of graphene to create electronic devices that operate much like existing silicon semiconductor chips. But those efforts have met with limited success because graphene - a lattice of carbon atoms that can be made as little as one layer thick - cannot be easily given the electronic bandgap that such devices need to operate.

De Heer argues that researchers should stop trying to use graphene like silicon, and instead use its unique electron transport properties to design new types of electronic devices that could allow ultra-fast computing - based on a new approach to switching. Electrons in the graphene nanoribbons can move tens or hundreds of microns without scattering.

"This constant resistance is related to one of the fundamental constants of physics, the conductance quantum," de Heer notes. "The resistance of this channel does not depend on temperature, and it does not depend on the amount of current you are putting through it."

What does disrupt the flow of electrons, however, is measuring the resistance with an electrical probe. The measurements showed that touching the nanoribbons with a single probe doubles the resistance; touching it with two probes triples the resistance.

"The electrons hit the probe and scatter," explains de Heer. "It's a lot like a stream in which water is flowing nicely until you put rocks in the way. We have done systematic studies to show that when you touch the nanoribbons with a probe, you introduce a method for the electrons to scatter, and that changes the resistance."

The nanoribbons are grown epitaxially on SiC wafers into which patterns have been etched using standard microelectronics fabrication techniques. When the wafers are heated to approximately 1,0000C, silicon is preferentially driven off along the edges, forming graphene nanoribbons whose structure is determined by the pattern of the three-dimensional surface. Once grown, the nanoribbons require no further processing.

The advantage of fabricating graphene nanoribbons this way is that it produces edges that are perfectly smooth, annealed by the fabrication process. The smooth edges allow electrons to flow through the nanoribbons without disruption. If traditional etching techniques are used to cut nanoribbons from graphene sheets, the resulting edges are too rough to allow ballistic transport.

"It seems that the current is primarily flowing on the edges," de Heer says. "There are other electrons in the bulk portion of the nanoribbons, but they do not interact with the electrons flowing at the edges."

The electrons on the edge flow more like photons in optical fibre, helping them avoid scattering. "These electrons are really behaving more like light," he said. "It is like light going through an optical fibre. Because of the way the fibre is made, the light transmits without scattering."

The researchers measured ballistic conductance in the graphene nanoribbons for up to 16 microns. Electron mobility measurements surpassing one million correspond to a sheet resistance of one ohm per square that is two orders of magnitude lower than what is observed in two-dimensional graphene - and ten times smaller than the best theoretical predictions for graphene.

"This should enable a new way of doing electronics," de

Heer adds. “We are already able to steer these electrons and we can switch them using rudimentary means. We can put a roadblock, and then open it up again. New kinds of switches for this material are now on the horizon.”

Theoretical explanations for what the researchers have measured are incomplete. De Heer speculates that the graphene nanoribbons may be producing a new type of electronic transport similar to what is observed in superconductors.

“There is a lot of fundamental physics that needs to be done to understand what we are seeing,” De Heer continues. “We believe this shows that there is a real possibility for a new type of graphene-based electronics.”

Georgia Tech researchers have pioneered graphene-based electronics since 2001, for which they hold a patent, filed in 2003. The technique involves etching patterns into electronics-grade SiC wafers, then heating the wafers to drive off silicon, leaving patterns of graphene.

This work has been detailed in the paper, “Exceptional ballistic transport in epitaxial graphene nanoribbons,” by Jens Baringhaus *et al in* Nature 2013, published online on 5th February 2014.DOI:10.1038/nature12952

Controlling photons with InGaN quantum dots

By emitting photons from an indium gallium nitride quantum dot at the top of a GaN micropyramid, researchers have created a polarised light source. The device can be used in applications such as energy-saving computer screens and wiretap-proof communications

Polarised light - where all the light waves oscillate on the same plane - forms the foundation for technology such as LCD displays in computers and TV sets, and advanced quantum encryption.

Normally, this is created by normal unpolarised light passing through a filter that blocks the unwanted light waves. At least half of the light emitted, and thereby an equal amount of energy, is lost in the process.

A better method is to emit light that is polarised right at the source. This can be achieved with quantum dots - crystals of semiconductive material so small that they produce quantum mechanical phenomena. But until now, they have only achieved polarisation that is either entirely too weak or hard to control.

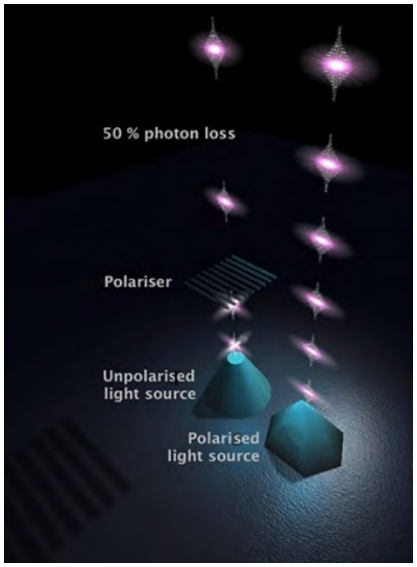
A semiconductive materials research group led by Per Olof Holtz, a professor at Linköping University, have now developed an alternative method.

The concept is based on InGaN QDs grown on top of elongated GaN hexagonal pyramids, by which the predefined elongation determines the polarisation vectors of the emitted photons from the QDs. This growth scheme should allow fabrication of ultra-compact arrays of photon emitters, with a controlled polarisation direction for each individual emitter.

With these, they have succeeded in creating light with a high degree of linear polarisation, on average 84 percent. The results are being published in the *Nature* periodical *Light: Science & Applications*.

“We’re demonstrating a new way to generate polarised light directly, with a predetermined polarisation vector and with a degree of polarisation substantially higher than with the methods previously launched,” Holtz says.

In experiments, quantum dots were used that emit violet light with a wavelength of 415 nm, but the photons can in principle take on any colour at all within the visible spectrum by varying the indium content.



Two ways of creating polarised light (Credit: Fredrik Karlsson, LiU)

“Our theoretical calculations point to the fact that an increased amount of indium in the quantum dots further improves the degree of polarisation,” says reader Fredrik Karlsson, one of the authors of the article.

The micropyramid is constructed through crystalline growth, atom layer by atom layer, of the semiconductive material GaN. A couple of nanothin layers where the metal indium is also included are laid on top of this. From the asymmetrical quantum dot thus formed at the top,

light particles are emitted with a well-defined wavelength.

The results of the research are opening up possibilities, for example for more energy-effective polarised LEDs in the light source for LCD screens. As the quantum dots can also emit one photon at a time, this is very promising technology for quantum encryption, a growing technology for wiretap-proof communications.

The work is described in detail in the article, "Direct generation of linearly polarised photon emission with designated orientations from site-controlled InGaN quantum dots," by A. Lundskog *et al* in*Science & Applications* (2014) 3, e139, published online on 31st January 2014. doi:10.1038/lsa.2014.20

The project has been conducted within Nano-N consortium funded by the Swedish Foundation for Strategic Research.

Disordered crystals: A replacement for classic nitrides?

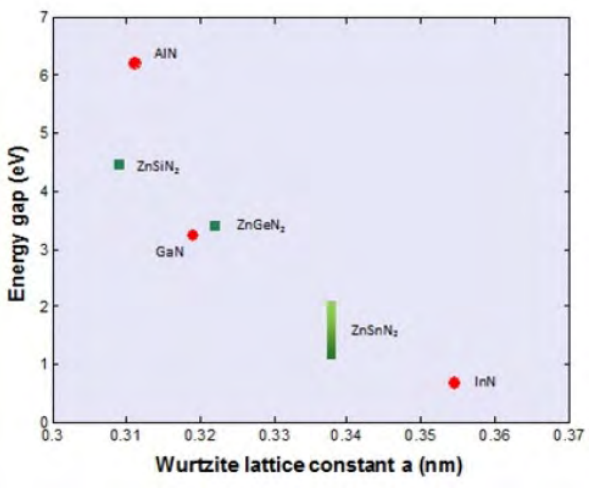
The race is on to identify the band gap energy and carrier mobility of the new semiconductor ZnSnN2

Recently, the European Commission has flagged the supply of both gallium and indium as "at risk," recommending that market conditions be closely monitored to avoid production bottlenecks.

Enter theorist Walter Lambrecht, who pointed out that there is an interesting family of semiconductors composed of zinc, silicon, germanium, tin and nitrogen which is analogous to the pervasive (Al,Ga,In) nitride family – and completely gallium and indium free.

Intriguingly, ZnSiN2 and ZnSnN2 fit into the category of what many are calling "earth abundant element semiconductors," a reference to the relatively low crustal abundance of gallium and indium.

Ultraviolet band gap ZnSiN2 has been synthesised previously, but the lower-energy tin-based family member (critical for photovoltaics and visible wavelength devices) has only recently been reported. In 2013, three groups, each using a different technique, obtained crystalline samples of ZnSnN2. These were Case Western Reserve University, the California Institute of Technology, and the University at Buffalo.



The race is now on to identify intrinsic properties such as band gap energy and carrier mobility of this new semiconductor. Surprisingly, the collaboration (Buffalo, London, and Liverpool) has observed experimental evidence for disorder-induced reduction of the band gap. This was predicted by density functional theory calculations to span from 1.1 to 2.1 eV.

The phenomenon occurs as the sub-lattice containing zinc and tin atoms is variously "scrambled" while the host material remains single crystalline. This could enable a radically new approach to band gap tuning for optoelectronic devices: through controlled disorder in a crystalline material via growth conditions, not alloying, as postulated three decades previously.

This work was conducted in conjunction with Steve Durbin at Western Michigan University and the University at Buffalo, David Scanlon at University College London and Tim Veal at the University of Liverpool.

The work is described in detail in the papers,

" Growth, disorder, and physical properties of ZnSnN2," by N. Feldberg *et al* in *Applied Physics Letters,*103, 042109 (2013). doi: 10.1063/1.4816438

and

"Growth of ZnSnN2 by Molecular Beam Epitaxy," by N. Feldberg *et al* in *Journal of Electronic Materials*.DOI: 10.1007/s11664-013-2962-8