



# COMPOUND SEMICONDUCTOR

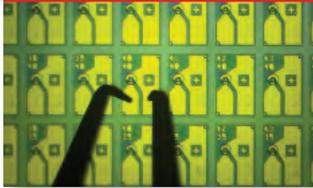
Connecting the Compound Semiconductor Community

Volume 19 Issue 4 2013

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Wafer-bonding for telco VCSELs



Extending the life of fab tools



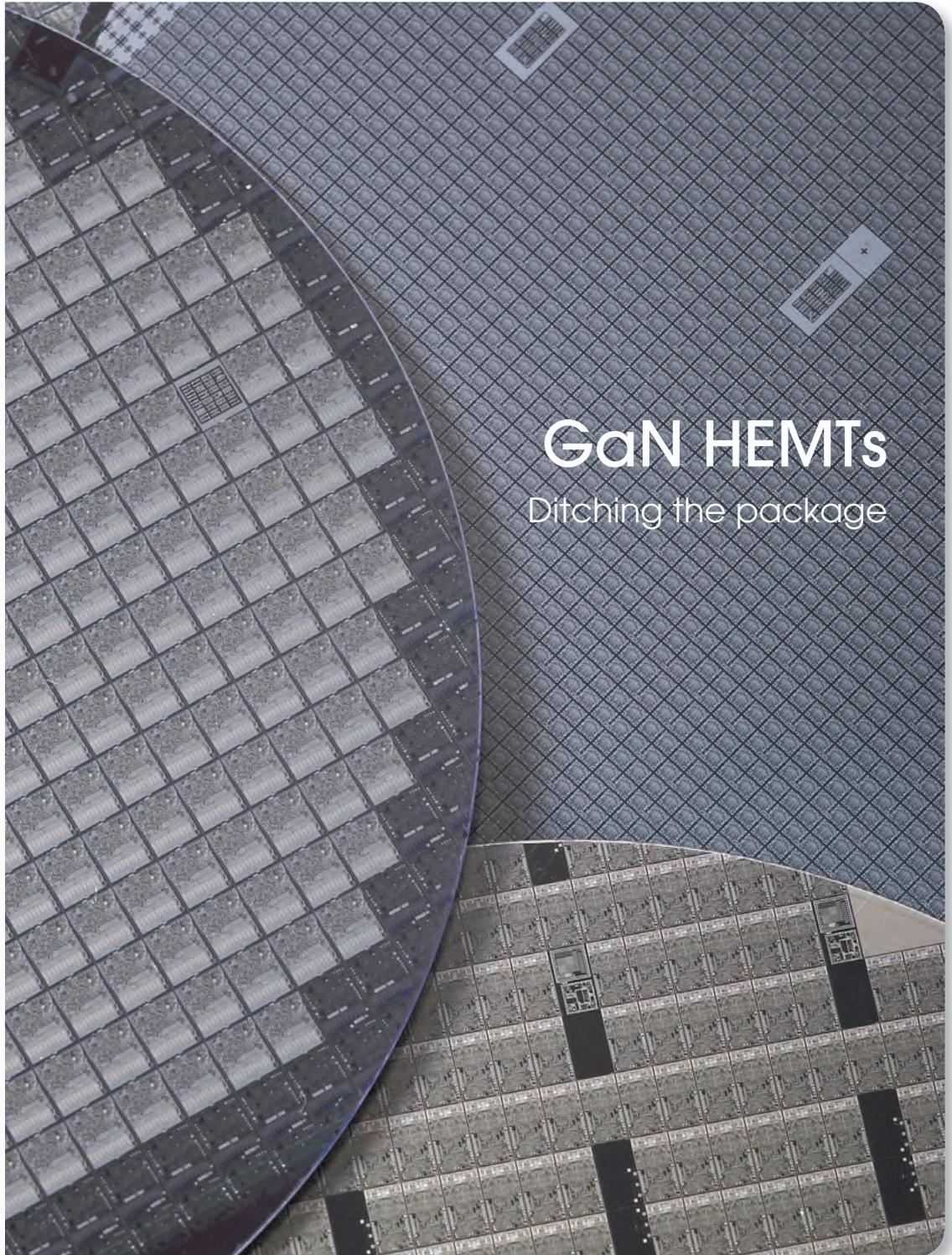
GaAs will fend off the CMOS threat



Scrutinizing GaN HEMT interfaces



UCSB: Auger causes LED droop



GaN HEMTs  
Ditching the package

inside **CS** COMPOUND SEMICONDUCTOR

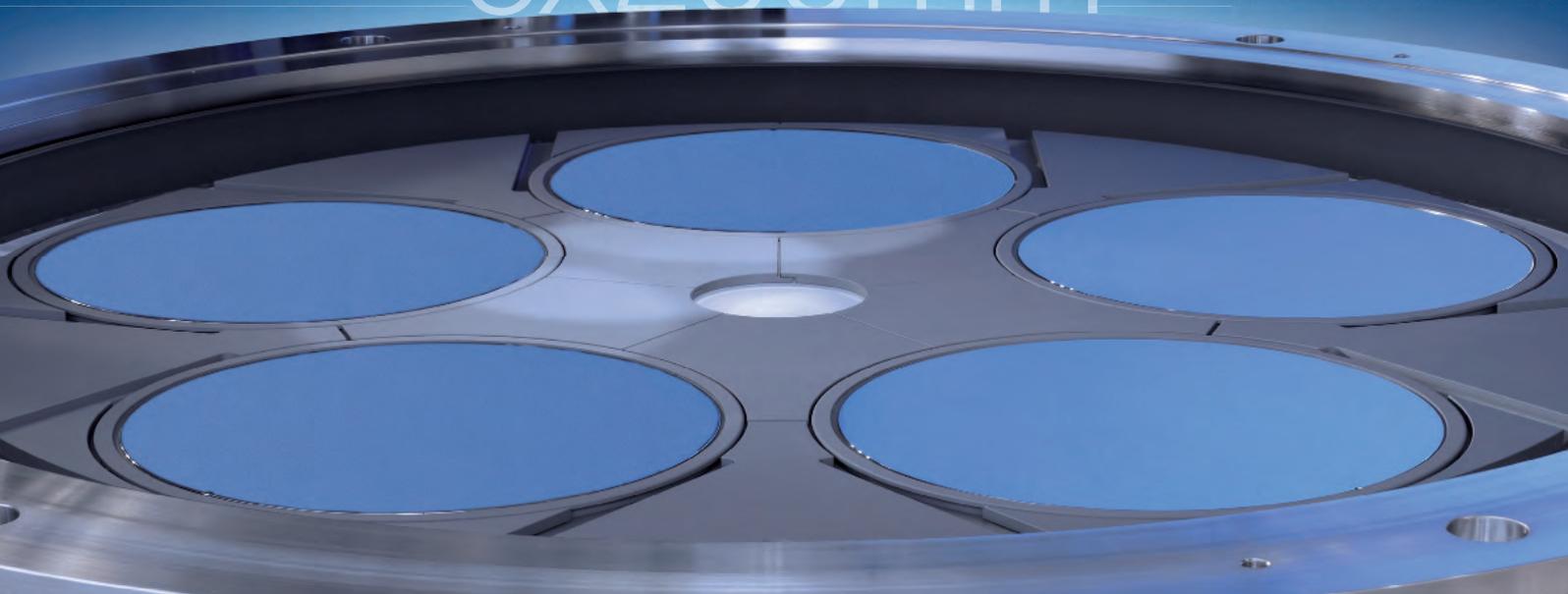
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# AIXTRON

## 200mm GaN-on-Si Batch Reactor

### 5x200mm



## AIX G5+



### AIX G5+ for GaN-on-Si

- Dedicated technology package
- Compatible with the AIX G5 HT platform
- Enables Si-style mass manufacturing
- Builds on planetary technology:  
Excellent and symmetric uniformities,  
controlled bow behavior,  
using standard Si substrates.



# editorial view

by Dr Richard Stevenson, Editor

## Don't ask me

FROM TIME TO TIME I'm asked if it would be a good idea to buy shares in a particular company within the compound semiconductor industry. When that happens, I try to refrain from giving advice: Although I have some understanding of the technology in this sector, I don't have enough business acumen to be confident of backing the right firm.

My confidence in my belief that I should *not* offer financial advice has been bolstered following a look at how the share prices of the leading III-V firms have fared in the last 12 months (if you want the details, take a look at *A mixed year for III-V shares* on p36).

The LED industry is currently caught up in a blood bath, due to supply outpacing demand by a significant margin, and I would have cautioned anyone that suggested investing in this sector.

But there is money to be made there if you back the right horse, in this case Cree.

Shares in this US outfit have rocketed by about 80 percent in the last year, with most of the gains coming in 2013. The company is churning out a healthy profit quarter after quarter,



and it is not waiting on the sidelines for the revolution in solid-state lighting to take off – it is rolling up its sleeves and launching competitive products that will make this happen.

The product line that impresses me the most is the recently released replacements for 40 W and 60 W incandescents – these competitively priced products propelled the share price north when they were announced.

The warm-white 60 W equivalent retails for \$12.97, produces 800 lumens and draws just 9.5 W, giving it an efficacy of just over 84 lm/W.

From my perspective, the only downside is that I can't buy them: Cree is targeting its domestic market, and selling these bulbs through Home Depot.

That's annoying, because I'm happy to invest in solid-state lighting: I can calculate the return it will give, and know that it's worthwhile.

After all, it's not like investing in shares, where a little knowledge can be a dangerous thing, and I can't be sure that I'd be making shrewd investments.

<b>Editor</b> Dr Richard Stevenson	richardstevenson@angelbc.com +44 (0)1291 629640	<b>Subscriptions Manager</b> Debbie Higham	debbie.higham@angelbc.com +44 (0)1923 690220
<b>Contributing Editor</b> Dr Rebecca Poole	editorial@rebeccapoole.com	<b>Chief Operating Officer</b> Stephen Whitehurst	stephen.whitehurst@angelbc.com +44 (0)2476 718970
<b>News Editor</b> Dr Su Westwater	suwestwater@angelbc.com	<b>Directors</b> Bill Dunlop Uprichard – CEO, Stephen Whitehurst – COO, Jan Smoothy – CFO, Jackie Cannon, Scott Adams, Sharon Cowley, Sukhi Bhadral	
<b>Director of SEMI Publishing</b> Jackie Cannon	jackie.cannon@angelbc.com +44 (0)1923 690205	<b>Published by</b> Angel Business Communications Ltd, Hannay House, 39 Clarendon Road, Watford, Herts WD17 1JA, UK. T: +44 (0)1923 690200 F: +44 (0)1923 690201 E: ask@angelbc.com	
<b>Senior Sales Executive</b> Robin Halder	robin.halder@angelbc.com +44 (0)2476 718109	<b>Angel Business Communications Ltd</b> Unit 6, Bow Court, Fletchworth Gate, Burnshall Road, Coventry CV5 6SP, UK. T: +44 (0)2476 718 970 F: +44 (0)2476 718 971 E: info@angelbc.com	
<b>Sales Manager</b> Shehzad Munshi	shehzad.munshi@angelbc.com +44 (0)1923 690215		
<b>USA Rep:</b> Brun Media: Tom Brun	E: tbrun@brunmedia.com Tel: +001 724 539-2404		When you have finished with this magazine please recycle it.
Janice Jenkins	E: jjenkins@brunmedia.com Tel: +001 724-929-3550		
<b>Director of Logistics</b> Sharon Cowley	sharon.cowley@angelbc.com +44 (0)1923 690200		
<b>Design &amp; Production Manager</b> Mitchell Gaynor	mitch.gaynor@angelbc.com +44 (0)1923 690214		
<b>Circulation Director</b> Jan Smoothy	jan.smoothy@angelbc.com +44 (0)1923 690200		

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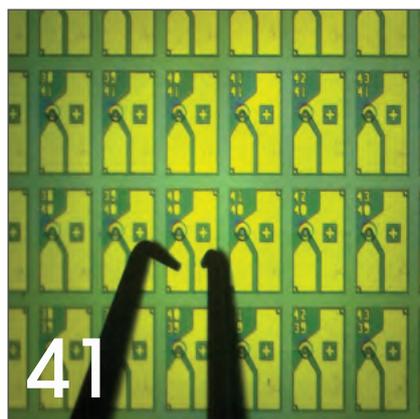
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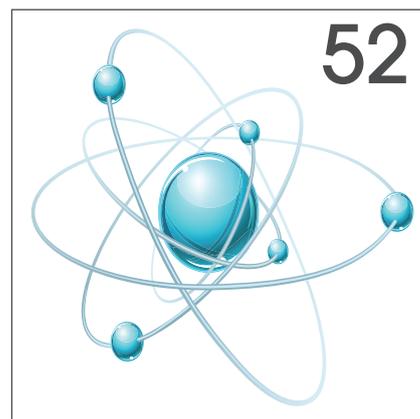
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Talk of silicon completely displacing GaAs in the RF front-end of cellular phones is premature. The future will instead involve smart RF suppliers collaborating closely with OEMs and chipset partners to offer complete RF solutions.

## 32 Efficient power conversion with package-free HEMTs

Packaging has its downsides: It increases the footprint and the price of a power MOSFET, while degrading its performance through unwanted increases in resistance and inductance. The best solution is to ditch the package, a step that allows GaN HEMTs to be cost-competitive with silicon incumbents.

## 36 A mixed year for III-V shares

If you were to have made money in the last 12 months from III-V shares, would you have had to invest in the RF sector, in toolmakers, or in the makers of laser chips? Or was it more important to identify the right company, rather than the burgeoning sector?

## 41 Ultra-low power VCSELs for optical networks

It is essential that tomorrow's optical networks are built with more efficient components. One promising device that will help is a 1310 nm VCSEL formed by fusing together active regions grown on InP wafers and mirrors formed on GaAs substrates.

## 46 Partnership propels multiple improvements in SiN deposition

Investors in deposition equipment want tools that have high levels of up time, deliver uniform films and offer an upgrade path that will prevent them from becoming obsolete within a few years. The equipment vendor and chipmaker must work together to improve the deposition system and its process.

## 52 Scrutinizing AlGaN/GaN heterostructures atom by atom

Conventional imaging techniques, such as various forms of electron microscopy, are incapable of delivering three-dimensional atomic resolution that can offer new insights into the characteristics of GaN-based heterostructures. But this type of measurement is possible with atom probe tomography.

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Magazine & Front Cover: Designed by Mitch Gaynor

# CSindustry awards2013

and the winners are...

## Substrates & Materials Award



For:

150-mm 4HN Silicon Carbide Epitaxial Wafer

## Device Design and Packaging Award



For:

III-Nitride Varactors with  
Capacitively-Coupled Contacts

## Compound Semiconductor Manufacturing Award



For:

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

## Innovation Award

Ferrotec - Temescal Division

For:

Auratus Deposition  
Enhancement Methodology

## Metrology, Test and Measurement Award

Jordan Valley  
Semiconductors

For:

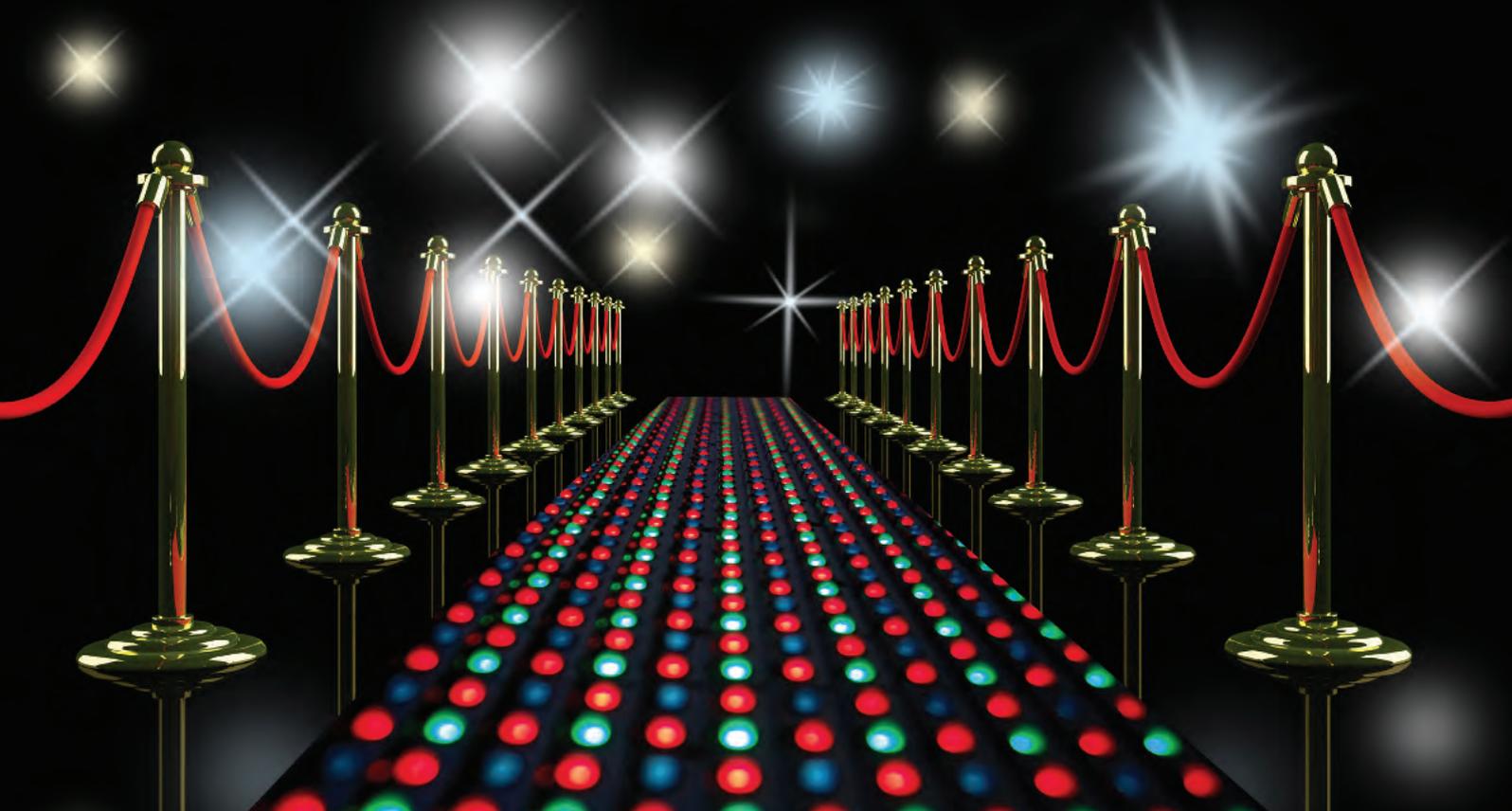
QC3 Fast HRXRD Metrology Tool

## R & D Award



For:

Near Junction Thermal Transport Program



# IR commences shipments of GaN-on-silicon devices

INTERNATIONAL RECTIFIER CORPORATION has qualified and shipped products built on its gallium nitride (GaN)- based power device technology platform for a home theatre system manufactured by a leading consumer electronics company. “Commencing commercial shipments based on our leading-edge GaN-based technology platform and IP portfolio extends IR’s leadership in power semiconductor devices and heralds a new era for power conversion, in line with our core mission to help our customers save energy,” states IR’s President and Chief Executive Officer, Oleg Khaykin.

“We fully anticipate the potential impact of GaN-based technology on the power conversion market to be at least as large as the introduction of the power HEXFET by IR over 30 years ago.”

IR says that this provides a capital-efficient manufacturing model that enables customers with improvements in

key application-specific figures of merit (FOM) of up to a factor of ten compared to state-of-the-art silicon-based technology.

“GaN has the potential to be infused into every business unit and product line within IR over the long-term. We are excited about GaN, and see it as one of the major drivers for our long-term revenue growth, and market share expansion. I would like to thank all of the individuals involved and congratulate them for this tremendous accomplishment,” Khaykin concludes.

The GaN-based power device technology platform is the result of ten years of research and development by IR based on the company’s proprietary GaN-on-silicon epitaxial technology.

The high throughput, 150mm GaN-on-Si epitaxy, together with subsequent device fabrication processes which are fully compatible with IR’s current cost



effective silicon manufacturing facilities, offers customers a commercially viable manufacturing platform for GaN-based power devices.

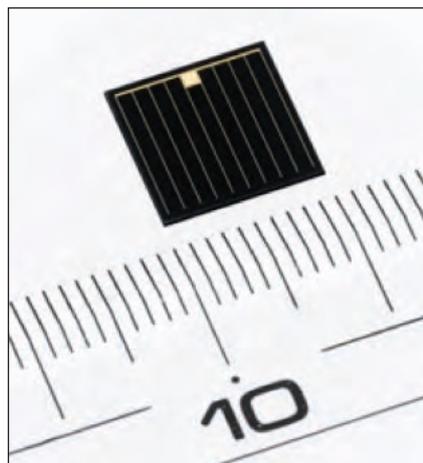
## Sharp’s multi-junction cell breaks efficiency record

SHARP CORPORATION has achieved what it claims is the world’s highest solar cell conversion efficiency of 37.9 percent.

This is based on a survey by Sharp as of April 24th, 2013, for non-concentrator solar cells at the research level.

The conversion efficiency was confirmed by the National Institute of Advanced Industrial Science and Technology (AIST). This is one of several organisations that officially certify energy conversion efficiency measurements in solar cells. The cell surface was approximately 1cm<sup>2</sup>.

Sharp achieved this latest breakthrough as a result of a research and development initiative promoted by Japan’s New Energy and Industrial Technology Development Organisation (NEDO) on the theme of “R&D on Innovative Solar Cells.”



NEDO is one of Japan’s largest public management organisations for promoting research and development as well as for disseminating industrial, energy, and environmental technologies. Compound solar cells utilise photo-absorption layers made from compounds consisting of two or more elements, such as indium

and gallium. The basic structure of this latest triple-junction compound solar cell uses proprietary Sharp technology that enables efficient stacking of the three photo-absorption layers, with InGaAs as the bottom layer.

By optimising the relative proportions of indium, gallium, and arsenic, Sharp succeeded in increasing the efficiency with which the cell absorbs sunlight at its various wavelengths. This improvement enabled Sharp to achieve a solar cell conversion efficiency of 37.9 percent.

Sharp’s aim for the future is to apply this latest development success to concentrator photovoltaic power systems that use lenses to collect and convert sunlight into electricity.

The company also foresees numerous other practical applications for the cells, such as on space satellites and vehicles.

# Soraa threatens to end halogen's reign

WITH the widespread adoption of LED lighting, Soraa has announced 230V GU10 and 100V E11 versions of its new Soraa VIVID 2 and PREMIUM 2 LED MR16 lamps.

The company says these are the first ultra-efficient replacements for 65-watt and 75-watt halogen lamps.

A technological breakthrough made possible by Soraa's GaN on GaN LEDs, the firm's new LED MR16 lamps deliver the industry's highest light output, while rendering vivid colours, richer reds and whiter whites, transforming ordinary lighting in any space into extraordinarily vibrant, brilliant and energy efficient lighting.

The announcement comes on the heels of Soraa's new lamp line availability announcement for the North American market.

"The Soraa VIVID 2 and PREMIUM 2 lamp lines represent a tipping point in the widespread adoption of LED MR16 lamps - we now have 65-watt to 75-watt equivalent lamps that produce full visible spectrum light and consume 80 percent to 85 percent less energy," says Tom Caulfield, President and COO of Soraa.

"And what's amazing is that we have just scratched the surface in terms of performance gains from our GaN on GaN LED technology. Look out halogens - your days are numbered."

Most LED lamps available today are based on LEDs made by depositing GaN on foreign substrates like sapphire, SiC or silicon. Consequently, these LEDs have high crystal defect densities that limit the amount of current densities they can handle, thereby limiting the amount of light they emit per unit area.

These high defect densities also constrain the LEDs to much lower temperatures in order to operate reliably. Both these limitations are amplified when these LEDs are used in a small form factor like an MR16 lamp, which is frequently installed in constrained or enclosed fixtures, and is used in



applications that require very high light output. The lamps that use these LEDs have to make compensating design choices like using multiple LED light sources to generate the required amount of light, and active cooling mechanisms to keep the LEDs within their operating temperature range.

In contrast, the Soraa VIVID 2 and PREMIUM 2 lamps' GaN on GaN LED technology leverages the 1000x lower crystal defect density advantage of the native substrate, thus emitting substantially more light and allowing reliable operation at much higher temperatures.

This enables a very simple and robust MR16 lamp design that uses a single LED light source and a simple heatsink, while producing 65W to 75W halogen equivalent light output and operating reliably at lamp temperatures of up to 1200C, a requirement for use in the most constrained fixtures.

"I believe the Soraa VIVID 2 and PREMIUM 2 lamp lines will have a profound effect on lighting design - smaller-form-factor, high-output LED MR16 lamps will now replace larger lamp types like PARs," adds Caulfield.

The Soraa VIVID 2 LED MR16 lamp has a CRI of 95 and R9 of 95 and is available in a complete suite of beam angles, colour temperatures and lumen outputs; and the SORAA PREMIUM 2 LED MR16 lamp has a CRI of 80 and is available in multiple beam angles and colour temperatures.

## Infinera expands digital network in Norway

INFINERA is expanding into the Nordic region with cable operator Agder Breiband (Agder). Agder selected the Infinera DTN and ATN platforms for the flexibility, scalability and simplicity of Infinera's Digital Optical Network solutions.

Agder, a broadband service provider in the south of Norway, offers customers high speed Broadband Internet, IPTV and VoIP services. Agder offers services via their partner Altibox.

Agder is deploying the Infinera DTN and ATN platforms in its regional backbone to provide high capacity transport for the voice, video and data services they deliver to their customers. The platforms share the common Infinera Management Suite (IMS) and work together seamlessly, making it simple to deploy new capacity quickly and flexibly. By deploying the DTN and ATN platforms, Agder can offer broadband services rapidly to customers.

"We selected Infinera for our network based on the flexibility of their solutions, ease of use and the ability to provide us with a simplified end-to-end solution for our network," says Terje Abusland, Technical Manager at Agder. "At Agder, we have a small team and it's critical for us to deploy with solutions that are cost effective for our business. Infinera's solutions were easy to inst all and our team was able to deploy the network in 7 days."

"We are pleased to announce Agder Breiband as our first customer in Norway," says Chris Champion, vice president of EMEA sales. "We continue to see traction across the globe with our solutions, providing customers like Agder with platforms that enable them to be successful in the markets they serve."

Agder's deployment of Infinera's DTN and ATN platforms provides them with a network that is easy to operate.

# Anadigics' InGaP technology powers Samsung Galaxy S4

ANADIGICS' AWL9581 802.11ac front-end IC (FEIC), AWT6651 ProEfficient power amplifier (PA), AWT6624 HELP4 PA, and AWC6323 HELP3E dual-band PA enable wireless connectivity in the Galaxy S4 by Samsung Electronics.

The smartphone offers a 5-inch full HD Super AMOLED display, 1.9 GHz quad-core processor, 13 megapixel camera, and Android 4.2.2 Jelly Bean operating system. The new Samsung Galaxy S4 also builds upon the success of its predecessor with both consumer and professional innovations, such as touchless interactions and government-grade security.

"We are ecstatic to enable both WiFi and cellular connectivity in the new Samsung Galaxy S4," says Ron Michels, chairman, president and CEO of Anadigics.

"The selection of Anadigics' differentiated, battery-saving solutions



for this flagship device not only exemplifies the tremendous performance advantages offered by our products, but also the strength of our relationship with Samsung. Our goal is to continue to support Samsung through each successive generation of mobile connectivity."

Anadigics' 802.11ac FEICs leverage the company's exclusive InGaP-Plus technology and patented design architectures to combine a high performance PA, low-noise amplifier (LNA), and RF switch on a single die. This level of integration on a single die greatly improves manufacturability and reliability for our customers. It also reduces PCB space requirements and simplifies RF front-end design to speed time-to-market.

Anadigics' AWL9581 5 GHz FEIC utilises InGaP-Plus to deliver low current consumption, significantly extending battery-life in mobile applications.

The complete family of FEICs provides outstanding error vector magnitude (EVM) and noise figure performance, which enables ultra-high data throughput. The AWL9581 is featured in the Galaxy S4 across multiple regions and carriers.

The company's ProEfficient, HELP4, and HELP3E power amplifiers also use InGaP-Plus and unique design architectures to provide greater efficiency in low power mode and extend talk-time.

What's more, Anadigics' ProEfficient PAs offer exceptional performance in high power mode to minimise current consumption when using 3G and 4G data services and maximise overall battery-life.

The AWT6651 is featured in the Galaxy S4 for China Mobile, the AWT6624 is being used in the Galaxy S4 for U+ in Korea, and the AWC6323 is being utilised in the Galaxy S4 for China Unicom.

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# IQE releases 150mm GaN-on-SiC

IQE has launched gallium nitride based; high electron mobility transistor (GaN HEMT) epitaxial wafers on 150mm diameter semi-insulating SiC substrates. The substrates are being supplied by the WBG Materials subsidiary of II-VI Inc, a provider of engineering materials and optoelectronic components.

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.

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

The 150mm GaN HEMT epi wafer products also enable cost reduction, production capacity and yield improvement, as well as potential for insertion into a wider range of chip fabrication facilities. To date, commercial market penetration of GaN HEMTs has been limited by the higher cost of epitaxial material grown on 100mm SiC substrates.

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

Russ Wagner, VP of IQE Wireless Business Unit says, "Scaling up to 150mm wafer diameter is a critical milestone on the path to technological maturity and wide market acceptance of GaN HEMTs on SiC. IQE has established an industry-leading position by offering a full range of GaN-based high-power RF transistor wafers in formats that enable the most cost-effective processing and system designs."

"We are very pleased with the quality of substrates supplied by II-VI Inc. and look forward to continuing our partnership as we execute volume production ramp and expand IQE's range of advanced high-power high-frequency transistor products for defence and wireless infrastructure applications."

Tom Anderson, General Manager of II-VI Inc. subsidiary WBG Materials, says, "The WBG Materials subsidiary of II-VI Inc. has developed high quality 4H - 150mm SiC substrates, for both the RF and power markets. These 150mm SiC substrates will greatly reduce device

costs by increasing the number of devices produced per wafer, enabling 150mm wafers to be processed using modern, high volume semiconductor tools designed for large wafers and by providing competitive sourcing and leveraging of high volumes into commercial markets."

"Our partnership with IQE in this 150mm product development has enabled rapid technology advances for both Groups and we are looking forward to continuing our work together to deliver this state-of-the-art product to our joint end users," concludes Anderson.

## Valence process equipment unveils new MOCVD system for LED manufacturing

VALENCE PROCESS EQUIPMENT has announced the commercial release of the VPE GaN-500 MOCVD system, a new metal organic chemical vapour deposition (MOCVD) system for production of high-brightness light emitting diodes (LEDs). The VPE system includes a reactor that is designed around a novel (patent pending) chamber and gas-injector, resulting in the highly efficient use of pre-cursor gases. The system has a capacity of 59 two-inch wafers with a future upgrade path to 72 two-inch or 20 four-inch wafers.

Frank Campanale, CEO of VPE, commented: "One of the biggest single factors contributing to the cost of an LED wafer is the volume of chemicals used in the MOCVD process. The novel chamber and gas injector design in the VPE GaN-500 MOCVD result in highly efficient use of gas and pre-cursor chemicals when compared to MOCVD systems currently in the market.

The GaN-500 has been field tested in a customer fab for more than one year. Over the course of hundreds of runs, materials performance, gas consumption, and machine reliability have been extensively monitored and validated. We are extremely excited to report that this testing has confirmed that our product can produce wafer uniformities and growth rates that are comparable with established systems, while at the same

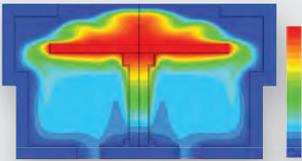
time consuming up to 40% less gases and chemicals."

In addition to low gas consumption, the VPE GaN-500 is designed to combine high reliability with low operating and maintenance costs. Wherever possible, the system uses standard off-the-shelf materials, so customers can make use of existing stocks of spares. Custom parts, such as chamber and heater components, are deliberately designed to minimize complexity, reducing maintenance and service costs.

"The focus on low COO does not compromise material quality" according to Tom Ryan, well-known characterization expert and VPE's VP of Product Management. "The design of the VPE chamber permits very rapid temperature ramping combined with fast stabilization and highly efficient gas switching. This leads to precise control of the MQW growth and excellent device properties."



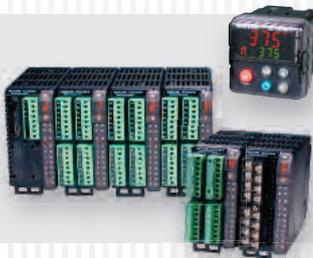
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# Mesuro can extract data from non-linear devices

MESURO, which offers testing and services solutions for the semiconductor industry is now delivering measurements needed for non-linear devices.

The firm says that whatever measurement set or application is needed from non-linear device data, its measurement services can deliver.

The company's laboratory allows for device testing up to 100W CW packaged devices to 6GHz Fundamental; up to 20W CW packaged devices in the X band; fundamental test up to 67GHz; and fixture design and manufacture.

Device characterisation allows customers to evaluate their device performance utilising Mesuro's test platforms for immediate use within designs and to gain experience of the WaveForm Engineering process that can aid in business case justification and provide confidence through verified data sets. All parameters available in the test platforms can be measured, including DCIV, S-Parameters, Pin/Pout and Power and Efficiency Contours.

With device modelling, non-linear measurement data has been exploited in various ways to create behavioural models for high frequency transistors. These include frequency-domain descriptive behavioural models, including Poly Harmonic Distortion (PHD) Models, S-functions and X-Parameters.

Formulations of these models have been developed in the travelling wave domain with a desire to represent non-linear behaviour of high frequency transistors.

Work demonstrated using the Cardiff Model formulations, based on PHD models, has shown that by considering higher order mixing terms in the PHD formulation, a better fit can be achieved around a more compact file size, without sacrificing accuracy.



When considering the performance of RF Power Amplifiers (PAs) or indeed other non-linear devices, it is the terminal RF I-V Waveforms that are the unifying theoretical link between transistor technology, circuit design, and system performance.

From a non-linear PA design perspective, the integration of RF WaveForm Engineering capability, whether passive or active, with RF Waveform measurement capability, is essential. With such systems, the practical design of PAs achieved by directly employing the theoretically-based WaveForm Engineering approach is now experimentally possible.

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# SiC rescues the power device market

STARTING IN LATE 2011, the power electronics downturn in 2012 was quite severe, exhibiting a 20 percent decline.

Yole Développement says this in its "SiC Market 2013: Technology and Market for SiC Wafers, Devices and Power Modules" report.

Yole's report focuses on the entire value-chain and covers all SiC applications in low, medium and high power ranges and provides all metrics up to 2020.

The market suffered from the global economic downturn combined with external factors like China controlling what happened in some selected markets (Wind turbine or Rail traction projects that have been stopped or postponed).

However, the SiC device market kept on growing with a 38 percent increase year over year. SiC technology is now commonly accepted as a reliable and pertinent alternative to the silicon world.

Most power module and power inverter manufacturers have already included it in their roadmap as an option or as a firm project. However time-to-market differs from application to application as a function of value proposals for cost, specifications, availability and so on.

Despite a quite depressed market last year, PV inverters have proven their appetite for SiC devices in 2012. They are the biggest consumer of SiC devices together with PFCs.

In 2011 and 2012 the SiC diode business was the most buoyant due to micro-inverter applications. However Yole is confident that both JFET and MOSFET will quickly catch-up and become dominant in revenue by 2016.

SiC device (bare-dies or packaged discretés) market reached about \$75 million in 2012 with a sharp domination by Infineon and Cree again. However the competition is little by little grabbing market share with STMicroelectronics and Rohm closing the loop.

Yole estimates there are now more than 30 companies worldwide which have established a dedicated SiC device manufacturing capability with related

commercial and promotion activities. Virtually, all other existing silicon-based power device makers are also more or less active in the SiC market but at different stages.

2012 has seen the ramp-up of some companies, such as Rohm, MicroSemi, GeneSiC or STMicro, facing the 2 giants Cree and Infineon, prefiguring a new market shaping in the coming years.

Four new companies - Raytheon, Ascatron, IBS and Fraunhofer IISB - have decided, almost simultaneously, to launch SiC foundry services or contract manufacturing services. This business model establishment addresses the demand of future SiC fabless and design houses that may look for specific manufacturing partners. It will also probably act as a possible second source for IDMs in cases of production overshoot.

In Asia, Panasonic and Toshiba are now clearly identified as credible contenders, along with Mitsubishi Electric, now developing SiC power modules. And Fuji Electric's new SiC line is now running within the Japanese national program.

No Chinese device maker has emerged yet, however, according to the huge investment plan in R&D, Yole's analyst suspects new IDMs will soon enter the business.

In the US, Global Power Device and USCi have now exited stealth mode and have strongly affirmed their intentions to take market share.

Ultimately, the unexpected closing down of SemiSouth in October 2012 has created chatter about the quite stable-until-then SiC business. Several reasons have been disclosed that explain this decision (over-sized company, market too long to take-off and so on), however Yole says we can't ignore that it discredits to some extent the Noff JFET technology. Only the future will tell...

Reshaping from discretés to modules Yole now sees the SiC industry reshaping, starting from a discrete device business and now mutating into a power module business. Originally, this was initiated by Powerex, MicroSemi, Vincotech or GeneSiC with hybrid Si/



SiC products, then other players such as Mitsubishi, GPE and more recently Rohm have reached the market with full-SiC modules.

This trend will become dominant in the coming years as integrators require power modules in most of their mid and high power systems (generally starting from >3kW).

Yole forecasts that SiC-based power module demand could exceed \$100 million by 2015 and top about \$800 million in 2020 depending on whether or not the auto industry will adopt SiC.

SiC enables high frequency and high temperature operation. That said, capturing these 2 added-values remains an issue as no existing set of technologies can fully answer that request now.

The path to success for SiC large implementation will need to go through new packaging solutions. Numerous bottlenecks need to be unlocked. These include chip bonding, metallic contact technique, gel filling, encapsulant and EMI.

Power device integrators generally rely on two, or even three sources to lower supply-chain risks. In SiC, it is now easy operating multi-sourcing for diodes, though not yet for transistors. MOSFET, JFET or BJT must be available from at least 2 companies with similar specifications.

# TriQuint's GaN-on-diamond technology is cutting edge

TRIQUINT SEMICONDUCTOR has produced, what it claims, is the industry's first GaN transistors using GaN-on-diamond wafers that substantially reduce semiconductor temperatures while maintaining high RF performance.

The firm's latest technology enables new generations of RF amplifiers up to three times smaller or up to three times the power of today's GaN solutions.

TriQuint received a Compound Semiconductor Industry Award in March commending its new GaN-on-diamond achievements. TriQuint's James L. Klein, Vice President and General Manager for Infrastructure and Defence Products, remarked that unlocking the true potential of high-efficiency GaN circuits will depend on achievements like those of TriQuint's advanced research and development program.

Operating temperature largely determines high performance semiconductor reliability. It's especially critical for GaN devices that are capable of very high power densities.

"By increasing the thermal conductivity and reducing device temperature, we are enabling new generations of GaN devices that may be much smaller than



today's products. This gives significant RF design and operational benefits for our commercial and defence customers," he said.

TriQuint demonstrated its new GaN-on-diamond, high electron mobility transistors (HEMT) in conjunction with partners at the University of Bristol, Group4 Labs and Lockheed Martin under the Defence Advanced Research Projects Agency's (DARPA) Near Junction Thermal Transport (NJTT) program.

NJTT is the first initiative in DARPA's new 'Embedded Cooling' program that includes the ICECool Fundamentals and ICECool Applications research and development engagements. NJTT focuses on device thermal resistance

'near the junction' of the transistor. Thermal resistance inside device structures can be responsible for more than 50% of normal operational temperature increases. TriQuint research has shown that GaN RF devices can operate at a much higher power density and in smaller sizes, through its highly effective thermal management techniques. TriQuint's breakthrough involves the successful transfer of a semiconductor epitaxial overlay onto a synthetic diamond substrate, providing a high thermal conductivity and low thermal boundary resistance, while preserving critical GaN crystalline layers.

This achievement is the first to demonstrate the feasibility of GaN-on-diamond HEMT devices. Results to date indicate TriQuint achieved the primary NJTT goal of a three-fold improvement in heat dissipation while preserving RF functionality; this achievement supports reducing power amplifier size or increasing output power by a factor of three.

Additional fabrication improvements and extensive device testing are underway to optimise the epitaxial layer transfer process and fully characterize enhancements that can be achieved in these new HEMT devices.

## M/A COM develop solderable flip-chip gaas schottky diodes

M/A-COM Technology has announced a new broadband Flip Chip Schottky Diode for multi-market applications. The MADS-001317-1500 is designed for customers who need a versatile, low cost, ultra-small Schottky solution for Police Radar, Point to Point, Electronic Warfare and Aerospace and Defence applications.

The MADS-001317-1500 is a package-less Schottky device with contacts that allow for standard solder reflow manufacturing processes. The high cut off frequency of this diode allows customers to use the device through millimetre wave frequencies.

The MADS-001317-1500 boasts excellent performance making it an ideal solution for single and double balanced mixers

in PCN transceivers and radios, police radar detectors, and automotive radar detectors.

The table below outlines typical performance of the GaAs based device. The MADS-001317-1500 is fabricated using a GaAs process which features full passivation for increased performance and reliability.

The low parasitic capacitance and inductance allow for operation up to 80 GHz," says Paul Wade, Product Manager.

"Due to wafer scale reduction, the device minimises unwanted parasitic and allows for exceptional performance beyond 80 GHz. Production quantities and samples of MADS-001317-1500 are available from stock.

Parameter	Units	MADS-001317-1500
Frequency	GHz	Up to 80
Capacitance @-10V	pF	0.045
Series Resistance	Ω	4
Breakdown Voltage (min)	V	4.5
Process	-	GaAs

# UV LED technology extends food life

SCIENTISTS have demonstrated an increased shelf life and improved nutritional quality of fresh produce with a new storage technology using ultraviolet aluminium gallium nitride (AlGaIn) LEDs.

In an exciting development, a combined team of scientists from Sensor Electronic Technology, Inc. (SETi) and the Food Components and Health Laboratory of the US Department of Agriculture (USDA)



have found a way to extend the shelf life of fresh fruit and vegetables stored in home refrigerators.

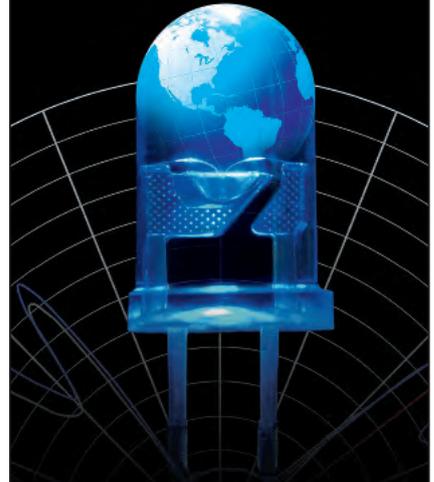
This 3-year program, which investigated the effects of light from certain types of UV LEDs, has led to more than double the shelf life of fresh produce, while retaining the nutritional quality and appearance.

The technology is currently being commercialised for the home appliance market. Remis Gaska, President and CEO of SETi says, "Findings of this exciting program are expected to have a major impact on the appliance business to extend the shelf life and preserve nutritional value of the fresh produce.

We look forward to the prospect of UV LEDs in residential refrigerators impacting on everyday life and reducing waste through spoilage."

Steven Britz, Research Plant Physiologist, Agricultural Research Service of USDA adds, "We are exploring the possibility that the UV effect involves the induction of defence mechanisms in the fruit itself in addition to inhibition of mold growth, since evidence indicates parts of the UV spectrum retards decay."

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## IQE launch wireless products division

IQE plc. is launching a new division, 'IQE Wireless', which will provide its customers with a 'one stop shop' for radio frequency (RF), wireless epitaxial wafer materials.

The new brand was launched at the start of CS-Mantech 2013, an international conference for compound semiconductor manufacturing technology, running from 13th to 16th May 2013 in New Orleans, Los Angeles, USA.

IQE is already firmly established as a supplier of epitaxial wafers for wireless products, including pHEMTs, HBTs and BiFETs, that provide the key enabling technology for wireless communications for smartphones, tablets, PCs, WiFi, base

stations and other wireless devices and equipment.

Vice President Russ Wagner, who has been appointed to head the new wireless division says, "IQE is clearly acknowledged as the world leading supplier of advanced semiconductor wafers for wireless products and enjoys excellent and close working relationships with customers in the RF space."

"The establishment of a dedicated wireless brand within the group allows the new division to further focus on enhancing its product offerings and customers' experiences as we continue to grow both our existing business and enter new and emerging markets."

## SiC module to deliver higher performance

CREE is introducing what it says is the industry's first commercially available 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, thereby enabling the designer

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 allows us to use them with significantly less derating than silicon IGBTs," states Jun Kang, research and applications manager, Yaskawa America, Inc. "This feature enables significantly higher frequency operation, which both increases fundamental output frequency and

reduces passive component size in the motor drive."

"Cree's SiC power module family can also provide significant benefits to applications such as solar inverters, uninterruptible power supplies (UPS) and industrial power supplies," explains Mrinal Das, product marketing manager, Cree Power and RF.

"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."

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## Bridgelux and Toshiba strengthen collaboration

BRIDGELUX has closed an agreement with Toshiba Corporation to extend their strategic technology collaboration on LEDs. The agreement was originally announced on April 22nd, 2013, and the companies have now completed the transfer of Bridgelux GaN-on-silicon technology assets to Toshiba and inaugurated this new phase of GaN-on-silicon LED collaboration. This included an expanded licensing and manufacturing supply relationship. Bridgelux will continue to develop and market its GaN-on-Sapphire LED products as a fabless solid state lighting company.

"We are thrilled to be moving into the next stage of our joint work with Toshiba to advance GaN-on-Silicon-based solid state lighting technologies," says Brad Bullington, Chief Executive Officer of Bridgelux.

He finishes by saying, "As we outlined last month, Bridgelux will focus on commercialising, productising and bringing to market GaN-on-Silicon technologies alongside a proven global scale semiconductor manufacturer. At the same time, we remain committed to our GaN-on-Sapphire business and look forward to continuing to provide world-class service to our customers."

# Osram leads LED project to serve many markets

ADAPTIVE FORWARD LIGHTING, or glare-free camera-controlled headlamps that react instantly, will be helping drivers even more in the future thanks to additional intelligent functions.

The key to this complex functionality is the integration of microelectronics and optoelectronics. This is one of the principal aspects of the research project sponsored by the German Federal Ministry of Education and Research (FMER) within the "Photonics Research Germany" program.

Osram is contributing its expertise as the project coordinator in LED lighting for the automotive sector. The aim of this joint project as part of the FMER "Integrated microphotonics" initiative is to develop the technical framework for a new class of energy-efficient LED headlamps with supplementary traffic safety functions. This could provide the basis for adaptive forward lighting systems (AFS) that offer drivers and passengers increased safety. Improved safety will come for example



from glare-free high-beam and low-beam that adapts to the speed of the vehicle.

At high speed the range of the light is automatically increased. In city traffic however a wider distribution of the light can improve road safety by illuminating more of the sidewalk and margins. These functions are fully electronic so there is no need for mechanical actuators. Osram has extensive know-how in chip and converter technologies. The company's Specialty Lighting division will be developing new electronic control gear for controlling the LED headlamp

system. The Fraunhofer Institute for Reliability and Microintegration (IZM) is contributing its expertise in interconnection technology and materials, and Infineon Technologies is offering its experience in automotive electronics and LED drivers.

The automotive industry supplier and lighting specialist HELLA KGaA Hueck & Co. will develop the entire optical system for the LED module and the headlamps, and will build prototypes. Daimler, a major engineering power-house in the automotive sector, will carry out the vehicle tests.

Project coordinator Stefan Grötsch, responsible for LED applications in automotive lighting at Osram Opto Semiconductors, is satisfied with progress so far. He says, "We have brought together major-league players in their respective sectors, assembling a wealth of expertise for this pioneering project around one table."

The project is being sponsored by the German Federal Ministry of Education and Research (FMER) under reference number 13N12510 and is scheduled to run from February 1st, 2013 to January 31st, 2016.

## Xilinx and Sumitomo Electric collaborate to smarten networks and reduce costs to market

XILINX AND SUMITOMO ELECTRIC are collaborating to bring smarter solutions to market. The firms say these solutions reduce CapEx and OpEx costs through the use of Sumitomo Electric's GaN power amplifier transistors and Xilinx SmartCORE IP that result in higher radio unit efficiencies.

Wireless system designers using Xilinx's SmartCORE IP can scale to support small cells to high-end macro cells, as well as active antenna systems (AAS).

This offers customers time-to-market advantages, lower development costs, high efficiency, lower SWaP (size, weight and power), and lower total cost.

Xilinx radio SmartCORE IP such as Digital Up and Down Converters (DUC/DDC), Crest Factor Reduction (CFR) and Digital

Pre-Distortion (DPD) IP cores, coupled with generation-ahead 28nm Zynq-7000 All Programmable SoCs, offers customers a single-chip implementation of the entire digital radio in addition to board level control and calibration typically found in an external processor.

"By collaborating with Sumitomo Electric, we are able to provide our customers with a smarter solution that is scalable to support the needs of broadband microcells, and up to the highest performance multi-antenna broadband macros and AAS installations," says David Hawke, director of wireless product marketing at Xilinx.

"Additionally, our radio IP, coupled with Sumitomo Electric's power amplifier transistors, allow OEMs to design equipment that ultimately save operator CapEx and OpEx, as well as reduce

device cost and power."

The high breakdown voltage and saturation velocity characteristics of GaN devices make it an ideal candidate for high-power and high-temperature base station applications.

The higher power density of GaN also allows for smaller devices, reducing size and cost.

"Sumitomo Electric's GaN-based power devices combined with Xilinx's SmartCORE IP will demonstrate the world's next generation of highly efficient solutions for the wireless market," adds Nobu Kuwata, general manager of Technology and Marketing Strategy Department at Sumitomo Electric Device Innovations, Inc. "Sumitomo Electric is committed to developing the products necessary to meet the requirements of our customers offering smarter solutions."

# Materials research thrives as Concentrated Photovoltaics industry stalls

As concentrated photovoltaic businesses soldier on, research into novel III-V devices is rife. Compound Semiconductor looks at what the future holds for the industry

JUST WHEN YOU THOUGHT the CPV industry was petering out, industry developments indicate otherwise. Although commercial front-runners, such as JDSU and Amonix, are scaling down operations, and GreenVolts has folded. Organisations lower down the business chain are seeing a surge in funds.

For example, the Climate Investment Fund recently extended its \$7.6 billion award for the development of concentrated solar plants in MENA nations, to include CPV development.

At the same time, IBM Research and partners have bagged \$2.4 million from the Swiss Commission for Technology to build an affordable version of a novel CPV set-up – the High Concentration PhotoVoltaic Thermal (HCPVT) system – that incorporates a thermal system to capture lost heat with water. IBM reckons recovering waste heat in this way will boost overall system efficiency to an admirable 80 percent.

But it's not just large-scale projects edging towards commercialisation that are scooping cash. Recent months have seen a flurry of research grants awarded to materials scientists and physicists keen to hone the III-V semiconductors fundamental to the efficient and affordable operation of these photovoltaics.

For example, in April last year, the UK-based Engineering and Physical Sciences Research Council (EPSRC) dished out some £500,000 to a team led by Liverpool University researchers to develop nitride-based cells for use in CPV systems.

Meanwhile, researchers from the Universities of Manchester and Salford have just won some £880,000 to conduct theoretical work on InAs, GaAs and CsSe quantum dots for solar cells.

And only last month University College London and University of Bristol researchers won £950,000, again from the EPSRC, to fabricate III-V quantum dot solar cells on silicon substrates for CPV systems. UCL researchers will pioneer MBE growth and device fabrication while Bristol colleagues will perform modelling to optimise performance.

Huiyun Liu, a key researcher from the UCL branch of this III-V QD project has seen a steady rise in the number of solar-funded projects. “[Commercial] companies have been struggling, but my research group is not,” he says.

“Our track record is in lasers, but over the last year the funding I have received has been for solar research. We have seen a dramatic shift from laser to solar research, and definitely more interest from companies.”

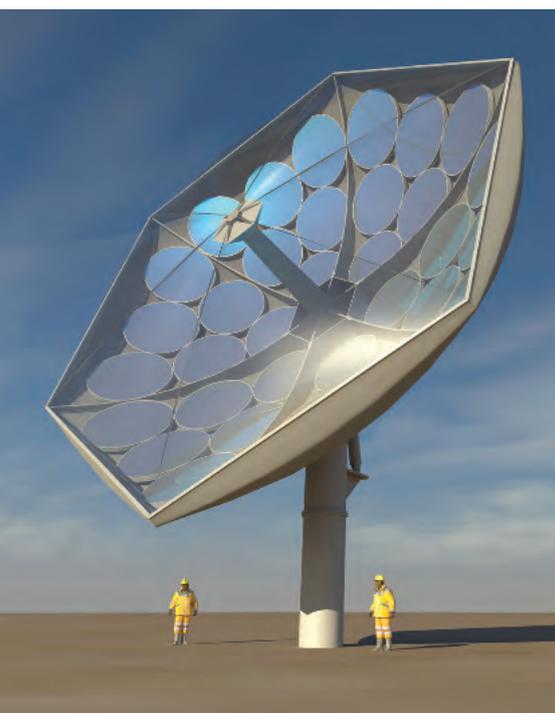
As Liu highlights, his latest EPSRC-funded project is also supported by the UK government owned Defence Science and Technology Laboratory (DSTL), Wales-based IQE and UK-based Sharp Laboratories of Europe.

“We’ve also been talking to the French oil company, Total. They are interested in this area as they want to develop high efficiency, low cost solar cells,” he says. “Right now III-V solar cells are too expensive, but they have this high efficiency... the [companies] that have come to us all say the same thing; it’s not making money now but we have to try.”

## Next generation cells

When designing III-V CPV solar cells, most researchers have adopted a multi-junction structure, connecting a number of semiconductor junctions with optimised bandgaps in series to boost efficiency.

While research into nitride-based solar cells is well underway, many existing multi-junction cell structures have been based on GaAs layers. For example US-based Spire Semiconductor claimed record peak efficiencies of 42.3 percent with its CPV InGaAs/GaAs/InGaP cells, (bandgaps of 1.89/1.42/0.94eV



The prototype HCPVT system under development uses a large parabolic dish, made from a multitude of mirror facets, which is attached to a tracking system that determines the best angle based on the position of the sun. Once aligned, the sun's rays reflect off the mirror onto several microchannel-liquid cooled receivers with triple junction photovoltaic chips -- each 1x1 centimeter chip can convert 200-250 watts, on average, over a typical eight hour day in a sunny region. The entire receiver combines hundreds of chips and provides 25 kilowatts of electrical power. The photovoltaic chips are mounted on microstructured layers that pipe liquid coolants within a few tens of micrometers off the chip to absorb the heat and draw it away 10 times more effective than with passive air cooling. Credit: IBM-Research

respectively). But III-V quantum dots promise to bring a better solar cell. Compared to the active layers used in conventional devices, these semiconductor crystals can be tuned to absorb light over a much wider range of wavelengths, boosting conversion efficiencies.

What's more, by working with quantum dots rather than planar layers, researchers avoid the strains that build up at the interfaces between different materials, opening the door to the growth of novel material combinations that simply wouldn't be possible in conventional devices.

With this in mind, Liu and colleagues intend to develop a "completely different" quantum dot solar cell system grown on silicon, both with and without a thin germanium buffer layer.

This bold move could swipe away the high GaAs substrate prices of current CPV cells and capitalise on cheap CMOS manufacturing costs. The end result

could be a very cheap, yet highly efficient solar cell with, as Liu says, at least a 30 percent conversion efficiency.

"IQE provides silicon wafers with the germanium buffer layer, and at the same time we are also working with Sharp to develop GaAs solar cells on germanium-on-silicon," the researcher explains.

"But we are also working on the direct growth of III-V multi-junction solar cells on silicon with another industrial partner. If we can use the direct growth approach on silicon, this is better... We are academics, and we want to try any possibility."

Right now, the team is looking at a range of materials systems based on III-V quantum dots that absorb near the peak of the spectrum, around 1eV.

As Liu explains: "We have previously worked with lasers and have now found that using the InAs/GaAs quantum dot system is not ideal for absorption in solar

cells, so we are looking at alternative systems with a different bandgap alignment and long carrier lifetime."

The key contenders are metamorphic InAs/GaAsSb and InP/GaAsP quantum-dot systems, and the researchers will also explore such materials combinations in the context of an intermediate band structure solar cell.

Here an intermediate energy band is introduced into the energy gap of a single semiconductor junction. Such a structure promises conversion efficiencies up to 63percent, but only if the photo-generated carriers in the intermediate level can be channelled solely to the host material.

Clearly such a device will require much more work yet, but as Liu highlights: "EPSRC is taking a longer term view by funding research such as this.

Maybe industry is struggling, but for the academic, it's definitely a good area to be working right now."

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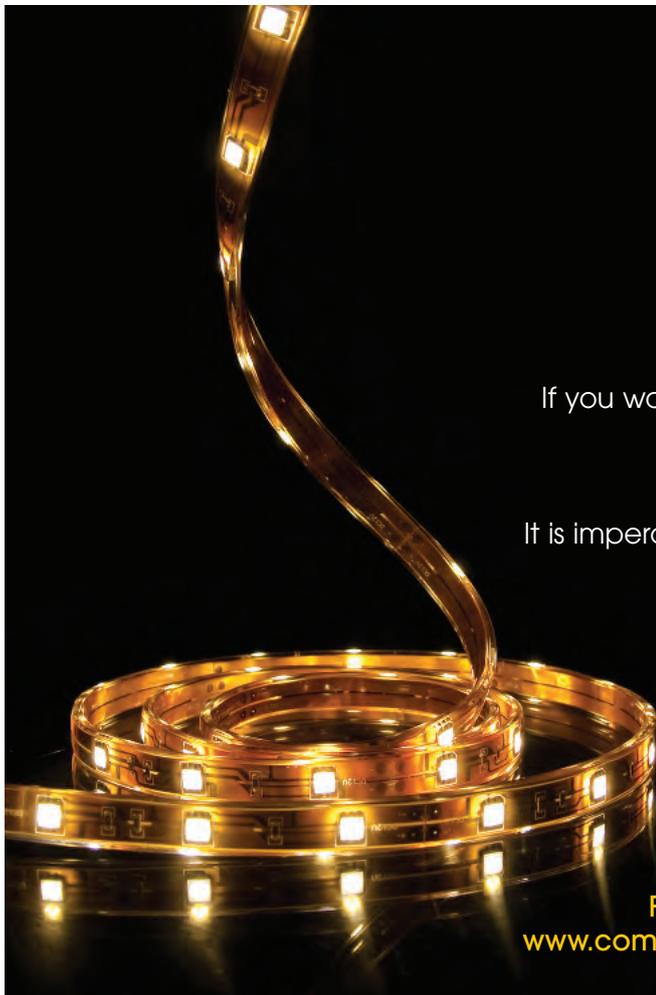
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# LEDs: The next dimension?

Seasoned chief executive, Giorgio Anania, explains why the world is now ready for 3D LEDs

DO A LITTLE research on Giorgio Anania, and you'll quickly realise he knows how to build a business. The Ivy League graduate made his name transforming start-ups from research outfits into million dollar commercial entities. His leading light, Bookham Technology – now called Oclaro – was one of the UK's fastest-growing businesses, and one of few to survive the telecoms downturn.

Today, Anania has set his sights on 3D LEDs. Currently standing as chief executive of Aledia, a developer of GaN microwire-on-silicon LEDs, he recently bagged the start-up \$13 million in equity and has plans for much more.

"I think it's clear these LEDs are going to be cheaper than 2D, planar [GaN-on-sapphire] devices," says Anania. "Material costs are cheaper – we're saving a lot of money by not having a thick GaN layer – and we can grow these things quickly; we get three times more throughput on the MOCVD machines."

As he is quick to point out, growing vertical GaN microwires onto silicon prevents the accumulation of wafer stresses that take place when GaN and InGaN layers are deposited on silicon. Here, differences in material expansion coefficients lead to lattice mismatches during processing, the end result being a wafer riddled with defects that degrade device yields and performance.

Crucially, Aledia recently transferred its manufacturing processes to 8-inch silicon wafers. Each wafer contains billions of co-axial GaN microwires, each with a diameter of less than a micron, and each acting as an LED, capable of emitting light from all sides. Anania remains tight-lipped on how the company actually grows the microwires on the wafers – only to confirm its a bottom-up epitaxy process – and jokes: "We've spent a year trying not to let the Samsung's of the world understand."

But as he highlights: "These things will be coming out of amortized silicon foundries, so you can [ramp up] volumes at the touch of a button. We've now got

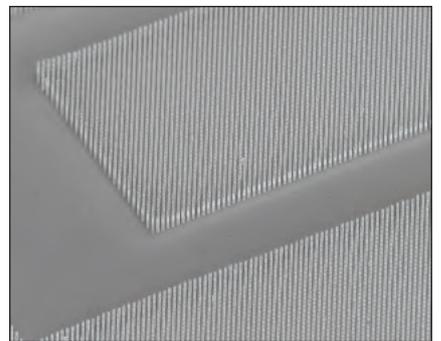
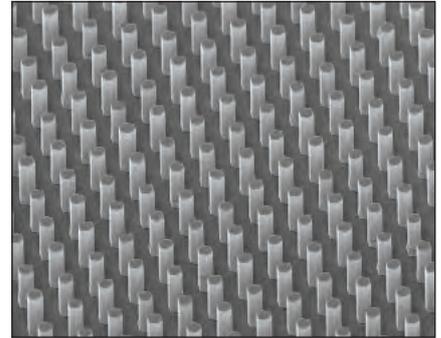
the speed, less material, a cheaper and bigger substrate and semiconductor foundry pricing."

But has the company's technology got the performance? Clearly Aledia has a good heritage. Its technology was developed over six years at CEA-Leti in Grenoble, France, and Aledia has received exclusive worldwide rights to all present and future CEA patents on microwire technology applied to lighting. What's more, the business has since filed several extra patents. But still, technical specifications are not forthcoming.

Anania's resolve to remain silent on figures is absolute, and he simply says: "We only have one other major competitor that's public, glo, based in California [and Lund, Sweden]. They've been around for at least nine years and we've been around for a year. They haven't given any numbers but we hope to soon, we just need a few more months."

Figures aside, what is clear already is while these LEDs will have some clever properties, the devices will not be breaking any performance records, at least in the near-term. The GaN microwires can be fabricated to emit over a broad range of wavelengths by varying the indium content. And so, incorporating different populations of microwires on a chip can give a range of white-light emitting microwire LEDs, without phosphors. But the technology isn't there yet. "This is generation three if you will, and that is where we're going and we will get rid of the phosphors completely," says Anania.

For now, Aledia's first white LEDs will be blue LEDs with phosphors. The company is busy working on these prototypes, and Anania reckons components will be ready for customer testing come quarter one, next year. As he says: "To get the sales quickly, you want products to look and smell as much as possible as existing products, as that's the easy-in. Initially we will not offer the best lumens per Watt, but many applications do not need this, what they really need is the best lumens per dollar... and our cost



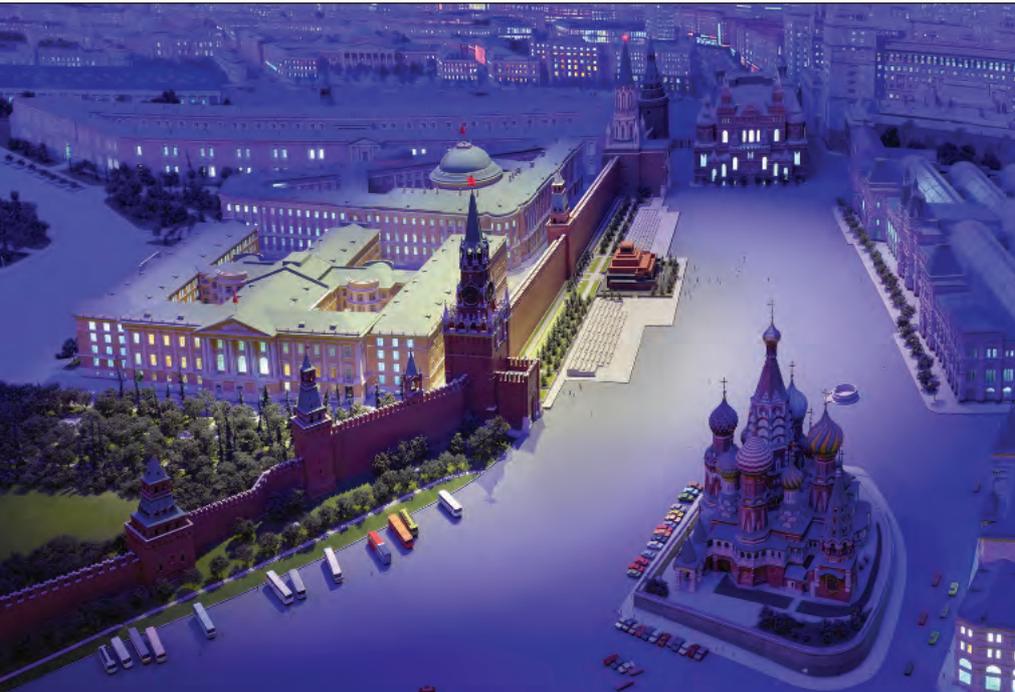
Microwire arrays: Aledia's microwires, as shown in the scanning electron microscopy images, are now grown on eight inch silicon substrates

structure is there."

And this is where Anania believes his company's 3D LEDs will win. He is convinced the LED lighting industry has changed significantly in the last year and a half.

"Before we saw a race for performance. A higher lumens per Watt meant greater cost reductions because you were getting more light out per square millimetre of chip; so you were offering a cost reduction on a per lumen basis," he explains. "But for many applications the lumens per Watt race is now tailing off." As Anania highlights, Asia-based players have since flooded the market with lower performing chips that cost a lot less.

"Everyone said we need high brightness for sure, but frankly, the volume sales have been in these mid-power chips," he says. "So the question is, what is a sufficient lumens per Watt to get you to market? Once you have that, then your lumens per dollar will make the sale."



## Lighting the roads to Russia

In the race to light up Russia's streets and parks, the Optogan-Philips joint venture prepares to shine the brightest, Compound Semiconductor reports

JUST LESS THAN A YEAR after industry rivals Optogan and Philips revealed plans to enter the market for road lighting in Russia together, the joint venture has launched manufacturing at Optogan's LED facility in St Petersburg, Russia.

Manufacturing outdoor luminaires based on III-nitride LEDs, the partners aim to ramp annual capacity to 50,000 luminaires for streets, yards and parks as soon as possible. As Andre Richter, head of the Philips-Optogan venture explains: "The products right now are based on successful, new Philips concepts. Manufacturing takes place here with local Russian components and we're looking to increase the Optogan content."

In the last year the duo claim to have reduced luminaire cost by some 30 percent, although as Richter states, these systems do not yet include Optogan's LEDs. This, says Richter, is something he is 'looking at' as well as integrating other Optogan components such as low temperature drivers, already

optimised for Russian operation, to the final product. Optogan currently delivers LEDs to other luminaire players.

So, in the meantime, what does each company gain from the partnership? For Philips, the answer is relatively straightforward; a foot in the doorway of the up and coming Russian LED market. Road lighting in Russia is expected to become one of the leading growth markets for LED products, tipped to double to €100 million by 2015. And of course, Optogan with its St Petersburg facility, already has a strong knowledge of local markets and customer demands.

But for a vertically integrated outfit such as Optogan, manufacturing LEDs, LED bulbs and LED luminaires and clearly entrenched in the Russia-based market, why partner with an outside competitor such as Philips? In short, experience.

According to Richter, globally, many companies manufacturing LED modules are trying to enter the outdoor lighting

Thanks to government subsidies, the Russian outdoor LED lighting industry is slated for rapid growth; will Philips's strategic alliance with Optogan ensure market share?

market. But despite making modules with the necessary optical performance, can these new entrants guarantee final luminaire performance?

"The outdoor market has very specific requirements in terms of the output and performance of luminaires," explains Richter. "Even for a company such as Optogan which is already successful in indoor applications, a lot can be learned, in terms of production technologies and quality standards, by linking up with a multi-national company such as Philips."

Crucially, the partnership should also accelerate time to market. Growth is predominantly driven by government energy efficiency programs, and as Richter says: "Pilot projects are taking place everywhere and these are scaling-up. In our judgement, this market is about to explode." So, as the world waits for Russia's widely anticipated outdoor lighting market to take-off, Philips and Optogan are likely to be amongst the first to scoop the action.

The partner's 'Avenue' luminaires, fresh off the St Petersburg production line, promise up to 100 lumens per Watt efficacy, and according to Richter will be the first in the Russian market to replace 400 W sodium bulbs, "output-wise and performance-wise".

Richter believes mutual interest has been critical to getting production off the ground so quickly. "There's been little competition and lots of common targets," he says. "Philips has contributed its experience of production technology while Optogan has made the space and provided a good location within its own LED fabrication facilities... as well as helping with legal processes."

So with Russia in hand, are the partners ready to face the rest of the world? Not yet. As Richter concludes: "For the time being there is huge potential in the Russian market, so I am focusing the venture on this nation only. For sure, you always consider different regions to operate in, but for now I will not deviate my focus from a very promising segment, and maybe risk losing direction."

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# Toshiba serves up SiC diodes for starters

As Toshiba sends its SiC diodes out to photovoltaic markets, what can we expect next?

WITH THE POWER ELECTRONICS market tipped to reach epic proportions - US analyst business Lux Research has predicted \$15 billion by 2020 - SiC device makers are jostling for space. Diodes from the likes of Cree, Rohm and Infineon have stormed into the photovoltaic inverter markets while transistors from many of these manufacturers are making inroads to high-end PV and telecoms segments.

But now, a 'new' entrant is vying for a piece of the SiC pie. Earlier this month, Japan-based electronics conglomerate, Toshiba, revealed volume production of Schottky barrier diodes had started at its Himeji Operations in Hyogo Prefecture, Japan.

Claiming a "SiC line-up [that] will meet demand for industrial and automotive applications" and revealing plans to capture a 30 percent chunk of the SiC power device market, the electronics heavyweight looks set to launch more than just diodes.

Pallavi Madakasira, Lux Research Analyst, is not surprised by Toshiba's relatively late entrance to this market. "We are seeing tremendous appetite from solar inverter manufacturers to boost inverter efficiency, this really is the Achilles heel of the industry today," she says. "Toshiba has been a passive player in the semiconductor space... SiC diodes is an easy strategy."

But the business' ambitious designs on market share are a different matter. "It's



Toshiba is to mass manufacture SiC diodes, but plans to grab market share suggest transistors could soon follow. [Credit: Toshiba]

astounding that Toshiba can have such an impressive strategy," she asserts. "The company does say it has a line-up of products, so I want to believe it has something in the works to develop. Manufacturing diodes alone is not going to get it to 30 percent market share."

Clearly the next step, transistors, will prove more difficult. While many manufacturers can remove the silicon diode from PV inverters and simply drop in a SiC version, replacing, say, a silicon IGBT for a SiC MOSFET or JFET will not be so straightforward.

Admittedly manufacturers are already doing this; PV inverter architectures to date haven't changed a great deal, but change is afoot. New inverter architectures that will really make the most of SiC MOSFETs and JFETs are under development, and this is where Toshiba will need back-up to bring a product to market, just like its competitors already have.

As Madakasira points out, Cree, a vertically integrated organisation, manufactures SiC diodes, MOSFETs and modules and as such, can demonstrate its diodes and transistors work in its modules. What's more, Germany-based power supply manufacturer, Delta Energy Systems, recently announced how integrating Cree's latest generation MOSFETs boosted the efficiency of its high-power PV inverters.

At the same time, Infineon has collaborated with a Japan-based photovoltaic inverter manufacturer on SiC devices and modules. "Infineon doesn't mention the name of this company, but we know they have achieved photovoltaic inverter efficiencies of up to 99 percent," says Madakasira.

"Toshiba now needs this validation, and that's not going to happen unless it finds a specific inverter partner in the industry," she adds. "We personally are not aware that it has worked or is working with any of the big inverter manufacturers."



Bridgelux LED arrays: As Toshiba ploughs funds into Bridgelux's GaN on Si LEDs, will strategic partnerships in power inverter markets follow? [Credit: Bridgelux]

Still, not surprisingly, Toshiba has a good track record of forging strategic partnerships. This time last year, the company - also a major lighting manufacturer in Japan - invested in US GaN-on-silicon LED developer, Bridgelux, to accelerate the commercialisation of LED-based lamps and fixtures.

Bridgelux's expertise with Toshiba's ability to scale up manufacturing is surely a winning combination, and as Madakasira speculates, the company could be about to try out the same approach on the power device industry. Still, the Japan-based giant must make a move soon.

"Cree and Infineon have both mind and market share. Toshiba needs to get this out of the way as soon as possible to even drive any kind of limited traction in the industry," concludes Madakasira.

"Due to the downturn of the solar industry, fewer inverter players are left. If Toshiba is not already engaged with these businesses it needs to act fast."

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# AlN substrates: bigger and better

CrystAL-N's 2-inch AlN spur UV LED market growth?

WITH THE ULTRAVIOLET LED market poised for massive growth, AlN substrate manufacturers are moving quickly to ensure LED makers choose these native, lattice-matched wafers over today's readily available, cheaper option, sapphire.

As established US-based heavyweights Crystal IS and Hexatech make great strides in growing substrates for in-house manufactured devices, Germany-based CrystAL-N has just unveiled 2-inch bulk AlN that promises to boost the performance of deep UV LEDs. This move spells incredibly good news for device manufacturers. Until now, most of the substrates offered to the open market have been 1-inch diameter, and a shift to 2-inch material can only help to cut the cost of making deep UV LEDs.

For the University of Erlangen-Nürnberg spin-off, the result is something of a breakthrough. The move from 1-inch to commercially acceptable 2-inch substrates has taken years of research, but chief executive, Paul Heimann, is confident his company's product is now ready for market: "Our wafers are definitely competitive and right now there aren't too many AlN vendors worldwide."

US-based AlN substrate incumbents, Crystal IS and Hexatech, also manufacture LEDs, with Crystal IS saving all of its home-grown crystals for its own devices. Hexatech is a little different, selling AlN substrates, but according to Heimann, they are just 1-inch to 1.5 inch in diameter – and cost around \$5000. CrystAL-N's larger, 2-inch versions hit a similar price point, coming in at €4000, so arguably offer better value for money.

Crucially, as CrystAL-N grows, other competitors have scaled back activities or are at an earlier stage of development. But it's not just about tracking the competition, quality-wise CrystAL-N's substrates also appear to make the grade. Dislocation densities are coming in at less than  $1 \times 10^5 \text{cm}^{-2}$ , on a par with smaller AlN substrates, and crucially, even at 2-inches, the wafers are UV transparent, helping to boost the light output through the substrate of the final LED. Hexatech currently offers 1-inch UV transparent substrates.

According to Heimann, many competitors grow crystals via physical vapour transport in tantalum carbide-based furnaces, which reduces transparency: "Here the carbon content is so high that the material is no longer transparent at 300 nm UV wavelengths. I know our competitors take the substrate, make the device on it and then etch away the substrate. This is a real pity as you struggle to produce such a perfect material and then you etch or grind it all away."

In contrast, CrystAL-N grows its crystals in a tungsten furnace. A 3 mm thick AlN-SiC layer is first grown on a low defect SiC seed wafer. The SiC seed is then cut away with the free-standing mixed crystal AlN-SiC layer then used as a seed for pure AlN growth. All in, growth takes up to ten days, and using the tungsten furnace circumvents the carbon contamination from tantalum carbide furnaces that plagues the competition.

"In our regime, crystal growth is aluminium polar, independent of the polarity of the seed," explains Heimann. "I see from [a rivals's] publications, crystal growth is nitrogen polar giving really nice looking crystals. Their specifications and XRD data look good and as a crystal grower, I like the shape of the crystals, but they are not UV transparent."

While Heimann will not be drawn on the performances of structures grown on his company's substrates, past tests on prototypes have shown "good" light output. "I do know that competitor's devices have a similar light output to sapphire-based LEDs, but the lifetime is much better," he says. "I think it's down to basic physics. If you want nice devices with a high aluminium content, take a native seed wafer, do your epitaxy and you'll have less dislocations and defects, and a better output and lifetime. AlN will produce better results, but there is still work to do on the epitaxy."

However, CrystAL-N has now set its sights on 4-inch wafers. Comparing his native substrate's roadmap to the path followed by SiC – 4-inch diameters are commonplace and 6-inch substrates are emerging – Heimann is confident 4-inch



Having just unveiled two inch AlN substrates, CrystAL-N is already looking to grow four inch material. Credit: CrystAL-N

bulk AlN is the future: "Perhaps we will have to apply 6-inch SiC seeds, so we will need bigger furnaces. But now we've reached 2-inch, we won't stop."

## Epitaxy woes

But while CrystAL-N focuses on delivering bigger and better AlN substrates, will these efforts trigger wider market adoption of the more exotic, sapphire alternative? Pars Mukish, LED technology analyst at Yole Développement, believes epitaxy issues must be dealt with first.

"It's really difficult to make [deep] UV-C devices," he says. "The main epitaxy technology is HVPE, which is not as developed as the traditional MOCVD used for visible LEDs."

To increase HVPE experience and address epitaxy issues, both Hexatech and Crystal-IS have established vertically integrated operations, growing AlN substrates and using these to manufacture deep UV LEDs. CrystAL-N didn't comment on whether it would follow the same route, but industry sources suggest the company is forging partnerships with chip companies in this field.

In the meantime, the deep UV LED industry is blossoming, albeit slowly. Established electronics heavyweights including LG Innotek and Samsung are eyeing the market as new entrants join, which, can only help to kick-start the market.

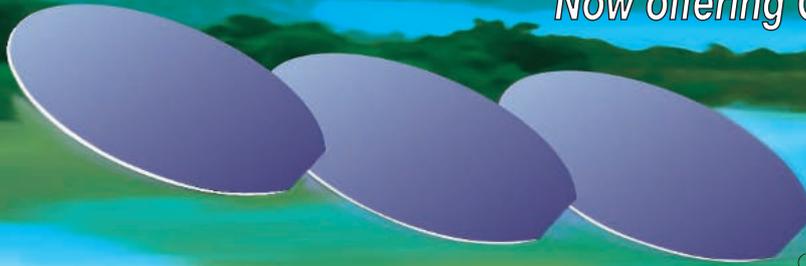
But as Mukish cautions: "If [these developments] trigger the market within the next two or so years, CrystAL-N can remain manufacturing only substrates. If not, they may well have to integrate vertically or close."

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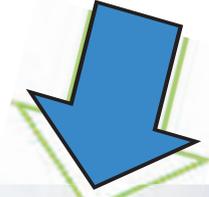


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# GaAs will fend off silicon CMOS in handset front-ends

Talk of silicon completely displacing GaAs in the RF front-end of cellular phones is premature and dead wrong, argues **TriQuint's Phil Warder**. In his view, the future will instead involve smart RF suppliers collaborating closely with OEMs and chipset partners to offer complete RF solutions that exploit the best technologies for each application.

WHEN IT COMES TO CELLULAR PHONES, GaAs technology is synonymous with RF design. That's been the case for many years, because design engineers have been able to rely on GaAs for its combination of superior performance and small die size. This material is used to manufacture HBTs used for building power amplifiers (PAs) that lie at the heart of most RF front-end designs. These GaAs-based amplifiers deliver very high levels of efficiency, which hold the key to long battery life in small form factors.

Today, these GaAs PAs are facing competition from silicon CMOS versions, which have already made some inroads in the 2G handset market. However, performance concerns have hampered the broad global adoption of this rival technology. So, as long as battery life and small size remain paramount in the eyes of handset designers, our view, at TriQuint Semiconductor, is that GaAs will retain its dominance in the mid-range and high-end 3G/4G market, thanks to its superior performance and significantly smaller size.

## Increasing complexity in the RF front end

The RF front-end is defined as all the components between the digital baseband transceiver and the antenna. Its basic building blocks include PAs that boost RF signals, switches that direct

the path of those signals and filters that block unwanted noise.

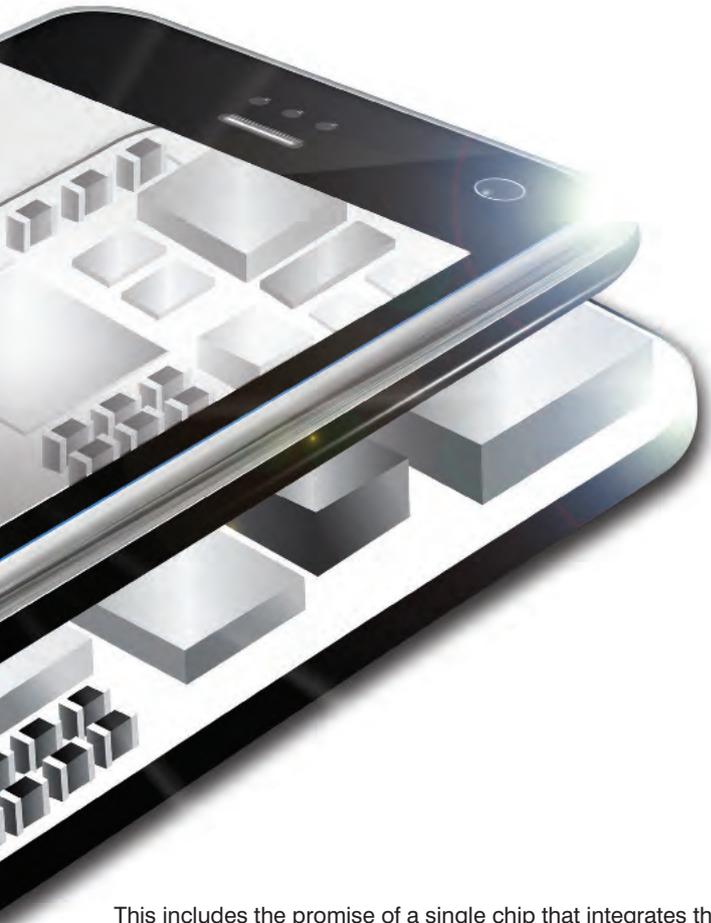
Increasing uptake of 3G/4G data-enabled smartphones, which are replacing 2G voice-only phones, is creating new challenges for design engineers. Along with meeting more stringent performance requirements, designers must accommodate a rapidly increasing number of frequency bands and filters within each mobile device. The ever-more crowded RF spectrum has also fueled demand for high-performance filters for mitigating the resulting interference issues.

In addition to DC-DC conversion that is used to reduce the current drain at lower output powers, design engineers are looking to enhance the front-end through the addition of complementary functions, such as envelope tracking modulators and antenna tuning. Many of these functions can be implemented in silicon with adequate performance. While there has been significant improvement in silicon performance, especially in switches and low-noise amplifiers, GaAs PA current drain still sets the industry benchmark.

## Silicon's attractive credentials

One of the biggest appeals of silicon technologies is their potential to unlock the door to higher levels of integration.

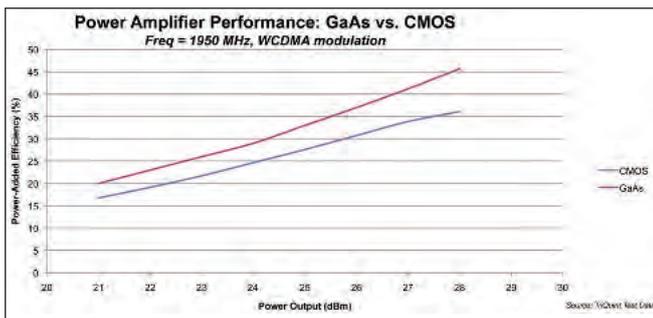




This includes the promise of a single chip that integrates the RF front-end with the transceiver. The allure of an entity that incorporates the transceiver, PA, antenna switch and filters is hard to deny, but CMOS struggles to maintain efficiency at higher powers. This means that an-all silicon chip may only appeal to designers who are willing to sacrifice performance in favor of CMOS integration.

Now that III-V suppliers are starting to face a potential threat from silicon, how will they respond? By continuing to do what they've always done: To deliver what their customers need. Handset designers are focused on optimizing the overall performance, size and cost of their front-ends across their broad product lines, and they don't concern themselves with the specific technologies used.

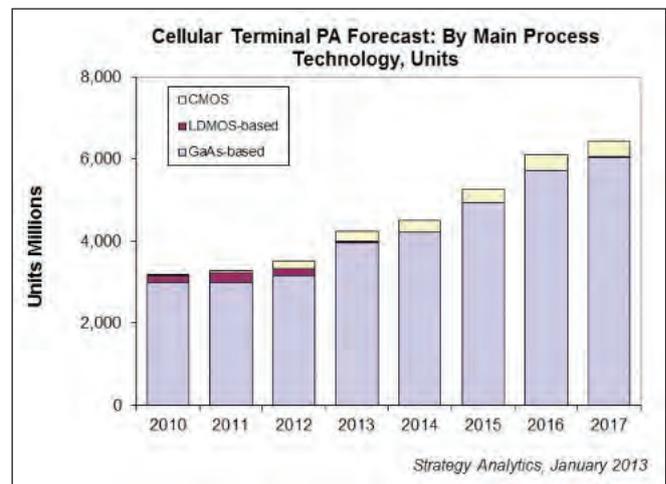
For III-V suppliers, the key to success is delivering a complete RF solution, which in many cases is an integrated module, not an individual die; utilizing the best technology for each application; leveraging both III-V and silicon technologies



GaAs power amplifiers (PAs) deliver superior efficiency, providing longer battery life for mobile devices — at about a third the size of comparable CMOS PA die

to continue pushing performance and cost frontiers; and recognizing that complete front-end solutions require advanced filtering technology.

While there will be variations within the vast global RF market, in many cases the best way forward is to combine the merits of GaAs and silicon. A good example of this strategy is our multi-mode, multi-band power amplifier module (MMPA): This combines high-performance GaAs PAs with a CMOS controller and silicon-on-insulator (SOI) switches. MMPAs provide a highly integrated approach for today's increasingly complex RF design, and they equip designers with more room on the circuit board while minimizing engineering time and resources. MMPAs can support more frequency bands than discrete architectures, while trimming board space by 20 percent. What's more, these multi-band amplifiers feature a versatile design, allowing manufacturers to adopt a common platform for releasing new products at a faster pace, while keeping a lid on design and manufacturing costs.

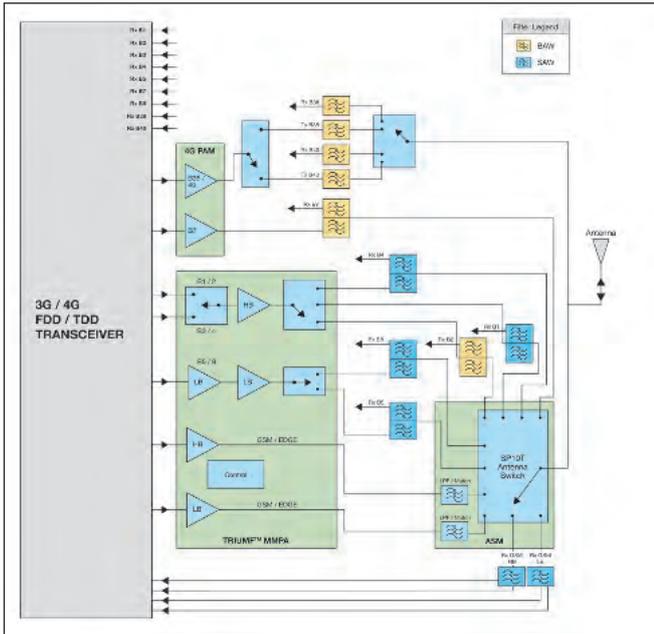


More than 90 percent of new smartphones and cellular phones use GaAs power amplifiers (PAs) to deliver longer battery life, although CMOS PAs are beginning to make inroads in entry-level applications

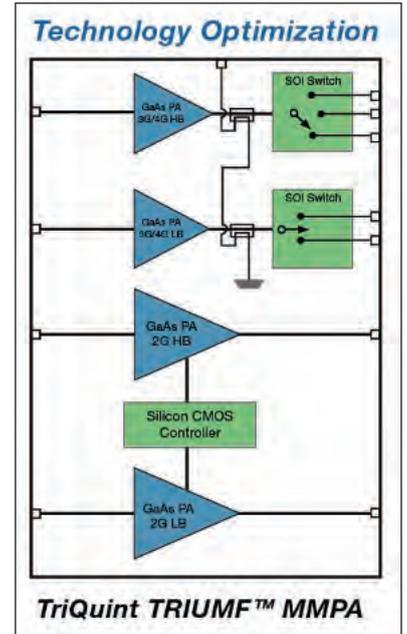
### Delving deeper

To select the best parts in these modules, one must evaluate the relative merits of GaAs and silicon technologies on a component-by-component basis. When it comes to PAs, GaAs continues to outperform silicon designs significantly in terms of current drain and die size. Due to this, GaAs will continue to be widely used for mid-range and high-performance applications, with silicon PAs targeting lower-end sockets where performance is not as important. Nonetheless, silicon will still have a home within even high-performance, GaAs-based MMPA modules. For example, silicon controllers and distribution switches can enhance MMPAs. Additionally, silicon is used for DC-DC converters and envelope trackers that further optimize battery current drain to improve the overall performance of both GaAs- and silicon-based RF architectures.

For years, designers leveraged another GaAs-based technology for its efficiency advantages in RF switches: pHEMTs. Now that steady progress in SOI switches provides comparable performance, this alternative is more widely used in mobile device designs. GaAs pHEMT switches will be reserved for



Left: The RF front end for mobile devices such as smartphones is becoming increasingly complex as a growing number of bands are added to support 2G/3G/4G voice and data services, as well as global roaming. This is driving demand for superior efficiency, as well as high-performance filters



Right: TriQuint's multi-mode, multi-band power amplifier module (MMPA) mixes GaAs and silicon technologies to achieve best-in-class performance

applications where a superior cost or size tradeoff can be achieved by integrating the switch with a GaAs PA die, rather than using two separate die.

Providing control and biasing circuits within amplifier modules is one area where silicon has been used for many years. In addition, power detectors, temperature sensors and regulators have a long silicon history. These silicon circuits often comprise one die within a multiple-die module. Recently, module control has been transitioning from a few dedicated functional digital pins to a control bus architecture. This change is driven by the increasing number of bands and functions in front-end modules, as well as the desire to minimize the required control pins out of the transceiver or baseband. Silicon will remain the preferred choice for control buses as the MIPI front end interface becomes more widely adopted.

One of the trends within cellular technology has been a steady increase in the number of frequency bands. This has made it more challenging to achieve good radiated performance in

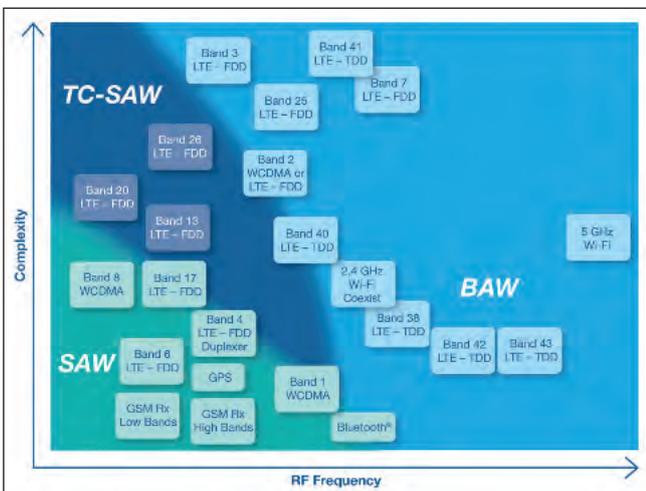
compact form factors, due to the expanded bandwidth. Making matters even worse, there is a desire for multiple antennas in MIMO (multiple-input and multiple-output) applications, and this is pushing space constraints. To address all of this, designers are exploring tuning technologies to optimize antenna performance. There are several competing variations in the RF space, including some silicon-based components; the market has yet to throw its weight behind one particular technology.

**Filtering out the noise**

Filters play a crucial role in the RF front end, because they selectively pass certain frequencies while rejecting unwanted noise. Unlike PAs, which can cover multiple bands, filters are band specific, so growth in phone band counts leads directly to growth in the number of filters or duplexers within each device.

Many of the new bands allocated for LTE present tough, technical problems associated with filter design. Amid a global spectrum crunch, new 4G bands are being squeezed next to pre-existing bands, often with minimal guard bands. To mitigate the resulting interference issues, it is essential to employ advanced filter technology. Traditional surface acoustic wave (SAW) technologies have been adequate in the past, but the most challenging 3G/4G frequency bands need advanced filter technologies, such as bulk acoustic wave (BAW) or temperature-compensated SAW – we offer all three.

In addition, service providers want to increase network capacity through the introduction of aggregation techniques, and high-performance filters can make this possible. Due to the rapid deployment of LTE, shipments of filters for the RF front-end are forecast to outpace the growth in PA content. These filters can be discrete components, or they can be integrated as filter banks or filter banks with switches. They also have the potential to be combined in components with higher levels of front-end integration. This represents an expanding market opportunity for III-V suppliers with advanced filter technologies – they are the key to delivering a complete RF solution.



The deployment of 4G LTE networks is driving band counts and increasing demand for high-performance filter technologies like BAW and TC-SAW

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## Delivering efficient power conversion with package-free HEMTs

Packaging has its downsides: It increases the footprint and the price of a power MOSFET, while degrading its performance through unwanted increases in resistance and inductance. The best solution is to ditch the package, a step that allows GaN HEMTs to be cost-competitive with silicon incumbents, argues **Alex Lidow from Efficient Power Conversion Corporation.**



BACK IN THE MID 1970s, I was a graduate student working on GaAs – supposedly the material for superseding silicon in the world of semiconductor electronics. I learnt a great deal from that experience, including two important lessons that I have heeded my entire career: GaAs will never broadly replace silicon because it is fundamentally too costly; and energy efficiency can directly improve the global standard of living, because it can make everything more cost effective.

Based on these insights, after leaving Stanford University in 1977, I joined the silicon chipmaker International Rectifier, working on the development of power MOSFETs based on silicon. Back then, the writing was on the wall for the aging bipolar transistor, and power MOSFETs promised to set a new benchmark for high frequency, high-efficiency power conversion.

I didn't work on this on my own, but teamed up with a colleague from graduate school, Tom Herman – he shared my vision for the power MOSFET. We carried out some basic device development and were rewarded with a host of fundamental patents, which yielded significant royalties. I went on to pursue this technology for 30 years, and while I worked my way up through the company, I played my part in the growth of a market that is now worth tens of billions of dollars per year.

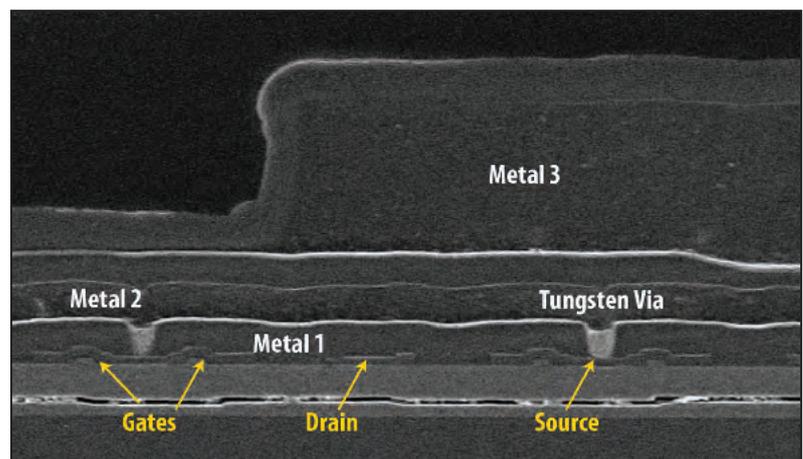
Eventually, however, it became clear that fundamental limits were starting to restrict the performance of the silicon MOSFET. Was this weakness now going to open the door to GaAs? No: By then there was a far more promising kid on the block – GaN.

To exploit the full potential of this wide bandgap technology, I left my job as CEO of International Rectifier in 2007, and joined forces with Joe

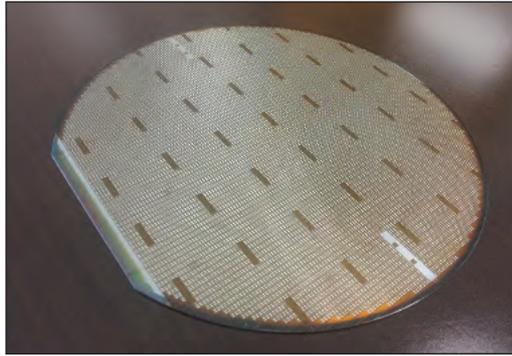


The shed where EPC first evaluated its enhancement mode GaN FETs

Cross section of the EPC enhancement-mode GaN transistor



An EPC 150 mm GaN-on-silicon wafer

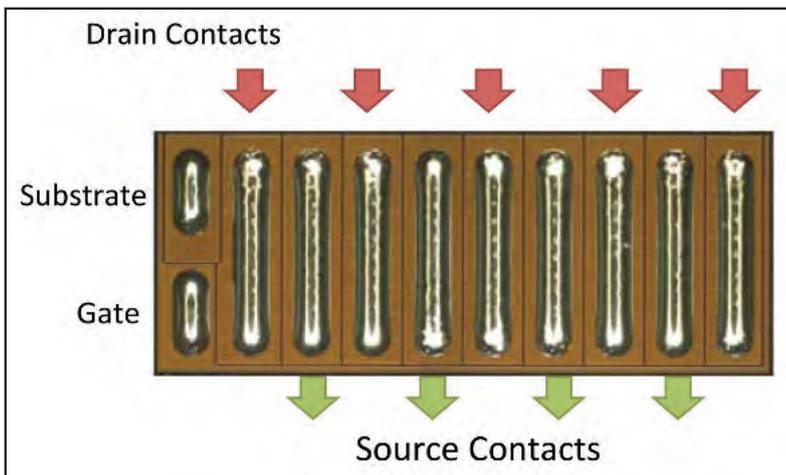


Cao and Robert Beach to found Efficient Power Conversion of El Segundo, CA. We set ourselves two goals: to be the first to develop an enhancement mode (normally off) transistor based on GaN grown on silicon; and to make a GaN transistor that costs less than the power MOSFET.

Initial funding for our venture came from a small investment from my mother, and a second infusion followed from our incredibly farsighted, patient partners in Taiwan. Teaming up with them has been incredibly beneficial, because they control a silicon foundry and they agreed to open its doors to our GaN-on-silicon wafers. Access to this line has held the key to us being able to achieve our goal of low cost.

We found it tough to succeed in our first quest, to develop an enhancement mode transistor. We began by building crude prototypes, using lab facilities at the University of California, Los Angeles, as well as the shed behind the house of our co-founder, Bob Beach. Performance of this device increased, and eventually reached a level where we were able to move this process to our partners' foundry in Taiwan. They had purchased a state-of-the-art MOCVD reactor that could be used to grow GaN-on-silicon starting materials. After many trials and errors – and long nights and weekends – we hit our first milestone, the fabrication of a lateral GaN HEMT capable of operating in enhancement mode. This development also led to the generation of many patent applications, some of which have started

Figure 1: EPC eGaN FETs are delivered in an LGA format as shown. Dimensions of this device are approximately 1.6mm x 4.1 mm



to issue after almost four years through the patent office.

### Shooting for the sweet spot

Our primary target was the mid-voltage market – devices with blocking voltages of around 100 V, which could be used for audio amplifiers, DC-DC converters and UPS systems. We selected this sector because, although it was relatively small, it had a relatively high pricing structure compared with the market for devices operating at lower and higher voltages (below 40 V, or 600 V and above). Another attractive feature of this mid-voltage market is that customers place significant value on the high-frequency performance of GaN, so they are willing to pay a higher price for this wide bandgap device than they would be willing to do in a more commoditized market.

Our status as a start-up and our limited funding made it tricky to package our devices. We couldn't partner with a large packaging subcontractor, because they did not want to be bothered by a small, risky customer.

In the end we decided to take a radical step, delivering our product without a package. Today all of our products are delivered in this manner, using a Land Grid Array (LGA) format with solder bars applied in wafer form. This approach may raise a few eyebrows, but it has been an unquestionable success. It doesn't just allow us to make a big step towards our goal of making a product that is cheaper than a packaged power MOSFET (on average the cost of the power package is as much as that for the silicon inside) – it also enhances performance.

During my years involved in the manufacturing and selling of power devices at International Rectifier, I heard many customer complaints about the packaging of power devices, including concerns that they were too big, and they had too much internal resistance and inductance. In comparison, our LGA format delivers the absolute minimum package size and cost, and has attributes such as zero parasitic resistance and inductance (see figure 1).

In 2009, we produced beta samples of our first product, the EPC1001. It outperformed all 100 V silicon-based devices in switching applications. We demonstrated its superiority over the incumbent technology by comparing the most common figure-of-merit for evaluating power MOSFETs: the product of the device on-resistance ( $R_{DS(ON)}$ ) and the overall gate charge ( $Q_G$ ). The performance of this device is far higher than that of state-of-the-art silicon MOSFETs (see Figure 2). Following several months of beta testing with customers, we made necessary adjustments and improvements to our device and launched our product line in March 2010. In order to distribute our product as widely as possible, and to get

as much customer feedback as possible, we selected DigiKey as our global distribution partner. This allowed us to deliver product to designers overnight, at a reasonable cost. Several awards, including Electronic Products' "Product of the Year" started to come in as acknowledgement of the advancement of the field by our GaN transistors.

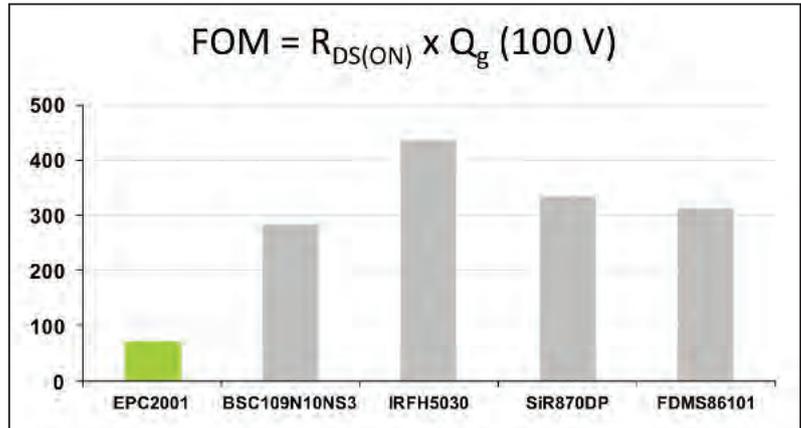
**Penetrating the market**

At this stage, I drew on the lessons that I had learnt from the early days of the power MOSFET, and applied them to our eGaN FETs. I knew that the answers to four key questions controlled the adoption rate of a product based on a new technology: Does it enable new applications? Is it easy to use? Is it reliable? And is it cost effective?

To give our company the best possible chance of success, we organized ourselves to best address all four questions. We hired applications engineers and field applications engineers at the top of their professions, and we devoted as much time to reliability testing as product development. We also wrote papers and even a book, *GaN Transistors for Efficient Power Conversion*, to help engineers climb the learning curve and exploit the true potential of our devices. And we convinced National Semiconductor, now Texas Instruments, to develop driver ICs that would allow users to squeeze the maximum performance from our devices. New applications such as Wireless Power Transmission, Light Detection and Ranging, and Envelope Tracking fueled the early-adopter cycle.

It is now three years since we launched our first product, but from our perspective, it is clear that our work has only just begun. Although we have achieved our goal of making an extraordinary enhancement mode transistor, and we have expanded our offerings to transistors ranging from 40 V up to 200 V, we are still trying to make the lives of our designers easier. It is paramount to select the right board layout when using our eGaN FETs, because this enables the greatest improvements in switching performance, it limits device overshoot, and it takes advantage of low parasitic packaging. Our efforts in this direction have revealed that the optimal eGaN FET PCB layout design offers a five-fold increase in switching speed, plus a 40 percent reduction in voltage overshoot, compared to the 40 V silicon MOSFET benchmark.

We continue to trim the cost of making our devices, and we believe that in three-to-four



years' time, our eGaN FETs will be cheaper to make than their MOSFET counterparts. Our biggest challenge is to economically grow the epitaxial heterostructure on a silicon wafer, and we are being supported in this endeavor by the equipment industry.

Figure 2: Comparison between EPC's first-generation eGaN FET and silicon power MOSFETs

An additional target for us is to expand our product range by developing higher voltage (600 V and above) enhancement mode FETs, as well as monolithic integrated circuits that include both driver circuits and power transistors. These developments will allow our GaN devices to effectively compete across 90 percent of the MOSFET, IGBT, and power IC markets.

Our overarching goal is to build a great new semiconductor company that enables efficient power conversion using GaN-on-silicon technology. We have been fortunate to attract outstanding professionals, as well as new graduates, willing to join a small startup that has embarked on a very big mission.

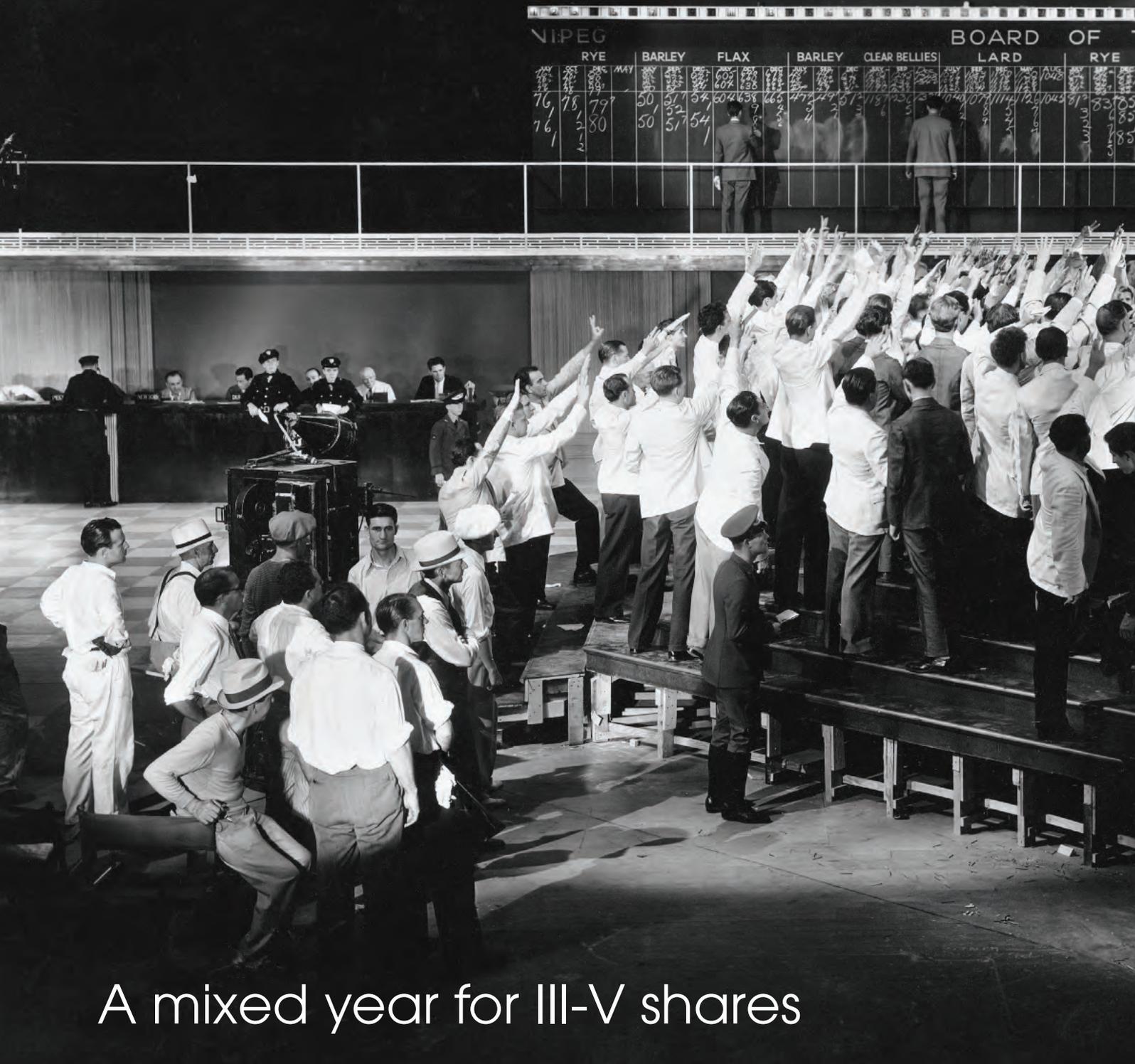
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The early EPC team receiving Electronic Products' "Product of the Year" award

**Further reading:**

- A. Lidow *et al.* 2012, GaN Transistors for Efficient Power Conversion, 1st Ed. Power Conversion Publications, El Segundo.
- M. de Rooij *et al.* eGaN FET – Silicon Shoot-out 9: Wireless Power Converters Power Electronics Technology 38 (2012)
- J. Strydom The eGaN FET-Silicon Power Shoot-Out Vol. 8: Envelope Tracking Power Electronics Technology 38 (2012)
- D. Reusch, The eGaN FET-Silicon Power Shoot-Out Vol. 13: Optimal PCB Layout Power Electronics Technology 39 (2013)



## A mixed year for III-V shares

If you were to have made money in the last 12 months from III-V shares, would you have had to invest in the RF sector, in toolmakers, or in the makers of laser chips? Or was it more important to identify the right company, rather than the burgeoning sector? **Richard Stevenson** investigates.



THE LED INDUSTRY is struggling, with supply outpacing demand by a significant margin. Prices of chips are falling fast, and it's a struggle for manufacturers to turn a profit.

Given these testing conditions, you might expect that it would be unwise to invest in an LED chipmaker. But that's not the case if you have spent the last 12 months backing the right horse: Cree. Over that period shares in the US firm have shot up by more than 80 percent, a rise in valuation that outperforms that of the other leading III-V public companies by more than 50 percent (for details, see the share price leader board on p39, which places vertically-integrated laser systems manufacturer

IPG Photonics and RF chipmaker second and third, due to share price gains of around 25 percent between the ends of April 2012 and 2013).

Most of the increase in Cree's valuation has occurred this year, and has been driven by two announcements: the unveiling of the company's second fiscal quarter results, which came out on 22 January; and the release of Cree's competitively priced LED light bulbs on 5 March.

The latter announcement, which helped to propel the share price beyond \$50, is evidence that the company is executing its plan to not just be a provider of LED chips – but also to be a producer of solid-state lighting and a driver of its widespread adoption. Cree is now selling warm-white emitting bulbs through the US hardware chain Home Depot. They deliver outputs that are equivalent to 40 W or a 60 W incandescents, and retail for \$9.97 and \$12.97, respectively. Bulbs are backed by a ten-year warranty and have very impressive efficiency figures: the 60W-replacement delivers 800 lumens and consumes just 9.5 W, while the 40W-replacement produces 450 lumens and draws just 6 W.

Cree's partnership with Home Depot shows that it is focusing on the domestic market. This makes sense, given that the US lags many other countries in the uptake of the compact fluorescent, a bulb that provides a sterner test to the LED lamp in terms of efficiency, and therefore running costs.

The size of the US market for LED light bulbs was highlighted by Cree CEO Charles Swoboda in a conference call on 23 April 2013 that discussed third fiscal quarter earnings: "There are currently more than 5 billion bulbs in people's homes across the United States, which could benefit from an upgrade to LED." To spur sales of this product, Cree will soon launch a national media campaign to promote the company's brand and its new product. "We believe this investment will drive sales of the LED bulb and further position Cree as the leader in LED lighting," claims Swoboda.

Diversification into the lighting business is just one part of Cree's plan for its future. Another aim is to grow sales of products based on the company's SC<sup>3</sup> LED technology, which employs advanced SiC technology and features advancements in LED chip architecture, phosphors, and package design.

According to Swoboda, SC<sup>3</sup> LEDs enable higher-density designs, novel optics and a lower cost-per-lumen. These devices have been deployed in Cree's latest CXA series of LED arrays that can deliver more than 10,000 lumens, and can be used for outdoor area lighting and high-bay lighting. In addition, this class of LED has set a lab efficacy record of 276 lumens-per-Watt, for a device driven at 350 mA and producing a correlated colour temperature of 4401 K.

Another goal for Cree is to be a leader in RF and power electronics, and drive a new generation of applications for these products. Efforts in this direction are well underway, and include a recent launch of a second-generation SiC MOSFET. This is claimed to deliver industry-leading power density and switching efficiency at half the cost-per-amp of the company's previous generation of devices. Cree's success on various fronts can be seen in its recent financial results. Second quarter earnings for the three months up to December 30, 2012, included record

sales of \$346 million and a profit of \$37 million. This is made up of LED products revenue of \$201 million, with profit of \$84.2 million and a 41.9 percent gross margin; sales of lighting products that netted \$122.7 million, with a profit of \$41.4 million and a 33.7 percent gross margin; and sales of power and RF products that generated \$22.6 million, with a gross profit of \$12.8 million and a 56.6 percent gross margin.

Third quarter sales in these three divisions were similar to the previous quarter, with total revenue rising by 1 percent to \$349 million. The gross margin for LED products increased by almost 2 percent, thanks to higher volumes, while the gross margin for lighting products fell to 30.6 percent, due to start-up costs related to the company's launch of its LED bulb.

The outlook for the future is promising. "We target quarter-four revenue to be in the range of \$365 million to \$385 million, which is comprised of double-digit lighting revenue growth, driven by both commercial fixtures in LED bulbs, single-digit growth in LED revenue and power and RF revenue up slightly," said Swoboda in a conference call discussing third quarter earnings. Overall, gross margins are expected to rise by about 1 percent, due to a combination of increased volumes, cost reductions and lower-cost new products.

## Vertical integration for high-power lasers

In second place on this year's share price leader board is the world's leading maker and provider of fibre lasers, IPG Photonics. During the last 12 months, shares in this firm made their biggest gains following the report of second fiscal quarter results in late July 2012, and since then the share price has hovered between \$55 and \$70.

The hike in July resulted from record quarterly revenue of \$137.9 million, which exceeded expectations; a year-over-year profit increase of 23 percent; and a very strong subsequent forecast. Company CEO Valentin Gapontsev attributed those strong results to: wider adoption of lasers by manufacturing companies; an increase in the rate of adoption of fibre lasers; and the fact that several key industries for the company – such as automotive and consumer electronics – were doing relatively well in a tough economic climate and investing in new technologies. At that point in time, Gaponstev could list five of the world's largest automotive companies among its customers, and he expected that they would be investing in more fibre lasers, which are well suited to processing aluminium – this metal is featuring in more and more car designs.

IPG's third fiscal quarter sales that spanned the three months up to 30 September, 2012, exceeded guidance, hitting \$156.4 million, while profit soared to \$42.4 million. Investors, however, focused on a book-to-bill ratio that fell below unity, and a forecast of slightly lower revenue for the fourth quarter. Shares slipped by about 10 percent when these quarterly earnings came out, but more than recovered by the time the next set of



Left: Cree's launch of a range of LED bulbs helped to drive up the company's share price

results were reported on 15 February.

On that day investors learnt that sales for the last quarter of fiscal 2012 were \$145 million, and the corresponding profit and gross margin were \$34.9 million and 51.8 percent. Commenting on these results, Gapontsev said: "We are excited by IPG's prospects for growth in 2013. Order flow was very strong in January despite a book-to-bill that was less than one in quarter four."

Again, investors were not impressed with results, and the share price fell by around 10 percent, but it climbed since then, before taking a small dip when first fiscal results were announced on 1 May. Sales for this most recent quarter are down \$3 million sequentially, while gross margin is up 1.5 percent. The next set of results should be better – guidance for the next quarter is for revenue in the range of \$155 million to \$165 million profit, which is expected to increase to about \$40 million.

## RFMD's diversification pays dividends

Manufacturer of RF components, RFMD, is third on the leader board. Its valuation has risen by just over 25 percent in the 12 months up to 30 April 2013.

CEO Robert Bruggeworth puts RFMD's financial success during that period down to the best customer diversification in the company's history. Talking to investors during a conference call on 23 April 2013 to discuss fourth fiscal quarter earnings (the three months up to 30 March, 2013), he remarked that the company is well positioned in the entry segment, where it is offering CMOS PAs: "We are accelerating the adoption of our RF CMOS technology into new markets and new customers, and we anticipate this will provide a path to lower costs and improved margins in our 2G product portfolio. This is especially meaningful in China where RFMD enjoys a leadership position."

At the other end of the spectrum, the company expects strong growth in sales of its 3G and 4G LTE devices that will be used in multiple flagship product launches. Success here is particularly valuable for RFMD, because RF content in these devices is rising fast. "It's also important because of the increase in device complexity related to the additional frequency band combinations and the increasing requirements for new technologies such as antenna tuning, envelope tracking and carrier aggregation," says Bruggeworth. "RFMD is an early pioneer and the current leader across these next-generation RF technologies."

RFMD netted sales of \$280.6 million in the most recent quarter, up 3.5 percent sequentially and a gain of 49 percent year-over-year. Income for the quarter was \$17.1 million. Guidance for the next quarter is revenue of \$285 million to \$290 million and a slight increase in profit.

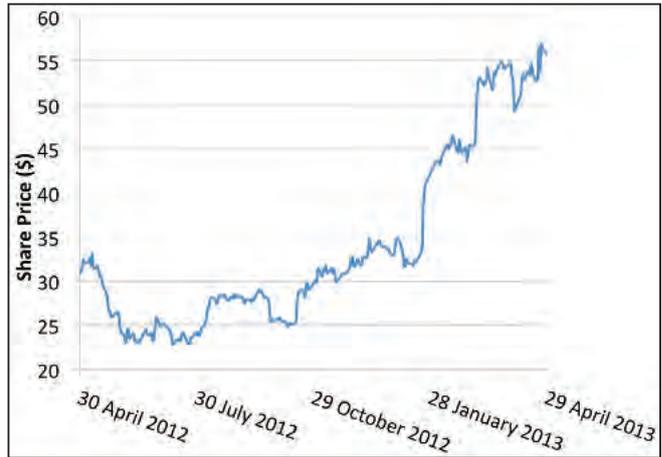
## Telco woes continue

Footnote to the table for a second year in succession is the manufacturer of telecom components, Oclaro. It has seen its share price plummet in the last two years from more than \$10 in April 2011 to now well below \$2. Although the merger with Opnext has increased the company's market share, it continues to operate at a loss. One of the lows of the last 12 months was the failure to meet guidance for the first fiscal quarter of 2013, which ended on 29 September, 2012. "As the new Oclaro, we were immersed in integration activities, and therefore did not fully contemplate all potential execution risks in our forecast," explained CEO Alain Couder, when discussing these quarterly results. According to him, the company was focusing on cutting costs, and the actions that it took at that time should deliver savings of \$9 million per quarter.

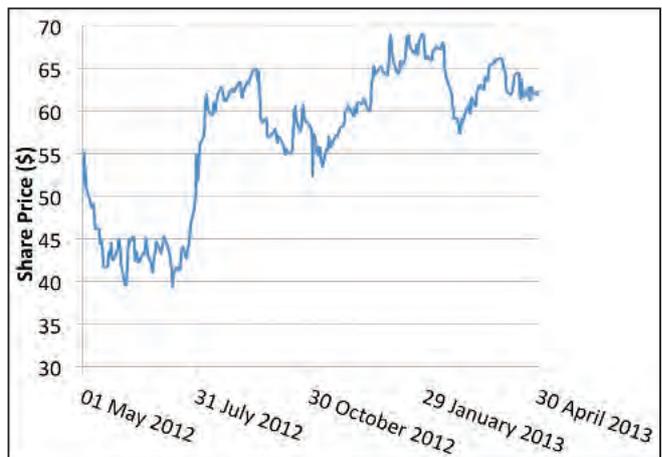
On 31 January this year, the company unveiled its second fiscal quarter results, and Couder claimed that Oclaro was making progress. However, he was not complacent, arguing for the need for further reduction in operating expenses and improved margins, plus the growth of revenues by capitalizing on new product introductions and strong customer relationships. This need for further improvement is abundantly clear from second quarter figures.

Gross margin was just 15 percent, and Oclaro made a loss of \$12.2 million, despite netting \$25 million from the sale of its interleaver product line and thin-film filter business. The company expects to generate revenues in the range of \$140 million to \$155 million in the third quarter, and make a loss – evaluated in terms of earnings before interest, taxes, depreciation, and amortization – of between \$13.5 million and \$25 million.

It will be interesting to see if Oclaro can get out of this hole and not foot the leader board again this time next year, and whether Cree, IPG Photonics and RFMD are able to maintain their positions at the top of the table. Maybe they will, but predicting that far ahead is never easy, because, as this survey shows, it's not just about backing the right sector within the III-V industry – it's about investing in the right company.



Cree's share price has risen in 2013, partly due to its launch of LED bulbs



IPG's share price jumped last summer, due to earnings that exceeded guidance and a strong outlook

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Compound Semiconductor share price leaderboard						
Rank	Company	Ticker	Share value, April 29, 2012 (\$)	Share value, April 30, 2013 (\$)	% appreciation	Change in Rank
1	Cree	CREE	30.81	55.80	81.1	+5
2	IPG Photonics	IPGP	49.00	61.91	26.3	+7
3	RFMD	RFMD	4.35	5.46	25.5	+7
4	Veeco	VECO	30.23	37.11	22.8	+9
5	TriQuint	TQNT	4.76	5.43	14.1	+13
6	Infinera	INFN	7.42	8.28	11.6	-4
7	JDSU	JDSU	12.45	13.55	8.8	+5
9	NASDAQ composite	IXIC	3060.06	3,290.31	7.5	-8
10	Hittite	HITT	52.88	55.83	5.6	-4
11	Riber (Paris)	RIB	3.78*	3.74*	-1.1	-7
12	Emcore	EMKR	4.58	4.37	-4.6	+5
13	IQE (London)	IQE	0.4032*	0.3683*	-8.7	+1
14	Anadigics	ANAD	2.25	1.92	-14.7	+1
15	Aixtron (Frankfurt)	AIX	18.21*	14.42*	-20.8	+1
16	Skyworks	SWKS	27.59	21.66	-21.5	-13
17	Finisar	FNSR	16.53	12.93	-21.8	-6
18	Rubicon	RBCN	9.66	7.31	-24.3	+1
19	AXT	AXTI	5.11	2.91	-43.1	-12
20	Oclaro	OCLR	2.93	1.37	-53.2	=

\* Converted to dollars using the exchange rates on 30 April of 1 EURO = 1.3108 USD and 1 GBP = 1.5508 USD

Table 1. It's been a mixed year for III-V stocks, with more companies lagging the NASDAQ than outperforming it



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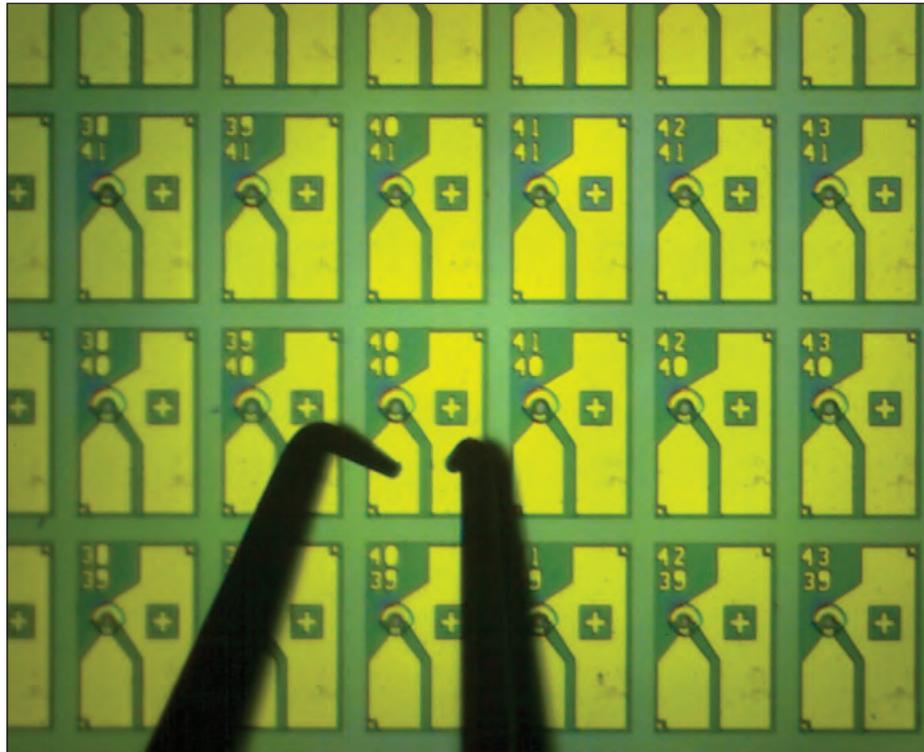
**SURGING SMARTPHONE SALES** and a growth in internet TV are helping to drive a rapid rise in Internet traffic. This is placing increasing strain on infrastructure, including optical networks and data centres. Upgrading capacity is essential, but this must go hand-in-hand with the introduction of more efficient components that do not prevent a hike in electricity consumption, which is already substantial. This can be partly addressed by turning to new classes of semiconductor devices that deliver tremendous improvements in efficiency.

One opportunity to do just that is to switch from the incumbent 1310 nm laser source – a directly modulated, uncooled distributed-feedback (DFB) laser – to a novel, wafer-fused VCSEL. DFB lasers are widely used to form part of 10 Gbit/s transceivers that have a reach of 10 km and are currently being shipped in high volumes and deployed in Ethernet and local area networks.

To cope with the rising levels of traffic, these transceivers are just starting to be replaced with 40 Gbit/s transmit-receive engines that comply to the IEEE Standard 802.3ba, which was ratified in June 2010. These engines, which will totally substitute 10 Gbit/s transceivers by the end of this decade, employ coarse-wavelength-division multiplexing (CWDM) technology and feature four uncooled 10 Gbit/s DFB lasers emitting at 1271 nm, 1291 nm, 1311 nm and 1331 nm. Using this laser source, transceivers have a typical power consumption of 3.5 W, with a significant proportion drawn by the laser drivers.

Power consumption could be slashed by replacing these DFB lasers with VCSELS. The power consumption of a transceiver in a Quad Small Form-factor Pluggable (QSFP) multi-source agreement (MSA) package, comprising a 4x10 Gbit/s VCSEL transmission optical sub-assembly (TOSA), is as low as 1 W – that is less than that of a single 10GBASE-LR transceiver based on DFB lasers, which has a typical power consumption of 1.2 W. So, in short, VCSELS offer a unique possibility to replace existing 10 Gbit/s transceivers with 40 Gbit/s transceivers without increasing the total power consumption of existing equipment.

Switching from DFB lasers to VCSELS can also drive down production costs. On-wafer testing is possible with VCSELS, but not with DFB lasers, which require a testing process that makes a significant contribution to overall production costs.



## Ultra-low power VCSELS for optical networks

It is essential that tomorrow's optical networks are built with far more efficient components to prevent the continual ramp in internet traffic from significantly increasing global energy consumption. One promising device that will help in this endeavour is a 1310 nm VCSEL formed by fusing together active regions grown on InP wafers and mirrors formed on GaAs substrates, says

**Alexei Sirbu from Ecole Polytechnique Fédérale de Lausanne (EPFL) and Eli Kapon from EPFL and BeamExpress.**

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Above: VCSELS offer on-wafer testing, which can trim manufacturing costs compared to edge-emitting lasers

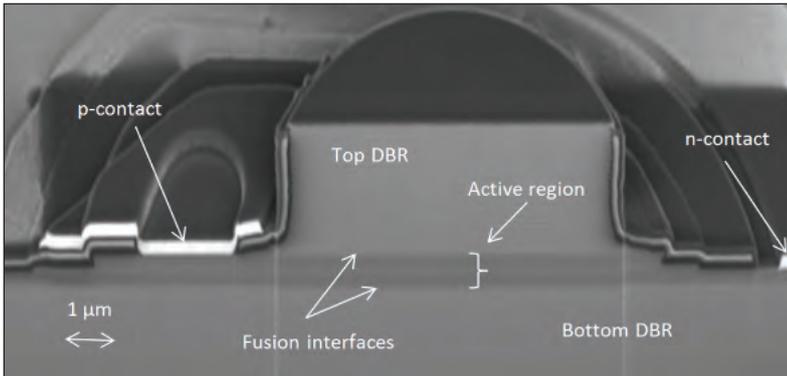


Figure 1. Similar to datacom VCSELS, wafer-fused 1310 nm VCSELS employ a GaAs substrate and can be fabricated in large volumes using standard processing steps in foundries that normally process AlGaAs/Ga(In)As-based devices

A further advantage of the VCSEL over its incumbent cousin is its substantially reduced sensitivity to changes in temperature. It is possible to design a VCSEL in a way that ensures that its threshold current does not change with temperature, but for DFBs, the threshold current at elevated temperature is always several times larger than that at room temperature. With currently developed VCSELS, 10 Gbit/s operation is achievable at a constant bias current of typically 7 mA across the full temperature range from 0°C to 85 °C, but with standard DFBs, the bias current must be constantly adjusted, depending on the ambient temperature. The operation of 10 Gbit/s VCSELS at a bias current at or below 7 mA enables the use of very low-power-consumption VCSEL driver arrays, which were developed for short-wavelength datacom VCSELS – these emit at 1μm or less.

**Wafer fusion**

Several approaches can be taken to fabricate 1310 nm VCSELS, including that pioneered by our team from Ecole Polytechnique Fédérale

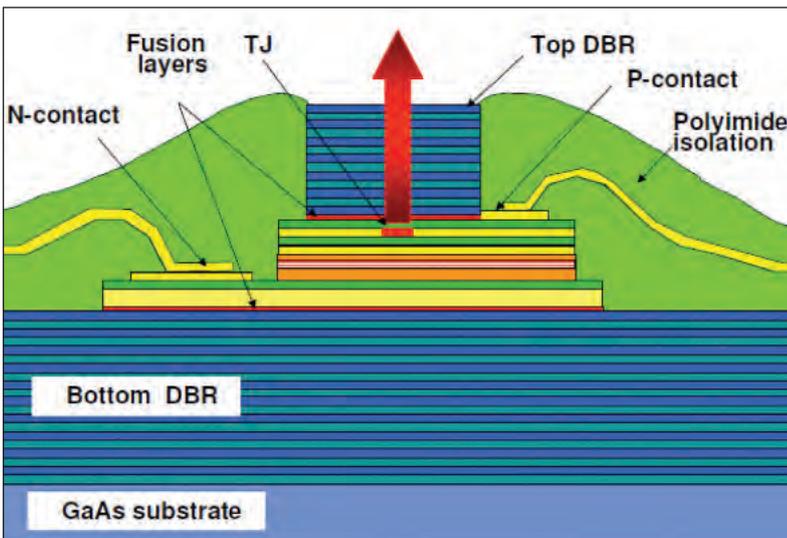


Figure 2. Wafer-fused VCSELS employ the same InP-based active region material system as well-established DFB lasers and the same AlGaAs/GaAs distributed Bragg reflectors as short-wavelength datacom VCSELS. In these devices, carrier injection into the active region is performed by a tunnel junction. Compared with standard datacom VCSELS, this new element allows implementation of un-doped DBRs that result in considerable reduction of optical losses in the VCSEL cavity

de Lausanne and BeamExpress. Our approach, which we have been developing for several years, has advanced to the stage where it is mature enough to challenge existing un-cooled 10 Gbit/s DFB lasers used for communication applications.

Wafer-fused VCSELS are essentially a marriage of an InP-based active region that is used in well-established DFB lasers and the AlGaAs/GaAs distributed Bragg reflectors that are employed in short-wavelength datacom VCSELS (see Figures 1 and 2). In these hybrids, a tunnel junction provides carrier injection into the active region. Compared with a standard datacom VCSEL, this new element allows implementation of un-doped DBRs that deliver a considerable reduction in optical losses in the VCSEL cavity. This enhancement counters the reduction in material gain resulting from the switch from a GaAs-based active region to one revolving around InAlGaAs/InP, and ultimately allows the 1310 nm band VCSEL to deliver a performance that is comparable to its shorter-wavelength sibling used in datacom and optical interconnects.

Our wafer-fused VCSELS share other similarities with their datacomm cousins: They are formed on a GaAs substrate, and they can be fabricated in large volumes in foundries using standard processing steps that are normally employed for producing AlGaAs/Ga(In)As-based devices. Device fabrication begins by taking two, 2-inch wafers with AlGaAs/GaAs DBRs and fusing them to either side of an InP-based active cavity with standard wafer-bonding equipment.

Despite using elevated temperature of 600°C, and the substantial difference in thermal expansion coefficients of GaAs-based and InP-based wafers that have been grown by MOCVD, our fused wafers have a very low density of defects in the active region (see Figure 3). This great material quality, and an active region that is incredibly small – its typical diameter is only 7 μm – leads to devices that are nearly always defect free, and are produced with a very high fabrication yield.

A great strength of the wafer fusion technique is that it allows the precise wavelength of the VCSEL to be set. This is crucial for making products that are based on CWDM, because this application demands laser emission within ±2 nm of the target wavelength. Fulfilling this requirement is possible with our VCSEL design, because devices are assembled from three separately grown elements: one active region and two DBRs. As a result, before the first and second fusion steps are undertaken, the active cavity and the DBRs can be adjusted by a proper selection and/or selective chemical etching.

In sharp contrast, in VCSELS with dielectric DBRs, the mode is tightly confined in the active region

and cavity adjustments require selective etching of the InP-based material – this reduces the precision of wavelength setting. There are also 1310 nm VCSELS that are formed by growing a semiconductor active region and DBRs in a single run, and with type of design it is again very challenging to hit the wavelength specifications. Standard epitaxial growth techniques have a thickness tolerance of about 1 percent, and this leads to variations in emission wavelength that exceed the tolerance that is acceptable for components based on CDWM.

After the VCSEL wafers have been formed, they are processed with standard steps, such as dry and wet chemical etching, and deposition of dielectrics and metals for contacts and bond-pads. This creates about 15,000 VCSELS on a wafer, which are all characterised at room and elevated temperatures using automated probe stations. Only after performing all the necessary tests, including high-speed modulation characterization on selected devices, are dies scribed from the VCSEL wafer.

### Coping with the heat

These VCSELS can deliver 10 Gbit/s error-free transmission over 10 km of standard, single-mode fibre at ambient temperatures as high as 100°C (see Figures 4 and 5). These tests were performed without any cooling at a constant bias current of

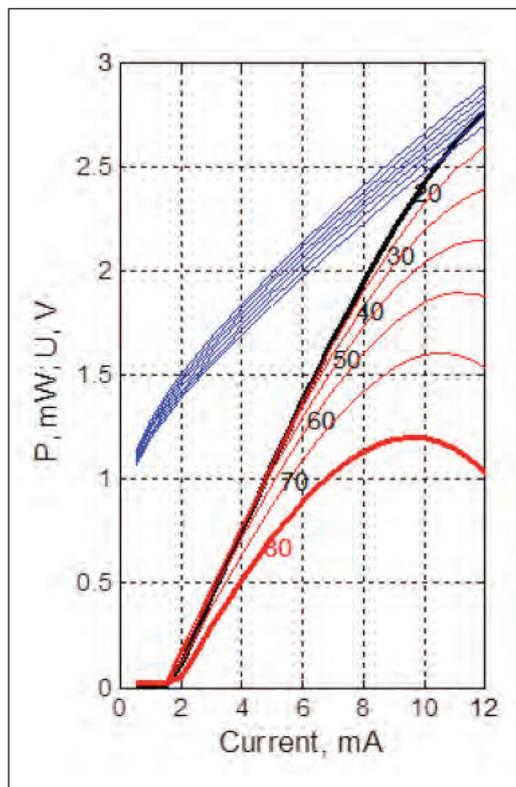


Figure 4. VCSELS can be designed in a way that the threshold current does not change with temperature, while for DFBs the threshold current at elevated temperature is several times larger than that at room temperature

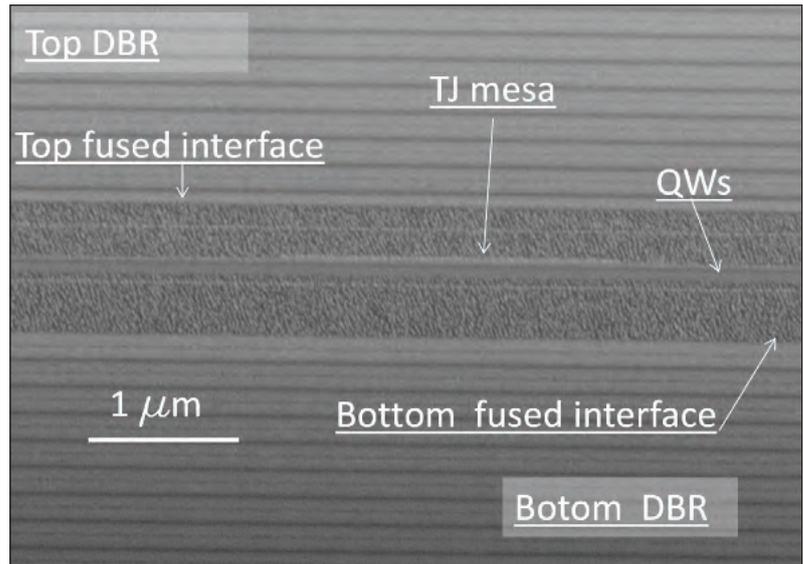


Figure 3. Even though the wafer fusion process is performed at an elevated temperature of 600°C and the significant thermal expansion coefficient mismatch between GaAs-based and InP wafers, the current fabrication process allows production of fused wafers with a defect-free, InP-based active region of the VCSEL

8 mA, demonstrating that these wafer-fused VCSELS can perform excellently in the category of un-cooled 1310 nm communication lasers.

If these lasers are to be deployed in industry, their excellent performance must be combined with a level of reliability that conforms to industry standards. To determine if that is the case, we subjected these devices to a two-year reliability test programme: They passed all the assessments associated with the GR-468-CORE Telcordia Generic Reliability Assurance Requirements for Optoelectronic Devices. These assessments, including different mechanical tests like shocks, vibrations and die shear; temperature cycling and electrical tests; have shown that wafer-fused VCSELS behave in the same way as existing, commercially available lasers.

This set of tests included accelerated life tests on first-generation devices operating at 10 Gbit/s at a 9 mA driving current. The results of this assessment enabled us to predict that, at 25°C and 70°C ambient temperatures, times to 1 percent failure are 291 years and 19 years, respectively (see Figure 6).

We have searched for defects in the active region of our device with various imaging techniques. This includes the use of scanning and transmission electron microscopy to scrutinise cross-sections and lamellas from degraded VCSEL material, which has been prepared for inspection via focused-ion-beam milling. The failure analysis study is ongoing and, if necessary, further optimization of fabrication will be implemented in new generations of the devices.

“

Results show that our wafer-fused VCSELS are ready for entering the rapidly growing market of 40GBASE-LR4 transceivers for data centres and telecom local area networks. It is clear to us that the telecom industry is set to benefit from the unique opportunity offered by this new generation of un-cooled 10 Gbit/s 1310 nm communication lasers

”

Results on more recent devices are even more promising. For VCSELS operating at 10 Gbit/s at a bias current of 7 mA, the predicted time to 1 percent failure at 70°C is now 50 years. Thanks to this progress, our wafer-fused VCSELS largely meet the telecom industry requirements for the time to 1 percent failure, which is more than 10 years at 70°C (see Figure 7).

These results show that our wafer-fused VCSELS are ready for entering the rapidly growing market

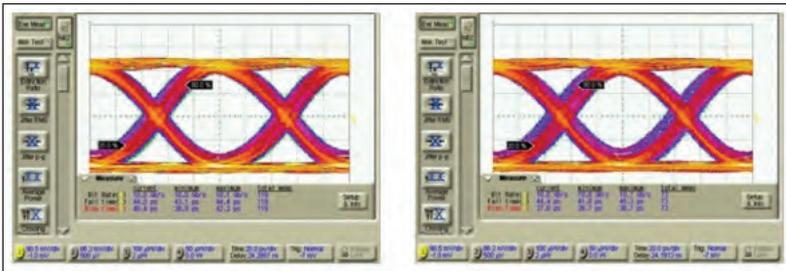


Figure 5. While with currently developed VCSELS, 10 Gbit/s operation can be achieved at a constant bias current of typically 7 mA in the full temperature range from 0°C to 85 °C, with standard DFBs the bias current needs to be constantly adjusted depending on the ambient temperature (eye diagrams above for 20°C). 10 Gbit/s operation at a bias current at or below 7 mA allows the application of very low power consumption VCSEL driver arrays that were developed for short wavelength (<1µm) datacom VCSELS

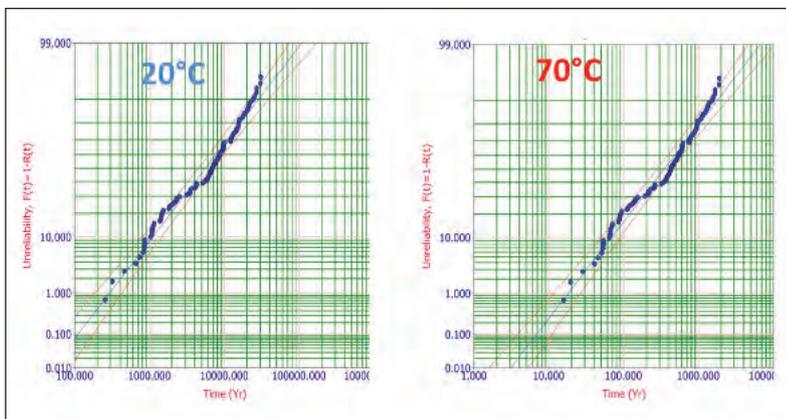


Figure 6. Using the aging parameters of the first generation devices that can be modulated at 10 Gbit/s at 9 mA bias current, one can predict time to 1 percent failure of 291 years and 19 years at 25°C and 70°C ambient temperatures, respectively

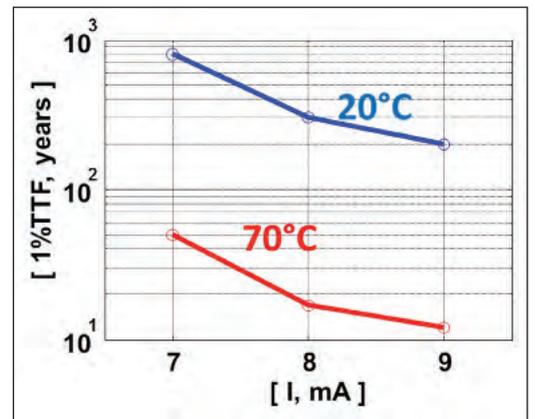


Figure 7. On recent devices that operate at 10 Gbit/s at a bias currents of 7 mA, the predicted time to 1 percent failure at 70°C increases to 50 years

of 40GBASE-LR4 transceivers for data centres and telecom local area networks. It is clear to us that the telecom industry is set to benefit from the unique opportunity offered by this new generation of un-cooled 10 Gbit/s 1310 nm communication lasers, which can reduce the cost and the power consumption of 40 Gbit/s modules to the level of 10 Gbit/s modules existing today.

One of the most promising opportunities for these 40GBASE-LR4 1W transceivers is as replacements for the 1 W QSFP packages, which are standard modules normally employed in the switching racks of data centres. If this upgrade is made, it is a very efficient way to considerably increase the throughput of existing data centres.

Although, like with any new technology, there are always concerns associated with the adoption of any new class of device, those that make the leap promise to slash the power consumption of their transceivers, and help to reduce the escalating energy costs associated with internet traffic.

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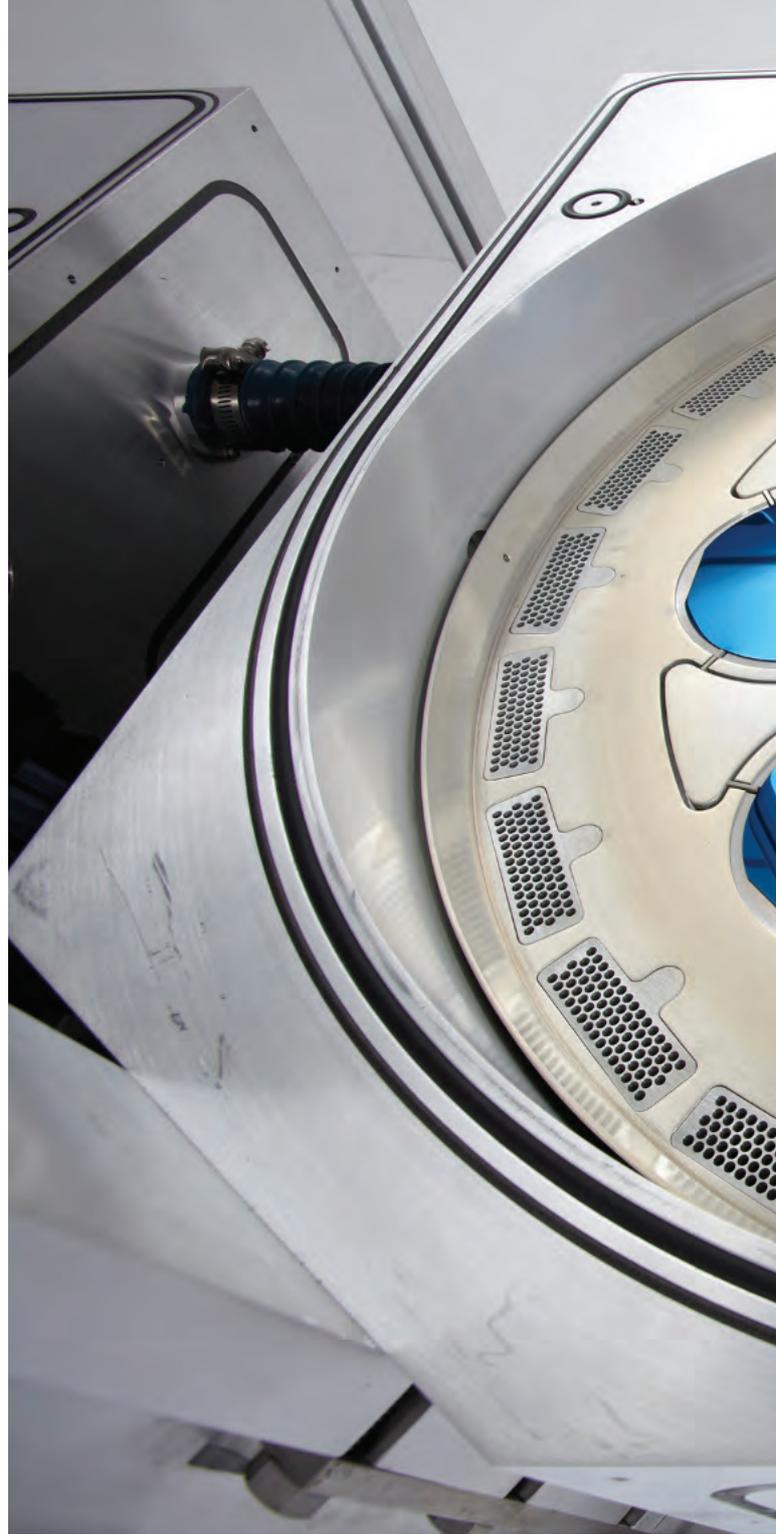
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## Long-term partnership propels multiple improvements in SiN deposition

Investors in deposition equipment want tools that have really high levels of up time, deliver incredibly uniform films and offer an upgrade path that will prevent them from becoming obsolete within a few years. To meet these requirements, it is essential that the equipment vendor and chipmaker work together to improve the deposition system and its process, argue

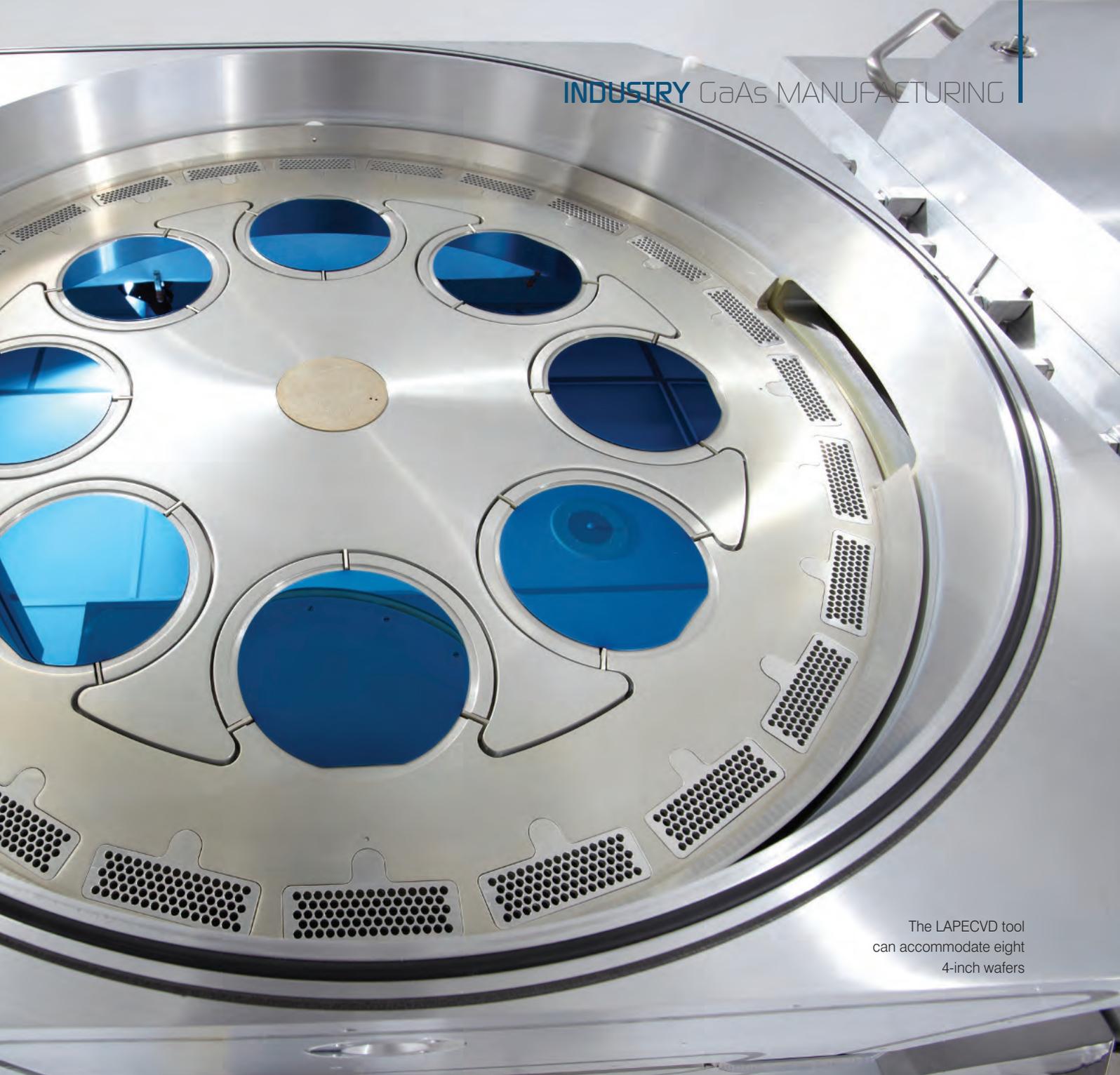
**Robert Mohondro from Plasma-Therm and Evan Law and Jim Meyer from RF Micro Devices.**



CHIP MANUFACTURERS want to make great products. But that's not enough for them to be judged a success – they must also turn a profit, because this ensures long-term viability.

One factor that has a big impact on the bottom line is the expense associated with investment in capital equipment. To prevent this from being excessive, production managers must make sure that the products that they buy aren't just capable of making the company's latest products, but also next-generation devices, plus those that they will be making in several years' time. In other words, they must calculate the return-on-investment associated with the purchase of new equipment.

This return can be increased by balancing the replacement of equipment with upgrades to existing tools. But for this to work well, there must be a strong, open and supportive relationship between the supplier of the equipment and its user. That's the case in the relationship between the authors of this article –



The LAPECVD tool can accommodate eight 4-inch wafers

Plasma Therm, a manufacturer of plasma etch and deposition tools, and RFMD, one of the world's leading manufacturers of compound semiconductor chips.

A strong relationship between these companies has been fundamental to driving a substantial increase in the productivity of a set of large-area, plasma-enhanced CVD tools. These tools are used to deposit  $\text{SiN}_x$  films, which are needed for interlayer dielectrics, passivation layers, hermetic encapsulation and electrical isolation, and also serve as an inter-metal dielectric for MIM capacitors and as a capping layer for thermal annealing. Highlights of this continuing collaboration include: development and commercialization of a large area tool; an indexer upgrade that led to a substantial reduction in mishandled wafers, which in turn trimmed the time spent on cleaning and maintenance of the reactor; and the optimization of an *in-situ* clean that reduces yield-impacting particles, while cutting consumable expenditure and down time. On top of this, the partnership has worked

together to improve showerhead manufacturing, which has led to greater levels of uniformity for the films deposited by the tool.

### Product development

Plasma-Therm has a long history in the development and production of multi-wafer PECVD systems. In 1995, it launched the VLR-PECVD, a tool with an 11-inch electrode that could process four 4-inch wafers in batch mode.

Following a request from RFMD for a higher throughput tool that could be upgraded to handle 6-inch wafers, Plasma Therm's engineers at Saint Petersburg, Florida, re-designed the system in 1999. This reactor – which featured a larger chamber, electrode and chamber fixturing, was designated the large-area (LA) PECVD tool. It could simultaneously process eight 4-inch wafers or five 6-inch wafers, so it offered a 42 percent increase in productivity over its predecessor. This equates to processing 5 more wafers per hour, or nearly 44,000 more wafers per year.



RFMD has installed several LAPECVD tools at its facility in Greensboro, NC

RFMD received a beta version of this tool in 2000, and following installation, engineers qualified the reactor for process and production. This system fulfilled its promise of higher manufacturing throughput, but it had some problems; most of which were minor and quite typical for any beta tool. These issues were successfully addressed in partnership with Plasma-Therm, creating a strong bond of trust between the two firms that continues to this day, and has led to further orders of LAPECVD tools.

Assistance to RFMD by Plasma-Therm through its Customer Improvement Program (CIP) did not stop with the delivery of the tools. Although the process worked as specified, there were intermittent issues, primarily handling, which Plasma Therm helped to investigate and address. Each issue was eventually resolved (see table 1, p51), and one of the outcomes of this investigation was for RFMD to establish a 'standard' process used for production that differs from the high rate process used for testing and qualification.

### Upgrading the indexer

One of the issues that required resolution relates to the indexer. This integral part of the processing chamber is a rotating fixture that is loaded with wafers. After one is added, the indexer subsequently lifts and rotates to the next position and the next wafer is loaded. Once completely populated, the load lock is isolated by a slot valve and the chamber is pumped and processing of all the wafers is initiated.

There were lingering, intermittent problem associated with the indexer, and both companies tried to come to a plausible, workable solution. Returning to the original design yielded a better overall replacement, but several intermittent indexing problems remained: Losing home position;

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Plasma-Therm's large-area plasma-enhanced CVD tool is a parallel plate design utilizing a 13.56 MHz power source to generate the plasma. Wafer temperature can be controlled from 100°C to 350°C

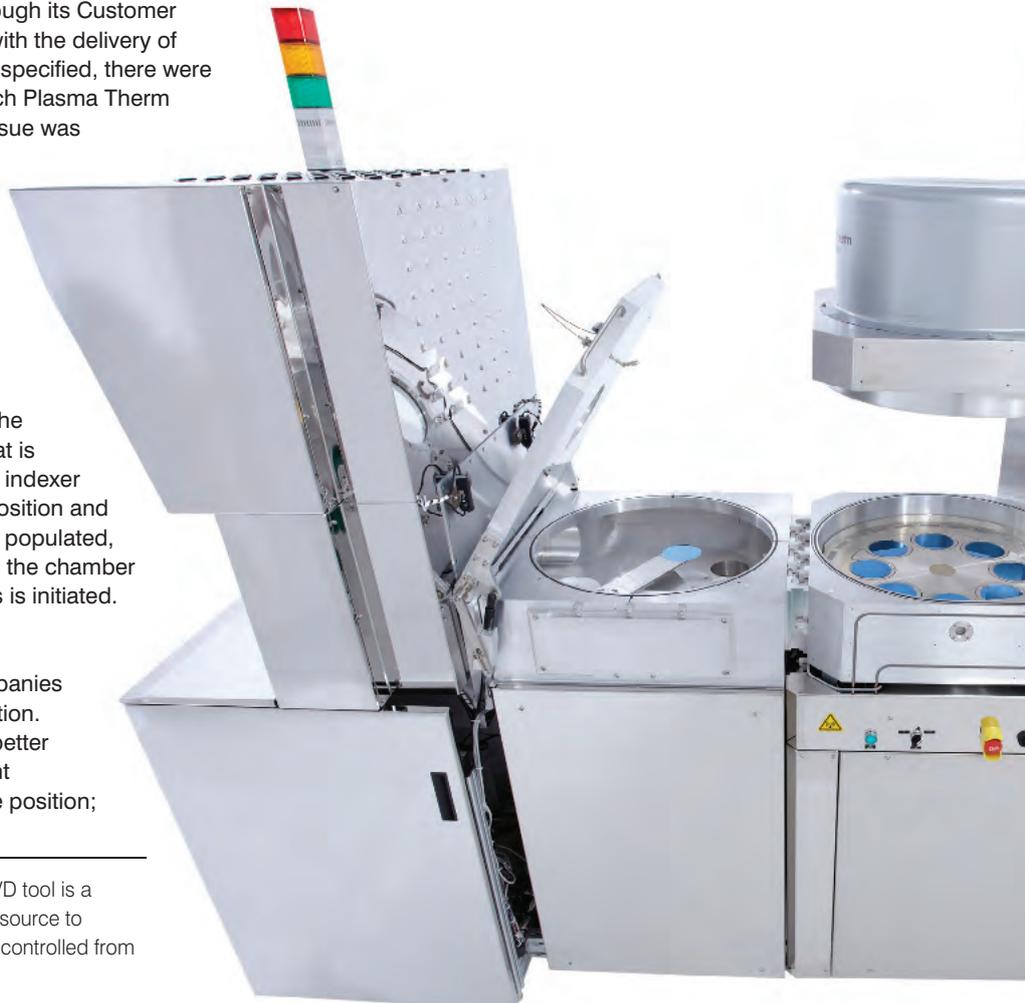
indexing to the same placement position; and wafer breakage, due to misplacement because of loss of home position. A further upgrade improved overall reliability, but intermittent faults persisted; primarily misplacement of wafers loaded onto the indexer was caused by inaccurate indexer positioning.

Engineers at both firms strived to get to the bottom of this, and through continuous investigations and testing, they were able to implement a final, very robust solution. This involved installing a drive and higher resolution encoding system at RFMD. Initially three systems were retrofitted in exactly the same way. When fully loaded the indexer was seen to have a minor issue with increased load (weight), which affected the sensitivity of the encoding mechanism. The approach taken in this effort was to normalize the load across all three tools and set the corresponding sensitivity for optimal operating conditions under load and teach each load position (see Figure 1). After several months of running with zero faults on these first three systems, RFMD's engineers upgraded their remaining tools with the drive and encoding package.

Improving the indexer led to an increase in wafer throughput. Addressing this issue propelled average wafer uptime from 91 percent to more than 97 percent, which equates to a productivity increase of over 10,000 wafers per year per tool (see Figure 2).

### Showerhead improvements

Working together, Plasma Therm and RFMD have also improved the across wafer and wafer-to-wafer thickness uniformity of  $\text{SiN}_x$



through modifications to the showerhead, a part of the upper electrode assembly that ideally distributes an even gas flow over the entire diameter of the process chamber. Initially, a lack of high uniformity in the SiN films on the wafers appeared to follow no pattern, but rather, was quite random. Further investigations at Plasma-Therm identified an issue with the showerhead. This led to a change in the manufacturing process for this part, plus the establishment of a final quality control procedure that drew on the findings of the process testing of the showerheads.

This effort has driven down the level of non-uniformity that is to be expected in SiN films deposited by the Plasma Therm tools beyond what was originally specified by RFMD. Typical thickness non-uniformities on the order of  $\pm 3-4$  percent have been the norm but the lower the uniformity the better and the 'magic'  $\pm 1.5$  percent target is the goal for the future.

The improvements made by Plasma-Therm have driven down the non-uniformities, and today, it is not uncommon for the non-uniformity of the SiN process to be less than  $\pm 2$  percent; and the uniformity is often significantly better than this. The showerhead, along with the chamber walls and internal chamber fixturing, is a major source of particles in any PECVD deposition system. To minimise these particulates, it is important to heat as many surfaces within the chamber. This leads to better adhesion of deposited material and less flaking or de-bonding of the deposited SiN<sub>x</sub> from the chamber fixturing. Parts that are heated include the upper electrode. After every *in-situ* clean, the showerhead is returned to its original manufactured operating condition.

Initially, the benefits of *in-situ* cleaning went unnoticed, due to the relatively high frequency of placement faults, which had to be addressed by opening the chamber. According to the initial preventative maintenance schedule, an open chamber clean was to take place every six months, but it made sense to also perform these cleans every time the chamber had been opened to address an indexer fault. The frequency of these faults varied from tool to tool, and in some cases took place every two-to-three months.

It is hard to know how long an *in-situ* chamber clean should be done, and this inevitably leads to 'overkill' in the cleaning process. This is very inefficient, because it reduces tool availability. One way to address this, which has



Figure 1. A robot is used to load the wafers into the tool. Each position on the indexer is 'taught' and the positions stored in memory for consistent loading and unloading

been pursued through the Plasma Therm-RFMD partnership, is to turn to Optical Emission Spectroscopy (OES). This provides clear, precise detection of when all the material has been removed (see Figures 3 and 4).

A common approach to removing SiN is to etch with a fluorine-based gas. This type of approach is used at RFMD, with *in-situ* cleaning involving a mixture of SF<sub>6</sub> and N<sub>2</sub>O – the latter acts as a source of oxygen that bonds with the free sulphur to increase the etch rate. Cleaning is typically carried out after 1.5  $\mu\text{m}$  of SiN deposition, using a process that takes about an hour to both clean (end pointed by OES) and carry out a subsequent post clean 'conditioning' deposition.

Thanks to improvements to the *in-situ* cleaning process, the intervals between open chamber cleans have been increased. In 2010, RFMD's engineers decided that it was acceptable to carry out the open chamber cleans just once every year, and in late 2011, this interval was extended to two years. These intervals have increased due to the improvements and cooperation by Plasma-Therm and RFMD to resolve the issues

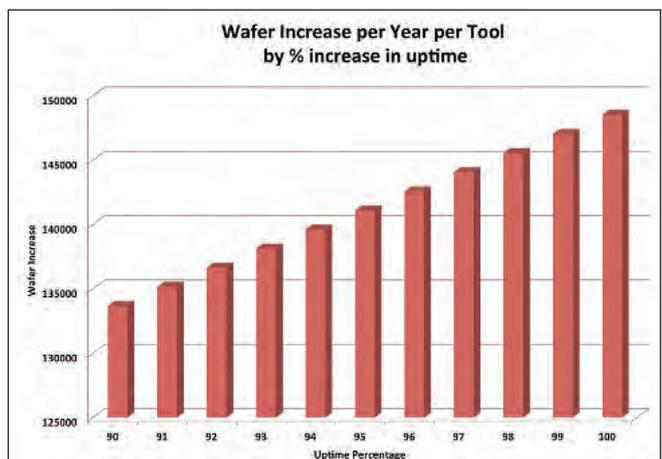
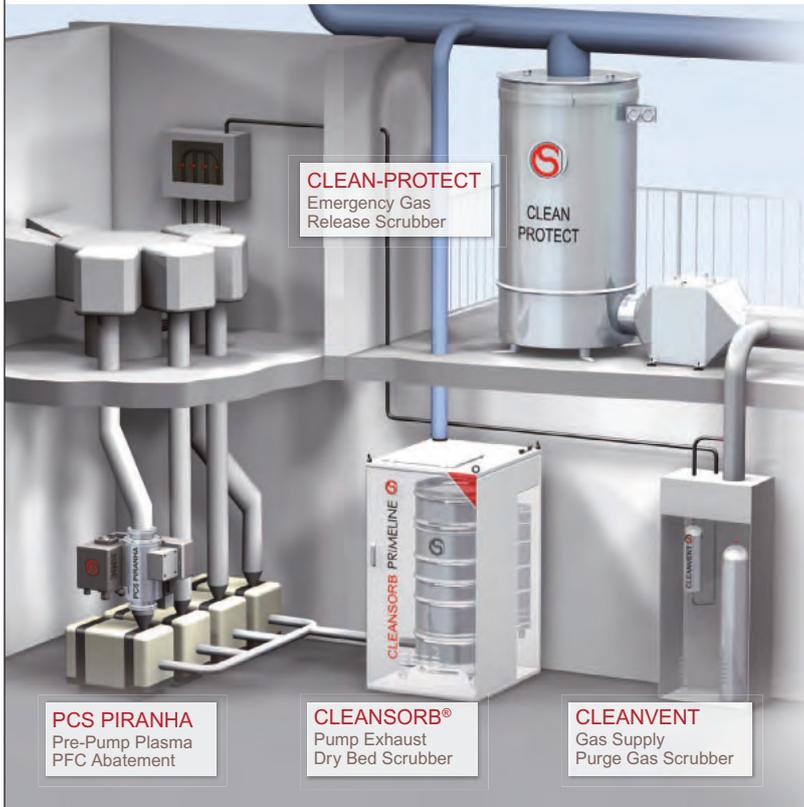


Figure 2. A small gain in uptime can translate into a throughput increase of thousands of wafers per year



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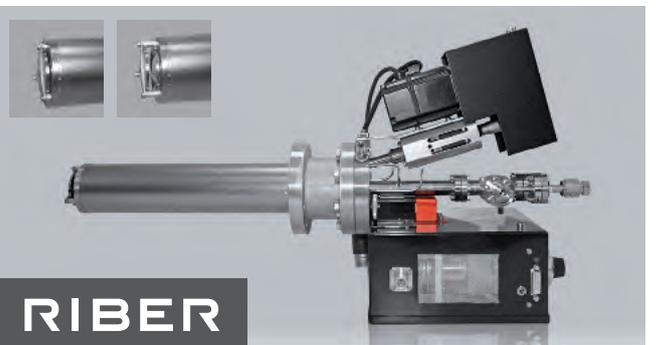
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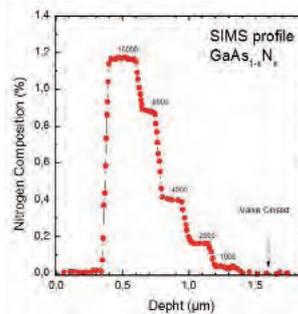
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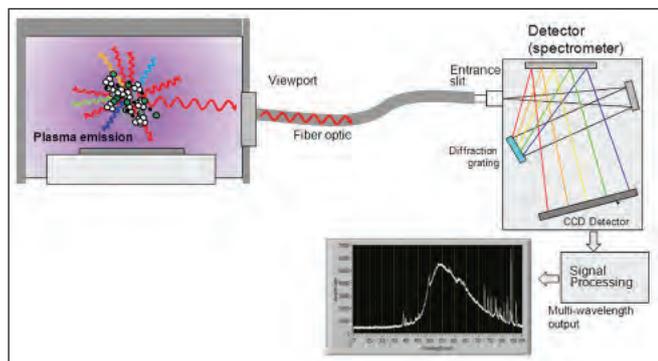


Figure 3. Optical emission spectroscopy can determine when the etching of SiN from the chamber is complete

that required a continuous, random opening of the chambers. Through 2012 and the beginning of this year, the LAPECVD tools are continuing to perform at a very high level, and by the first quarter, 2013, uptime over the entire toolset had risen to 98.6 percent. This success is the fruit of a relationship that has been built on trust and has now been going for nearly 20 years. When trust is established, candid and fruitful discussions ensue and equipment performance is improved, benefitting all concerned. Simply put, working together works wonders!

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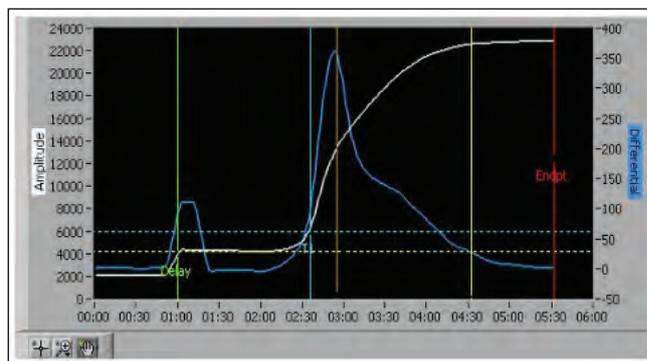


Figure 4. The EndPointWorks optical emission spectroscopy trace showing endpoint for a chamber clean. The x-axis is time and the Y (left) is signal amplitude. The Y (right) axis is a differential that is a calculated part of our endpoint software. This trace includes a cleaning step, plus chamber conditioning to prepare the chamber for further wafer depositions

• The authors would like to thank Ken Mackenzie, Pete Telford, Jeff Allen, Rich Gauldin, Arnie Colina and the CFT team from Plasma-Therm as well as Mike Fresina, John Erickson, Doug Wend from RFMD and Ron Hess (formerly with RFMD) for all their help and continued belief in the partnership. Mackenzie was the principle investigator with Ron Hess on the process improvements for the *in-situ* cleans and Jim Meyer was the lead and main “wrench” in all the tool upgrades over the years with factory support at Plasma-Therm from Pete Telford.

Item	Parameter	Testing/Process Results (high rate)	RFMD STANDARD PROCESS
1	Deposition Rate	≈ 520Å/min	≈ 90Å/min
2	Film Thickness	≈ 11.4kÅ	≈ 500 to 5000Å
3	Deposition Non-Uniformity - ATW	< ±1%	AVG = 1.65% st.dev. = 0.42 (within wafer – 5mm exclusion)
4	Deposition Non-Uniformity - WTW	±0.3%	AVG = 1.05% st.dev. = 0.57 (wafer to wafer – 5 wafer load)
5	Deposition NU - Batch to Batch	±0.3%	For 975Å thick film the batch to batch variation (standard deviation from target) is on average 10.7 Å
6	Stress*	-305±25MPa	300±25MPa (Tensile)
7	Refractive Index	2.0	2.0
8	Deposition Temperature	200°C	250°C
9	Thickness Control	Yes	1 step dep process
10	Plasma Clean Chemistry	Yes	Yes
11	Plasma Clean Control	Yes	Clean every 120 kW hours = ≈1.5microns of deposition

2D1C = Two deposition cycles followed by 1 in-situ clean/ chamber conditioning deposition  
 3D1C and 4D1C are under investigation.  
 \* Stress is adjustable

Table 1. Improvements to the showerhead have led to lower levels of non-uniformity

# Scrutinizing AlN/GaN heterostructures **atom** by **atom**

Conventional imaging techniques, such as various forms of electron microscopy, are incapable of delivering three-dimensional atomic resolution that can offer new insights into the characteristics of GaN-based heterostructures. But this type of measurement is possible with atom probe tomography, say **Baishakhi Mazumder, Man Hoi Wong, Jack Zhang, Stephen Kaun, Jing Lu, Umesh Mishra and James Speck** from the University of California, Santa Barbara.



GaN HAS MANY ATTRIBUTES. It can handle very high electric fields, electrons can zip through this material at very high speeds, and when this wide bandgap semiconductor is paired with Al(Ga)N, it is possible to form a two-dimensional electron gas (2DEG) with a high charge density.

Thanks to all of these beneficial characteristics, it is possible to produce a range of high-performance HEMTs that can deliver incredibly high output power from the S-band through to

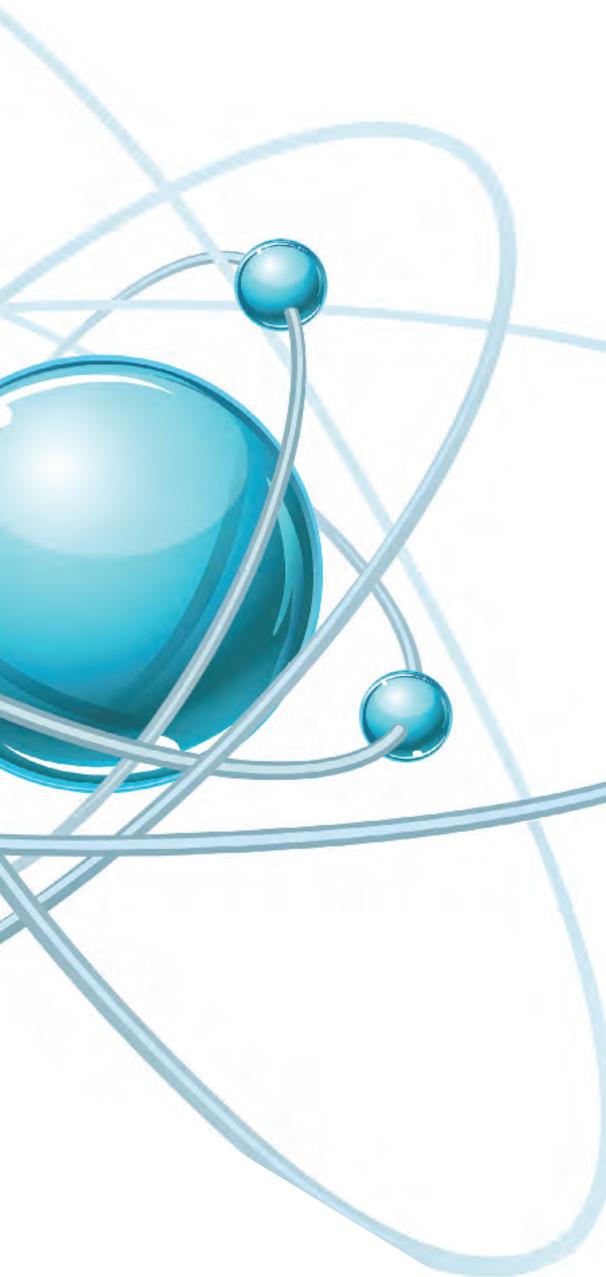
the W-band with high efficiency. These transistors also sport a high drain current density and a high cut-off frequency, making them suitable for integrated digital or control functions. What's more, monolithic integration of miniaturized enhancement- and depletion-mode (E/D) GaN HEMTs can deliver an unprecedented combination of high frequency and high-breakdown characteristics. This promises the feasibility of high-density, GaN-based, mixed-signal circuits.

Like other classes of transistor, shrinking device dimensions has spurred GaN HEMTs to higher speeds. However, continuing in this vein is getting more challenging as parasitics will limit device performance, and it now appears that the best way to quash parasitics as these transistors move to millimetre- and sub-millimetre-wave frequencies is to turn to a disruptive device technology based on the N-polar (0001) orientation of GaN.

The reason why this switch is beneficial is that there is a lack of inversion symmetry in wurtzite III-nitride materials: The polarization of N-polar crystals is opposite to that of the Ga-polar (0001)

Growth Technique	Attempted AlN interlayer (thickness (nm))	$n_s$ ( $\times 10^{13} \text{ cm}^{-2}$ )		$\mu$ ( $\text{cm}^2/\text{V}\cdot\text{s}$ )		$R_s$ ( $\Omega/\square$ )	
		RT	77 K	RT	77 K	RT	77 K
I. PAMBE	-2	1.65	1.65	2030	9400	188	42
II. MOCVD	-2	1.15	1.10	1280	3316	425	171
III. MOCVD	-0.7	1.10	1.12	2186	8946	259	63

Table I. Hall measurements including 2DEG sheet density ( $n_s$ ), mobility ( $\mu$ ), and sheet resistance ( $R_s$ ) for AlGaIn/AlN/GaN heterostructures grown by plasma-assisted MBE, ammonia MBE, and MOCVD



conduction band offset and high polarization charge density at the AlN/GaN interface. AlN can also fulfill other roles: Inserting it between an AlGaN barrier and GaN channel layer improves the electron mobility by reducing alloy scattering.

In both classes of GaN HEMTs, the 2DEG is confined at the AlN/GaN interface with a net positive fixed polarization charge. The transport properties of this electron gas, which impact HEMT performance, are directly related to the roughness and abruptness of the interface, as well as the chemical purity of the AlN. Meanwhile, at the opposite AlN/GaN interface – which has a net negative polarization charge – deep donor trap states form that are uncovered by deep level transient spectroscopy. Extensive electrical characterization has been used to try and uncover the physical nature of this trap, but it remains a mystery.

If a characterisation tool is to help to uncover these physical properties of AlN/GaN heterostructures, it will have to reveal compositional and interfacial profiles of polar AlN/GaN interfaces, and expose the incorporation of unintentional impurities into the HEMT's mobility-enhancing AlN interlayers.

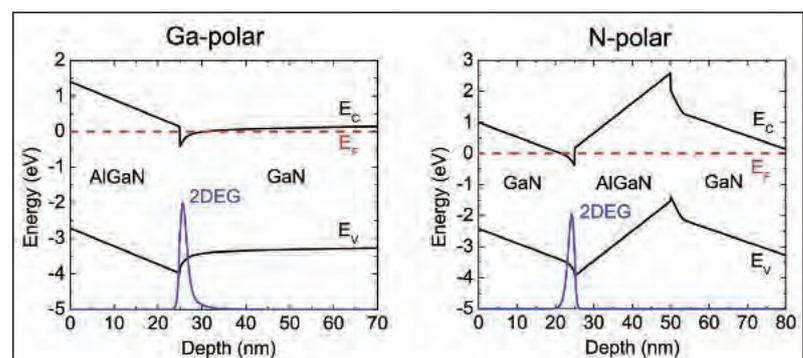
### Probing atomic structures

Unfortunately, the widely used techniques for scrutinizing semiconductor structures are of limited assistance. Although high-resolution microscopes – namely Transmission Electron Microscopy (TEM) and Scanning TEM (STEM) – provide high lateral spatial resolution imaging and detailed structural information, they are limited to two-dimensional atomic resolution, and they fail to address the critical and fundamental capability of generating three-dimensional atomic resolution. This restriction to just two dimensions also hampers techniques for extracting chemical

crystals. This means that polarization-induced electric fields in N-polar heterostructures are opposite to those in the Ga-polar counterpart, inducing a 2DEG above the wide-bandgap barrier layer, instead of below it (see Figure 1). Thanks to this, N-polar GaN HEMTs with an inverted structure – a GaN channel, an Al(GaN) barrier and a GaN-buffer – possess an inherent back-barrier that confines electrons and diminishes short-channel effects. The new architecture allows contact to the 2DEG through the channel layer, which has a narrower bandgap and lower surface barrier to electrons, compared with the wide-bandgap Al(GaN) barrier. Ultimately, this means that N-polar devices have much lower ohmic contact resistances than conventional, Ga-polar HEMTs.

For both Ga-polar and N-polar HEMTs, the idea of employing AlN as the charge-inducing barrier is attracting much attention, because of the large

Figure 1. Equilibrium band diagrams of (a) generic Ga-polar (0001) and (b) N-polar (000 $\bar{1}$ ) heterostructures



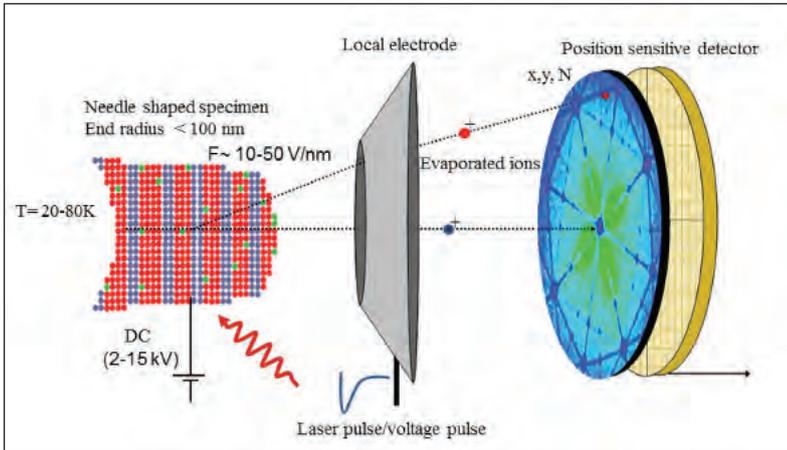


Figure 2. Atom probe tomography can provide a three-dimensional map of a structure on the atomic scale

information, such as electron energy loss spectrometry (EELS), energy-dispersive X-ray emission spectrometry (EDS) and secondary ion mass spectrometry (SIMS). What is needed is a reliable technique that delivers precise, three-dimensional characterization at sub-nanometre levels. Such a technique can also be useful for determining dopant diffusion profiles around the drain/source, providing interface profiles between junctions, and uncovering the roughness of a multilayer contact.

Atom probe tomography is capable of doing all of this, and has the unique capability to combine detailed composition – with better resolution than EELS or SIMS – with the determination of structural features near the atomic scale. Three-dimensional maps can be constructed of detected atoms or molecules with equal efficiency (detection efficiency is greater than 50 percent) and without prior knowledge of the composition.

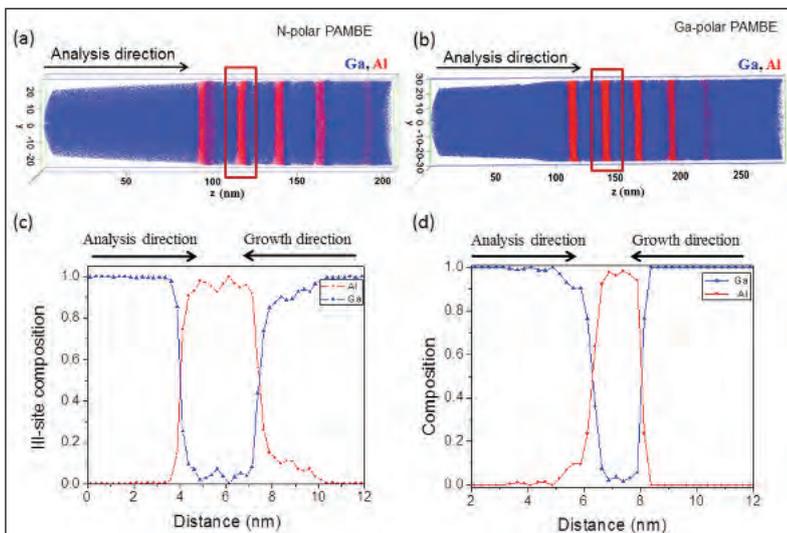


Figure 3. Three-dimensional atom distributions of plasma-assisted, MBE-grown (a) N-polar (b) Ga-polar  $\text{Al}_x\text{Ga}_{1-x}\text{N}/\text{GaN}$  heterostructures, where the red and blue dots represent aluminium and gallium atoms, respectively. A cylindrical volume with a 20 nm diameter was selected for the composition measurement from the centre data set of both samples, in order to make the interfaces perpendicular to the cylinder. (c) and (d) show chemical profiles of aluminium and gallium in the pure AlN layer indicated in red rectangle in (a) and (b)

This technique has a spatial resolution better than 0.3 nm, an analytical sensitivity of 1 atom per million and it can be used to study volumes greater than  $10^6\text{ nm}^3$ .

Atom probe tomography is based on a combination of field ion microscopy and mass spectrometry (see Figure 2). Like the former technique, a needle shaped specimen with an end radius of less than 100 nm must be prepared before the measurement can begin. This specimen is cooled to cryogenic temperature under an ultra-high vacuum of around  $10^{-11}$  mbar and subjected to an electric field, which creates an incredibly high DC field at the apex of the tip – it is tens of volts per nanometre. In addition to this field, voltage or laser pulses are applied to the specimen, triggering ionization of surface atoms that are subsequently field evaporated. The extracted ions are projected onto a position-sensitive detector that records their locations, which are linked to the former positions of the atoms on the tip. The isotopic identity of these atoms is revealed with a time-of-flight mass spectrometer that determines the mass-to-charge ratio of the ion. Armed with this information, it is possible to generate a three-dimensional reconstruction of the locations of tens of millions of neighbouring atoms.

Our team at the University of California, Santa Barbara, has used atom probe tomography to scrutinise nitride-based heterostructures. This effort kicked-off with a detailed study of a series of MBE-grown, GaN/AlN/GaN heterostructures, which were deposited on Ga-polar and N-polar GaN substrates using two different nitrogen sources: plasma nitrogen and ammonia.

The sample grown with a plasma nitrogen source has two AlN layers separated by a 20 nm-thick GaN layer. To study any effect of a gallium adlayer on the AlN/GaN interfaces, the first AlN layer was grown under metal-rich conditions, while the second was deposited under a slightly nitrogen-rich condition (prior to growth of the second AlN layer, the gallium adlayer was desorbed during a growth interruption, and no gallium was supplied during AlN growth). Note that when we switched to an ammonia source of nitrogen, we had intrinsically nitrogen-rich deposition conditions.

Atom probe tomography allowed us to identify differences in the atomic structure of both these samples (see Figure 3). A compositional profile based on a cylindrical volume with a 20 nm diameter reveals aluminium compositions of the N-polar and Al-polar AlN layers of 0.98 and 1, respectively, which are in close agreement with the target compositions.

Our approach also exposes the asymmetric nature of the AlN/GaN interfaces in the metal-rich GaN/AlN/GaN heterostructure. For N-polar, chemical abruptness is observed at the top

interface between AlN and GaN, while the bottom interface between this pair of materials is diffuse. Meanwhile, the opposite situation occurs in our Ga-polar structure: The top interface is chemically diffuse, and the bottom one is abrupt.

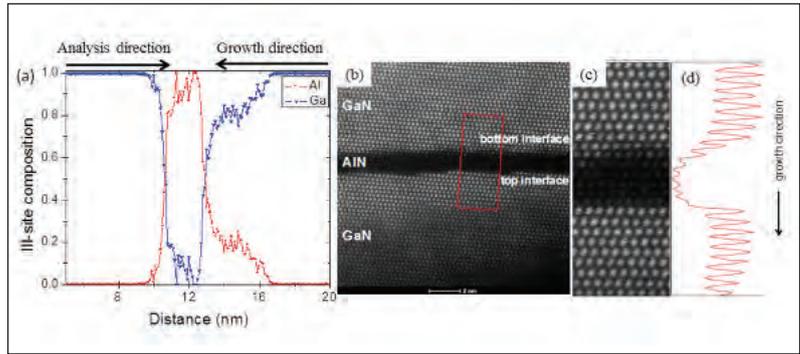
**What about artefacts?**

Artefacts can plague atom probe measurements. We took this into account when interpreting our results, investigating the possibility that the tip shape changed during the measurement, due to differences in the evaporation field of AlN and GaN. This evaporation field is higher for the former material, ruling out any possibility of an artefact causing our results, which would require an opposite state of affairs for differences in evaporation fields.

Our findings are strengthened by atom probe analyses on N-rich GaN/AlN/GaN heterostructures grown by both MBE-based techniques. Measurements confirmed observed asymmetry did not originate from the metal-rich, plasma-assisted MBE process. What we have concluded is that all GaN/AlN/GaN interfaces are asymmetric, and that inversion of crystal polarity reverses the characteristics observed in these regions, regardless of growth conditions (Figure 4a).

To provide an independent validation of our atom probe results, we employed STEM, high-angle annular dark-field imaging to scrutinise our N-polar samples grown by MBE with ammonia as the nitrogen source. A cross-sectional micrograph obtained with this technique reconfirms the asymmetry of the GaN/AlN/GaN interfaces, with the top interface appearing abrupt, while the bottom one looks diffuse. A line intensity profile across the GaN/AlN/GaN interfaces clearly shows this asymmetry. In agreement with the results from atom probe tomography, TEM images and line intensity profiles indicate a diffuse interface of about one unit cell.

The upshot of this study is that we have revealed how the polarity at GaN/AlN interfaces impacts their structural and compositional characteristics. If they are positively polarized, they are abrupt; but if they are negatively polarized, they are diffuse (this conclusion holds whether the heterostructure is Ga-polar or N-polar). It is possible to relate these findings to the well-known electrical properties of GaN/AlN/GaN heterostructures. The highly polar interfaces between GaN and AlN seek to minimize their electrostatic potential energy, through screening of polarization charges by free carriers. At a positively polarized interface, neutralization occurs via the accumulation of a 2DEG – electrons come from intrinsic donors, and for Ga-polar structures these come from the surface; but for N-polar, they come from traps. In contrast, it is not possible to neutralise a negatively polarized interface with a two-dimensional hole gas, because very few holes



exist in unintentionally doped III-N materials. This observation tallies with the results of calculations by scientists at Rockwell International in the late 1970s. According to their work, interfaces with a large charge imbalance reconstruct and become chemically diffuse.

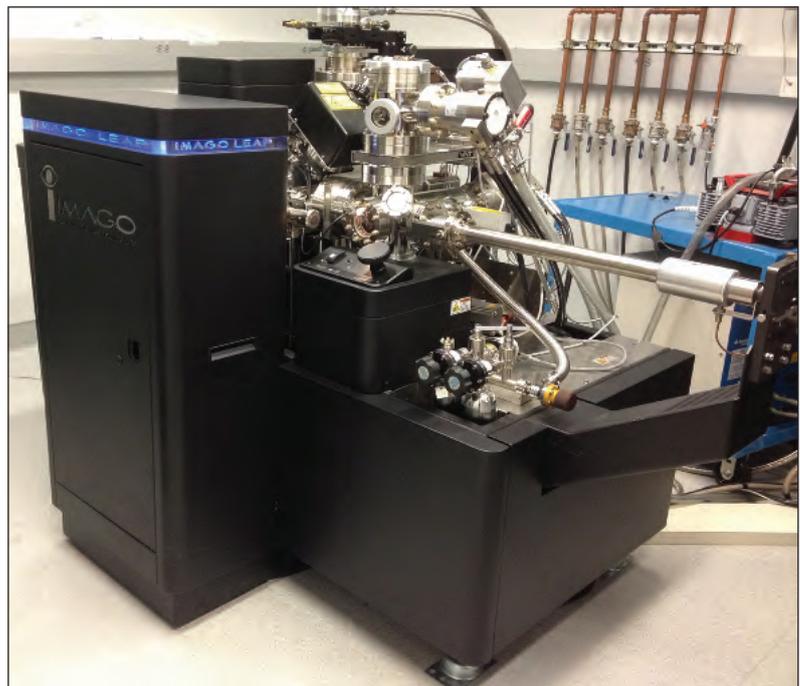
**Adding AlN interlayers**

We have also studied three different AlGaN/AlN/GaN HEMT structures that were grown by either plasma-assisted MBE or MOCVD. They feature an AlN interlayer that reduces the penetration of the electron wavefunction into the AlGaN barrier, and ultimately minimises the impact that alloy scattering can have on 2DEG mobility.

For MOCVD growth, the optimal thickness of the AlN layer is 0.7 nm, while for plasma-assisted MBE it is 2 nm. In addition, we grew a structure with a 2 nm-thick AlN layer by MOCVD: Although we knew that the thicker MOCVD interlayer would degrade material quality, we felt that it would provide a useful comparison with the MBE-grown sample. All samples were scrutinized with atom probe microscopy, and the findings compared with results of Hall electrical data. Atom probe microscopy proved very insightful, revealing a

Figure 4. (a) Chemical profiles of aluminium and gallium of the pure AlN layer grown by ammonia MBE (b) High angle annular dark-field STEM image of the AlN layer shown in (a). The step-terrace features at the interfaces were due to a 4° miscut. The enclosed region in (b) is enlarged in (c) along with the corresponding line intensity profile in (d)

The power of atom probe tomography is associated with its capability to generate three-dimensional maps of material with atomic resolution



“

At the critical sub-100-nm length scale, three-dimensional resolution achievable by atom probe tomography offers unique insights into the structural and chemical properties of active device layers and interfaces for growth optimization

”

massive difference between the two samples (see Figure 5). A well-defined AlN interlayer exists in the sample grown by MBE, but for both MOCVD-grown samples there is no distinct AlN interlayer, but rather an unintentionally graded AlGaN alloy.

Armed with this knowledge, it is far easier to interpret the Hall data for these samples, which were gathered at room temperature and 77 K and obtained via the van der Pauw Hall technique (see table 1). Our measurements, which show a deviation of below 5 percent between the sheet resistances measured across each sample, reveal that the lower the gallium content in the AlN interlayer, the higher the sheet concentration. For the sample that has a 2 nm-thick interlayer and was grown by plasma-assisted MBE, we recorded higher mobilities due to reduced alloy

disorder and interface roughness scattering. Meanwhile, the MOCVD-grown equivalent with an unintentional AlGaN interlayer is plagued by the combination of increased alloy disorder and interface roughness scattering, which both drag down 2DEG mobilities. Interestingly, despite high gallium concentrations in the interlayer, a very high 2DEG mobility was measured in the MOCVD-grown heterostructure that nominally contained a 0.7 nm-thick AlN layer. Note that we cannot infer that unintentional gallium incorporation into AlN will occur in all MOCVD reactors. It is in fact quite probable that our particular gas flow sequence played a role in the unintentional incorporation of residual gallium in the boundary layer.

Values for electron mobility have been put in perspective by performing a measurement at 300K on an MOCVD-grown AlGa<sub>N</sub>/Ga<sub>N</sub> heterostructure without an AlN interlayer. The mobility in this structure was 1600 cm<sup>2</sup>/Vs, about 500 cm<sup>2</sup>/Vs lower than both the sample grown by plasma-assisted MBE and featuring a 2 nm-thick AlN layer, and the MOCVD-grown structure that was designed to have an AlN layer that is 0.7 nm-thick. Our work showcases the capability and value of site-specific atom probe analysis on electronic devices. At the critical sub-100-nm length scale, the three-dimensional resolution achievable by atom probe tomography offers unique insights into the structural and chemical properties of active device layers and interfaces for growth optimization. Atom probe tomography can thus be a very powerful tool in correlating the electrical properties of a device to material properties. These capabilities, along with the means to provide a wealth of quality information, will strongly impact the processing and analysis of devices and components.

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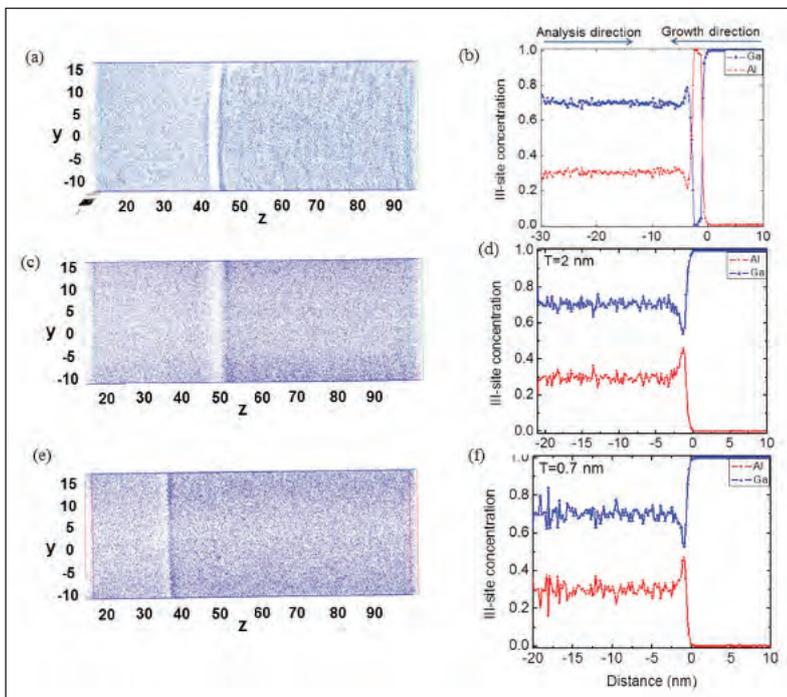


Figure 5. Atom probe microscopy reveals that different growth techniques lead to variations in the composition of a thin interlayer that is nominally made of AlN. Measurements were made of the three-dimensional distribution of gallium atoms from AlGa<sub>N</sub>/AlN/GaN heterostructures grown by plasma-assisted MBE with 2 nm interlayer (a) and MOCVD with 2 nm and 0.7 nm interlayer (c) and (e), respectively. Group III-site chemical composition profiles (b) (d) and (f) were taken from (a), (c) and (e), respectively

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Taiwan LED Lighting Industry Association

# Researchers 'unambiguously assign' LED droop to Auger processes

Electron emission spectroscopy offers new insights into the cause of droop

RESEARCHERS from the University of California, Santa Barbara, and École-Polytechnique, France, say that they have conducted an experiment that enables them to unambiguously assign LED droop to an Auger process.

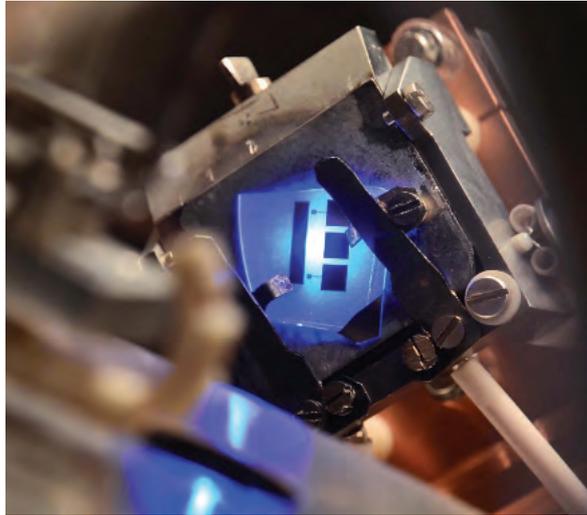
This is by no means the first time that an Auger process – a non-radiative interaction involving three carriers that leads to the promotion of an electron or hole to a higher energy state – has received the blame for LED droop, the decline in device efficiency as the current through the chip is cranked up. However, up until now, the evidence has been circumstantial, claims the US-French team.

According to Claude Weisbush, who is affiliated to both institutions, one of the biggest weaknesses of circumstantial evidence is that it allows droop to be explained by many competing theories. Along with Auger, this efficiency-sapping malady has been attributed to mechanisms such as electron leakage from the quantum well, poor hole injection and localisation of carriers at defects.

Weisbush argues that the experiment that he and his co-workers have performed changes all of this. It provides a direct measurement of hot electrons, which come from an Auger process involving two electrons and a hole.

"Such hot electrons are difficult to produce in semiconductor structures," says Weisbush. "Very high electric fields can generate hot electrons, as can energy barriers that launch hot electrons into the semiconductor, but for the LEDs we have, there are no strong electric fields or sufficiently high energy barriers." So, he argues, the only possible cause of hot electrons is an Auger process taking place in the LED.

To measure the energy of these



A blue LED made by the Taiwanese chipmaker Walsin Lihwa has been used to study the influence of Auger processes on LED droop

electrons, the team performs a very elegant experiment. They place a commercial, conventional LED in a vacuum and bias it at a range of voltages. To measure the hot electrons produced by the device, they add one or two monolayers of caesium to the surface of the  $p$ -side of the device, so that electrons passing through the chip can exit it and be detected by a spectrometer. Simultaneous measurements of the power of the light emitted by the LED are also made.

Weisbush explains that detecting hot electrons is not, in itself, conclusive proof that Auger recombination is the primary cause of droop. What provides this is that the hot electrons start to appear at exactly the same time that droop kicks in.

At injected currents of 4 mA and higher, two high-energy peaks are observed: one at 0.3-0.4 eV and another at about 2 eV. These energies do not correspond exactly with those of Auger electrons at their initial kinetic energies, because these carriers have to first travel through 200 nm of  $p$ -GaN, and there is very fast longitudinal-optical phonon emission in this material.

Other research groups admire the

experimental work carried out by this team, but not all are convinced that the data provides unquestionable proof that Auger recombination causes droop.

"The result is definitely a positive contribution to the droop question," says theorist Weng Chow from Sandia National Laboratories in Albuquerque, NM. According to him, this work provides a good basis for tying up loose ends: "For example – and speaking as a non-expert – I wonder if the authors can extract from the measurement an Auger electron density relative to the low energy electron density? And from that, perhaps, they can estimate an Auger coefficient?"

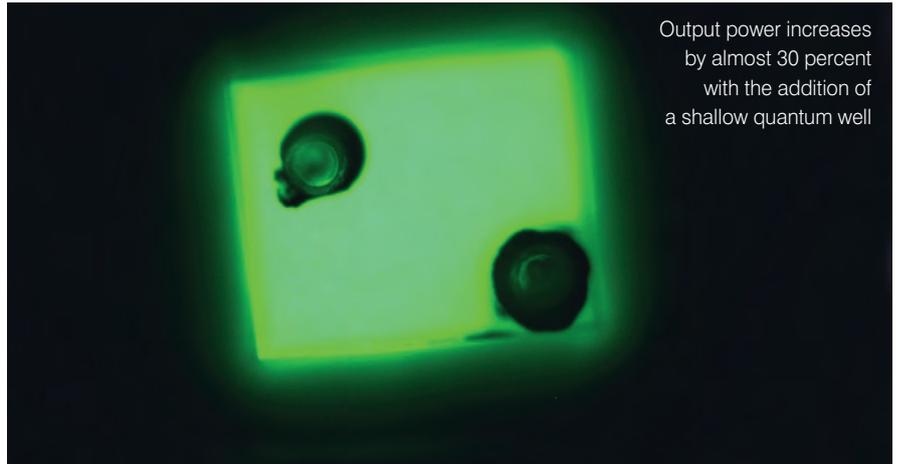
Meanwhile, Fred Schubert from Rensselaer Polytechnic Institute, in Troy, NY, questions whether some of the detected electrons have simply leaked out of the quantum well. Schubert says that Auger recombination is an undisputed effect and it will occur in LEDs: "But we believe that Auger recombination is not tenable as a major contributor to the efficiency droop." Four reasons are given to support this claim: the Auger coefficient is too small; the temperature dependence of the Auger process is opposite to the temperature dependence observed for efficiency droop; it's not possible to fit experimental results to the well-known ABC model, which includes an Auger term; and a more general explanation for droop is needed that accounts for its occurrence in LEDs made from other material systems.

Weisbush and his colleagues are going to be looking at other material systems, and also other devices. They hope to offer new insights into InP-based telecom lasers, and determine whether the loss mechanism is Auger recombination or intervalence band absorption.

J. Iveland *et al.* Phys. Rev. Lett.  
110 177406 (2013)

ENGINEERS from the Chinese Academy of Sciences have increased the efficiency of green LEDs by almost one-third by adding a shallow quantum well to the active region.

This effort will help the quest to close the difference in efficiency between blue and red LEDs and their green cousins, which are plagued by strong polarization fields and a large lattice mismatch. Ultimately, this will make the use of lighting systems based on all three types of LED more attractive. Several groups have already modified the architecture of the green LED to improve its efficiency.



Output power increases by almost 30 percent with the addition of a shallow quantum well

## Shallow wells bolster green LED emission

Modified active region trims electric fields, increases electron-hole overlap and boosts brightness

“For staggered, graded and chirped multi-quantum wells, the emitting-well-layer is divided into two layers or three layers,” explains lead-author Hongjian Li. “However, the strong indium diffusion during the epi-growth of the InGaN active region makes the precise control of indium composition difficult.”

He and his co-workers take a slightly different approach, which involves maintaining the composition in the emitting layer, and inserting before it a shallow quantum well layer with a far lower indium composition. According to Li, it is far easier to carry out the growth of this structure, and that should make it easier to transfer the growth process to mass production.

Inserting a shallow quantum well has additional benefits: It reduces the strength of the polarization fields within the structure, and it increases the crystal quality of the InGaN emitting layer.

Although this approach might appear to deliver similar results to that of a graded multiple quantum well, Li asserts that there is a fundamental difference between the two structures: “Carriers won’t recombine within the shallow well layer due to the low indium composition, but for graded multi-quantum wells,

carriers will recombine within the whole graded well.”

The researchers have investigated the characteristics of their LED architecture with APSYS software produced by Crosslight of Vancouver, Canada. In addition, the team have fabricated and measured the performance of chips based on this design.

Modelling efforts were based on assessing the band structure and carrier distributions of an LED with a shallow  $\text{In}_{0.10}\text{Ga}_{0.9}\text{N}$  quantum well just 2 nm-thick before the 3 nm-thick InGaN emitting layer, which has an indium composition of up to 30 percent. Results were compared with a more conventional design, with 3 nm-thick InGaN quantum wells.

Insertion of the shallow quantum wells led to less band-bending in the light-emitting wells, which is claimed to result from alleviation of the electrostatic field within the active region. In addition, the novel design pushed carriers towards the centre of the well and increased electron-hole wavefunction overlap from 18.3 percent to 25.8 percent.

LEDs with dimensions of  $256\ \mu\text{m}$  by  $300\ \mu\text{m}$  were fabricated by processing

2-inch, sapphire-based epiwafers grown by MOCVD. Heterostructures featured a 30 nm-thick GaN nucleation layer; a  $2\ \mu\text{m}$ -thick GaN layer; a  $2\ \mu\text{m}$ -thick, silicon-doped GaN layer; a multi-quantum well region; a 20 nm-thick *p*-type AlGaIn electron-blocking layer; and a 200 nm-thick *p*-GaIn layer. The active region for the novel LED contained 12 periods of 2 nm-thick, shallow  $\text{In}_{0.10}\text{Ga}_{0.90}\text{N}$  quantum wells, and 3 nm-thick  $\text{In}_{0.30}\text{Ga}_{0.70}\text{N}$  emitting layers, sandwiched between 12 nm-thick GaN barriers. A control structure was also formed that had a more conventional active region: 12 periods of 3 nm-thick  $\text{In}_{0.30}\text{Ga}_{0.70}\text{N}$  emitting layers interlaced with 12 nm-thick GaN barriers.

The team performed photoluminescence measurements at 85 K and 298 K on both structures. The design with a shallow quantum well had a narrower, stronger photoluminescence peak, which is believed to result from superior crystal quality. No emission can be detected from the shallow quantum well. Driven at 150 mA, the device with the shallow quantum well produced 49.3 mW at an emission wavelength of about 525 nm. In comparison, the output from the control sample was 38.4 mW.

The 29 percent increase in output power is attributed to enhanced radiative efficiency that stems from greater electron-hole overlap.

Li says that the team now plans to transfer the technology that they have developed to a high-volume LED manufacturing process. They will also optimise the design of this green-emitting chip.

H. Li *et al.* Appl. Phys. Express  
6 052102 (2013)

# Nickel enhances graphene contacts

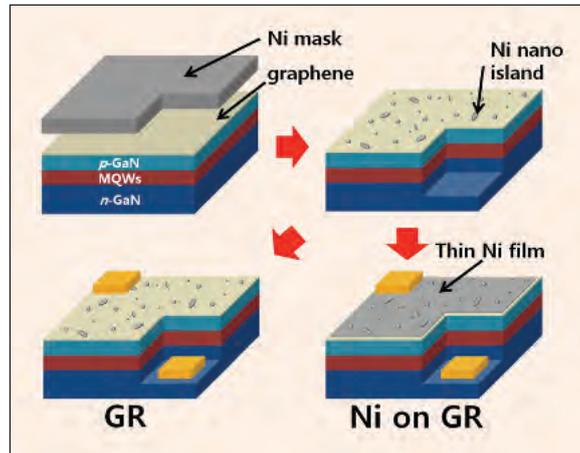
Covering a graphene contact with a thin layer of nickel allows the performance of an ultraviolet LED built with this upper electrode to get close to that of a conventional device

GRAPHENE is yet to fulfil its potential as a great electrode for making ultraviolet LEDs. But it has recently made great strides in that direction, thanks to the efforts of a partnership between two universities in South Korea: Gwangju Institute of Science and Technology and Chonbuk National University.

One of the most attractive features of graphene is its incredibly high transparency over a vast spectral range, but when it is used as a *p*-contact in ultraviolet LEDs, it leads to a very high turn-on voltage. The South Korean team has now partly addressed this, showing that this voltage can plummet from 13.2 V to 7.1 V by adding a thin nickel film onto this allotrope of carbon.

The tremendous transparency of graphene partly stems from its thinness – it is only 2-3 nm thick. “Graphene is grown on a metal foil, with compositing grains, so that it is a monolayer somewhere and could be a bilayer elsewhere,” explains corresponding author Dong-Seon Lee from Chonbuk National University. In comparison, a standard *p*-contact for ultraviolet LEDs, indium tin-oxide (ITO), is typically several hundred nanometres thick. Although this greater thickness hampers transparency, it aids sheet resistance, which is inversely proportional to film thickness. Graphene lags in terms of sheet resistance, but not by much, thanks to its mobility that is three orders of magnitude higher than ITO.

The researchers learnt how to enhance graphene-based ultraviolet LEDs by first studying the performance of three different blue-emitting devices: one had an ITO layer, another a graphene layer, and a third had a nickel film on top of the graphene. All three blue-emitting chips had the same heterostructure, and were formed by MOCVD growth on GaN-on-sapphire templates. To add a graphene layer, the team mixed this material with



Nickel is used twice in the fabrication of LEDs with novel contacts: first as mask (that is not removed perfectly), and again in combination with graphene, to lower sheet resistance

PMMA and deposited the result on the wafers, before warm acetone removed the acrylate.

To make graphene-only LEDs and those with the contact made from nickel and graphene, a 100 nm-thick layer of nickel was deposited onto the graphene-coated structures to act as a mesa-etching mask (see Figure). Etching with reactive ions and an inductively coupled plasma exposed the n-GaN, before the nickel mask was etched in hydrochloric acid.

Fabrication of the nickel-on-graphene LED involved deposition of a 3 nm-thick nickel layer. This device, and that with just the graphene contact, were then annealed in nitrogen at 500 °C.

The team has studied the transmittance of all three types of contact. For graphene, it exceeds 90 percent from 300 nm to 700 nm; while for ITO it is above 80 percent above 400 nm, but falls to 70 percent at 380 nm; and for nickel-on-graphene, it is about 75 percent for all wavelengths above 380 nm. Sheet resistance for the graphene sample is 1250 Ω/□, while the addition of nickel drops this to 690 Ω/□. In comparison, for ITO it is just 43 Ω/□. Lee admits that this is an issue: “One of the most important things in graphene research must be

[the development of] a growth technology enabling not only ultra-high transparency, but a comparable sheet resistance to ITO.”

The team has scrutinised the surface of the graphene-coated LED with a scanning electron microscope and found that the wet-etching process for removing the nickel mask is not perfect – it leaves traces of the material. These nano-islands that remained cover a very small fraction of the surface but are not believed to impact the optical transmission or sheet resistance of the graphene.

Driven at 20 mA, forward voltages for the ITO, nickel-on-graphene and graphene LEDs were 3.5 V, 4.8 V and 6.2 V, respectively. According to the team, graphene leads to a higher forward voltage than ITO, due to higher sheet and contact resistances. The addition of a thin nickel layer onto the graphene leads to the diffusion of these metal atoms, which have a lower workfunction and reduce the Schottky barrier height.

The team went on to apply its nickel-on-graphene contacts to ultraviolet LEDs emitting at 380 nm. At 20 mA, this device produced 83 percent of the output of the ITO control. This shows that for ultraviolet LEDs, when the carbon allotrope is coated with nickel, it can get close to the performance of the more traditional ITO-based design – and further optimisation should enable this structure to surge ahead.

“Our next plan is to use the metal-combined-graphene-transparent as an electrode for a diverse range of optoelectronic devices, such as solar cells, detectors and transistors,” says Lee.

J.-P. Shim *et al.* Appl. Phys. Lett.  
102 151115 (2013)



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# LEDs

## Cree reveals first no-compromise, ceramic, mid-power LEDs

The firm's latest III-nitride XH LEDs are claimed to deliver breakthrough reliability and performance

Cree has released the new XLamp XH Series of LEDs.

The firm says this is the first family of mid-power, ceramic LEDs that offer no-compromise performance and reliability.

Unlike today's common mid-power plastic packages, XLamp XH-G and XH-B LEDs enable lighting manufacturers to create a new generation of more energy-efficient, longer-life LED lighting solutions without sacrificing cost or performance.

XH LEDs are optimised for fluorescent-replacement-lighting applications, such as troffers and panel lights, where high efficacy, lifetime and smooth appearance are critical.

The XH-G LED delivers leading efficacy levels of up to 170 lumens-per-watt at 65 mA, 5000 K, 80 CRI and 25°C.

What's more, the ceramic-based XH LEDs are designed to deliver the long L70 lifetimes at high temperature and high current operation of Cree's other high-power LEDs, such as XP and XT LEDs.

In comparison, plastic LEDs are known for very short L70 lifetimes at high-temperature and high-current operation. The XH LEDs allow lighting manufacturers to offer products that meet the reliability expectations of LED technology.

"We're excited that Cree is offering high-quality, ceramic-based, mid-power LEDs designed for real-world lighting applications," says Roger Suen, supply chain management director, Light Engine. "The XH LED family gives us confidence in providing products that deliver stable lumen maintenance and good color consistency that cannot be duplicated by plastic packages."

"The use of plastic packages for lighting solutions places a high degree of risk for end-customers and the industry in general," adds Paul Thieken, Cree director of marketing, LED components. "The XH LEDs

provide peace-of-mind to lighting manufacturers while enabling them to better differentiate their products in the marketplace."

Both XH-G and XH-B LEDs share a common 3.0 mm x 3.0 mm footprint package with a 13 percent wider beam angle than most plastic mid-power LEDs. Cree XLamp XH LEDs are offered in 2700K to 7000K colour temperatures with high-CRI options available.

Samples are available now and production quantities are available with standard lead times.

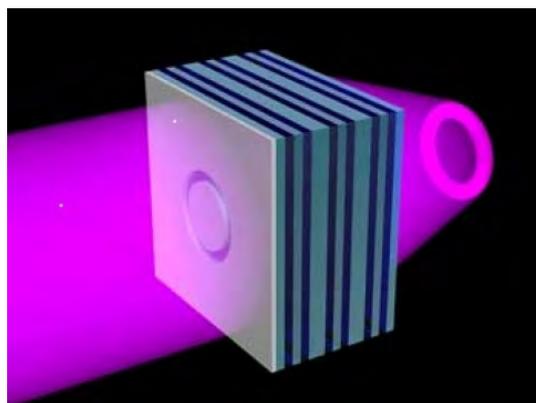
## Flat lens makes it all the better to see you with

A novel new lens could lead to improved photolithography, nanoscale manipulation and manufacturing and high-resolution 3D imaging

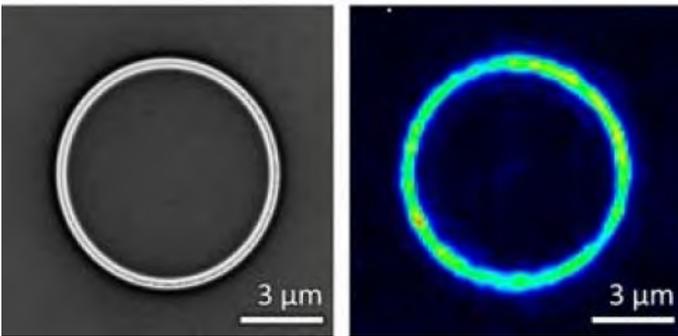
For the first time, scientists working at the National Institute of Standards and Technology (NIST) say they have demonstrated a new type of lens.

It bends and focuses ultraviolet (UV) light in such an unusual way that it can create ghostly, 3D images of objects that float in free space.

The easy-to-build lens could lead to improved photolithography, nanoscale manipulation and manufacturing, and even high-resolution three-dimensional imaging, as well as a number of as-yet-unimagined applications in a diverse range of fields.



*The ultraviolet (UV) metamaterial formed of alternating nanolayers of silver (green) and titanium dioxide (blue). The metamaterial has an angle-independent negative refractive index, enabling it to act as a flat lens. When illuminated with UV light (purple) a sample object of any shape placed on the flat slab of metamaterial is projected as a three-dimensional image in free space on the other side of the slab.*



*Right image: Here a ring-shaped opening in an opaque sheet on the left of the slab is replicated in light on the right.*

*Left image: SEM micrograph of a ring-shaped opening in a chromium sheet located on the surface of a flat slab of metamaterial. Bottom right: Optical micrograph of the image projected beyond the slab under UV illumination, demonstrating that the metamaterial slab acts as a flat lens. (Credit: Lezec/NIST)*

“Conventional lenses only capture two dimensions of a three-dimensional object,” says one of the paper’s co-authors, NIST’s Ting Xu. “Our flat lens is able to project three-dimensional images of three-dimensional objects that correspond one-to-one with the imaged object.”

An article published in the journal *Nature* explains that the new lens is formed from a flat slab of metamaterial with special characteristics that cause light to flow backward - a counterintuitive situation in which waves and energy travel in opposite directions, creating a negative refractive index.

Naturally occurring materials such as air or water have a positive refractive index. You can see this when you put a straw into a glass of water and look at it from the side. The straw appears bent and broken as a result of the change in index of refraction between air, which has an index of 1, and water, which has an index of about 1.33. Because the refractive indices are both positive, the portion of the straw immersed in the water appears bent forward with respect to the portion in air.

The negative refractive index of metamaterials causes light entering or exiting the material to bend in a direction opposite to what would occur in almost all other materials. For instance, if we looked at our straw placed in a glass filled with a negative-index material, the immersed portion would appear to bend backwards, completely unlike the way we’re used to light behaving.

In 1967, Russian physicist Victor Veselago described how a material with both negative electric permittivity and negative magnetic permeability would have a negative index of refraction.

Permittivity is a measure of a material’s response to an applied electric field, while permeability is a measure of the material’s response to an applied magnetic field.

Veselago reasoned that a material with a refractive index of -1 could be used to make a lens that is flat, as opposed to traditional refractive lenses, which are curved. A flat lens with a refractive index of -1 could be used to directly image three-dimensional objects, projecting a three-dimensional replica into free space.

A negative-index flat lens like this has also been predicted to enable the transfer of image details substantially smaller than the wavelength of light and create higher-resolution images than are possible with lenses made of positive-index materials such as glass.

It took over 30 years from Veselago’s prediction for scientists to create a negative-index material in the form of metamaterials, which are engineered on a subwavelength scale. For the past decade, scientists have made metamaterials that work at microwave, infrared and visible wavelengths by fabricating repeating metallic patterns on flat substrates.

However, the smaller the wavelength of light scientists want to manipulate, the smaller these features need to be, which makes fabricating the structures an increasingly difficult task. Until now, making metamaterials that work in the UV has been impossible because it required making structures with features as small as 10 nanometers, or 10 billionths of a metre.

What’s more, because of limitations inherent in their design, metamaterials of this type designed for infrared and visible wavelengths have, so far, been shown to impart a negative index of refraction to light that is traveling only in a certain direction. This makes them hard to use for imaging and other applications that rely on refracted light.

To overcome these problems, researchers working at NIST took inspiration from a theoretical metamaterial design recently proposed by a group at the FOM Institute for Atomic and Molecular Physics in Holland. They adapted the design to work in the UV- a frequency range of particular technological interest.

According to co-authors Xu, Amit Agrawal and Henri Lezec, aside from achieving record-short wavelengths, their metamaterial lens is inherently easy to fabricate. It doesn’t rely on nanoscale patterns, but instead is a simple sandwich of alternating nanometre-thick layers of silver and titanium dioxide, the construction of which is routine.

And because its unique design consists of a stack of strongly coupled waveguides sustaining backward

waves, the metamaterial exhibits a negative index of refraction to incoming light regardless of its angle of travel.

The researchers say this realisation of a Veselago flat lens operating in the UV is the first such demonstration of a flat lens at any frequency beyond the microwave. By using other combinations of materials, it may be possible to make similarly layered metamaterials for use in other parts of the spectrum, including the visible and the infrared.

The metamaterial flat lens achieves its refractive action over a distance of about two wavelengths of UV light, about half a millionth of a metre - a focal length challenging to achieve with conventional refractive optics such as glass lenses.

What's more, transmission through the metamaterial can be turned on and off using higher frequency light as a switch, allowing the flat lens to also act as a shutter with no moving parts.

"Our lens will offer other researchers greater flexibility for manipulating UV light at small length scales," says Lezec. "With its high photon energies, UV light has a myriad of applications, including photochemistry, fluorescence microscopy and semiconductor manufacturing. That, and the fact that our lens is so easy to make, should encourage other researchers to explore its possibilities."

The new work was performed in collaboration with researchers from the Maryland NanoCentre at the University of Maryland, College Park; Syracuse University; and the University of British Columbia, Kelowna, Canada.

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## Panasonic UV lasers and phosphors energise white lights

The company's newly developed technology will enable wider variation in design and a higher brightness and smaller form factor in data projectors and vehicle headlights

Panasonic Corporation has developed a semiconductor white light source capable of outputting luminous flux in the 10,000-lumen class.

An increased light output was achieved due to the high-efficiency, low-loss design and modularisation of the near-ultraviolet semiconductor laser used in the light

source.

A high luminous flux of white light was realised through the development of a phosphor material that is not subject to luminance saturation even when irradiated with high-intensity laser light.

Luminance saturation is when the optical power may decline as the intensity of incident radiation increases.

The use of a laser with a smaller light-emitting area and superior light emission directionality to LEDs has made a compact optical configuration that boasts higher brightness and a smaller form factor possible. Panasonic says this technology opens the way to the greater use of semiconductor light sources in the projection and lighting market.

The new technology has the following features:

- By increasing the output of the near-ultraviolet laser in the light source to ten times that of a conventional Panasonic laser, the industry's highest light output of 60 watts (W) has been achieved. This is based on a survey by Panasonic on near-ultraviolet laser up to May 24th, 2013. The miniaturised laser module, a component where two or more semiconductor lasers are mounted functioning as a light source, can be incorporated into a wider range of equipment.
  - The use of a newly developed phosphor material has increased blue light emissions by 40 percent when irradiated with 60W near-ultraviolet semiconductor laser light. This contributes to the realisation of a 10,000-lumen class high-luminous flux white light source through the red, green and blue phosphors.
  - The generation of red, green and blue lights from only one type of laser light using a rotating phosphor wheel simplifies the optical system and ensures that the laser is projected directly onto the screen. The phosphor wheel is a component where light is shined onto the surface of a disc, onto which phosphor has been applied, which is then rotated by a motor on the central shaft, continuously creating phosphor light.
- This development is based on the following new technologies:
- High-output, low-loss laser design technique with wider near-ultraviolet laser optical waveguide and optimised light loss control.
  - Phosphor material technology that utilises the high-density crystalline structure of SMS (Sr<sub>3</sub>MgSi<sub>2</sub>O<sub>8</sub>) phosphor to control the density of the luminescent centre and thus prevent luminous saturation.

- Wavelength conversion technology that uses a rotating phosphor wheel that absorbs near-ultraviolet laser light and converts it to red, green and blue luminescent light.

Conventional laser white light sources require multiple visible light semiconductor lasers that emit blue and other colours, which creates a trade off between small form factor and high brightness. Some laser wavelengths are even projected directly, without passing through the phosphor material.

Conventional phosphors are not suitable for use as high-intensity light sources, as they are subject to significant luminance saturation when laser light is focused on them.

Panasonic holds 39 patents in Japan and 22 overseas patents, including pending applications, for this development.

This newly developed technology received the Distinguished Paper Award from the Society for Information Display (SID), an international conference for displays and related products held last week.

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## Crystal IS UV LEDs awarded at 2013 BlueTech Forum

The firm's III-nitride LEDs have massive potential, particularly within the water space

Crystal IS has won a Disrupt-o-Meter Award at the 2013 BlueTech Forum in Amsterdam.

Crystal IS was selected from a range of participants for the water sector award honouring innovative, industry-revolutionising technology.

"We are thrilled to be recognised by this global forum composed of water industry leaders, market experts and our peers," said Therese Jordan, SVP of Business Development at Crystal IS. "This honour signifies the global market's confidence in our technology and its future impact."

Crystal IS fabricates its LEDs on home grown AlN substrates which are claimed to far surpass diodes fabricated on sapphire.

BlueTech Research monitors the global water market for companies with innovative and disruptive technologies and a strong go-to-market strategy. The Disrupt-o-Meter Award is given to the water technology company that has the highest potential to not only influence existing markets, but open up new markets because of its ability to be used in various applications.

What's more, the award analyses the company's business model and the quality of service provided with the technology.

Paul O'Callaghan, CEO of BlueTech Research, says, "BlueTech Research has long been tracking and analysing the market potential for innovative and disruptive water technologies. We believe that the technology presented by Crystal IS represents one of the strongest opportunities in the technical space in the next 5 to 10 years, and are excited about the potential for LEDs in the market, particularly within the water space."

"UV LEDs represent one of the top five potentially disruptive water technologies, with the global UV water disinfection market worth \$1.1Bn. UV LEDs have the potential to disrupt this market and access market share, and equally importantly, to open up new applications and markets previously inaccessible to conventional UV lamp technology," continues O'Callaghan.

Crystal IS reported record outputs of greater than 60mW for its UVC LEDs earlier this year. As part of this award, Crystal IS will have the opportunity to showcase their products in the 2013 WEFTEC Innovation Pavilion at the conference in Chicago, IL this October.

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## SPTS & QMF unite to grow SiC on 300mm silicon

The aim of the joint project is to provide a cost-effective buffer material to enable fabrication of gallium nitride (GaN) devices on silicon substrates

The Queensland Micro and Nanotechnology Facility (QMF) of Griffith University and industry partner SPTS Technologies have announced the epitaxial growth of 3C SiC films on 300mm silicon wafers.

This breakthrough is the result of over 10 years research at QMF on low temperature SiC deposition on silicon and the joint development by QMF and SPTS of a commercial reactor to extend the epitaxial growth process to commercial scale production of SiC coated silicon wafers.

The ultimate target of the joint project is to provide a cost-effective buffer material to enable fabrication of GaN devices on silicon substrates.

Fabricating GaN LEDs and power devices on large diameter silicon wafers is viewed as a path to improve performance and reduce cost, thereby increasing commercial acceptance of these devices. However, existing buffer layers used to bridge the large thermal

and lattice mismatch between silicon and GaN are costly and not completely effective for large scale production.

A 3C-SiC film provides an effective buffer layer lattice-matched for GaN growth on silicon, as well as an impervious barrier to prevent silicon from diffusing into GaN, of particular concern to power devices.

Initial estimates are that the new SiC on silicon coating process in volume production would add no more than \$25-35 to the cost of a silicon wafer, substantially increasing the appeal of silicon as a substrate for LEDs and GaN power devices.

“We believe we are the first in the world to grow 3C-SiC epitaxially on 300mm silicon wafers, which means following the same crystal structure as the silicon crystal substrate,” says Alan Iacopi, QMF Director of Operations.

“The reactor development project with SPTS has allowed the QMF R&D process to be extended from small wafers up to 300mm wafers with semiconductor industry specifications; in fact, we have already achieved SiC film thickness uniformities of around 1 percent on 300mm wafers using the new reactor,” he adds.

“SPTS is excited to be a partner in this project, as we see the QMF SiC technology as a potential breakthrough in reducing the cost of LEDs and improving the performance of GaN power devices,” according to William Johnson, President and CEO of SPTS.

He continues, “Based on our extensive background in vertical furnace technology, the new reactor has been designed for high temperature vacuum processing of batch loads of 150mm to 300mm wafers, with process automation suitable for commercial application. There are a number of buffer and template wafer suppliers offering alternative solutions; however, we see a strong business case for device manufacturers adopting the QMF/SPTS SiC solution to optimize process and control substrate costs.”

Iacopi adds, “The Griffith University and SPTS partnership has far reaching implications in terms of demonstrating how Australian research entities (like QMF) can collaborate with international industry to advance frontier technologies and bring industrial benefit to Queensland. We have all the ingredients to develop a high tech economy in Queensland, including technically leading Universities, the Australian National Fabrication Facility infrastructure, entrepreneurial spirit, and start-up company investment support.”

## Europe to boost micro- and nanoelectronic industries

A new initiative is supporting research, development and innovation and improvement in the entire semiconductor ecosystem

The European Semiconductor Industry Association (ESIA) welcomes the European Commission’s Communication “A European strategy for micro- and nanoelectronic components and systems”.

The actions outlined in the Communication will strengthen the competitiveness and growth potential of the micro- and nanoelectronics industry in Europe, and build upon the European initiative on Key Enabling Technologies (KETs) and HORIZON 2020.

ESIA believes that this Communication takes a decisive approach to reinforce the European semiconductor industry, and to increase its contribution to the wider European economy.

ESIA commends the acknowledgment that semiconductors play a crucial role in driving business transformation and responding to growing societal needs. This communication recognises the electronics industry as a key force to address the challenges the economy in the EU is facing.

ESIA fully supports the Commission’s multi-level strategy including financial support for research, development and innovation (R&D&I), as well as the improvement and better use of relevant legislation. Given the very high diversity of the European market, ESIA is pleased to see the entire semiconductor ecosystem being addressed.

With a clear focus on R&D&I, market pull for new application areas, education and production, the strategy builds on the four pillars ESIA has been promoting as a basis for a dedicated European industrial policy for the micro- and nanoelectronics sector.

Rick Clemmer, ESIA President and CEO of NXP Semiconductors, states, “Pilot lines and prototyping are a welcome addition to the European R&D stimulation programme. But this concept should not be limited to semiconductor manufacturing as such. Joint semiconductor downstream application pilots will provide significant additional leverage in economic growth and employment in areas such as the Internet of Things and Smart Cities, including Intelligent Traffic Systems, Smart Buildings and Smart Grids.”

Executing on this Communication has the potential to reverse the current trend in the European semiconductor market, which has seen production in Europe drop to

less than 10% percent of world production in 2011.

“Leadership in innovation is key to developing a sustainable advantage for European industry and we need to build on the scientific excellence in Europe to turn great ideas into globally competitive technologies and related manufacturing,” comments Carlo Bozotti, President and Chief Executive Officer of STMicroelectronics.

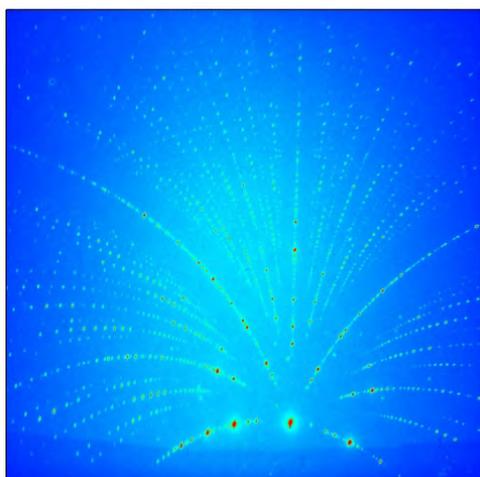
“With traditional strengths in analogue and power as well as more recent innovations in technologies, companies in Europe have the capability to continue to lead the development of the next wave of electronic products. The actions outlined in the Commission’s Communication demonstrate a clear commitment to Europe’s future,” adds Bozotti.

Hendrik Abma, Director-General of ESIA, says, “ESIA welcomes the ambition and vision of the European Commission’s strategy. ESIA has consistently underlined the importance of the European semiconductor industry to the competitiveness and vitality of the European economy, as well as to tackling the grand societal challenges, such as energy efficiency and aging populations.”

ESIA looks forward to the full implementation of the European Commission’s strategy for micro- and nanoelectronic components and systems. ESIA is fully aware that the strategy’s successful execution requires significant alignments among all stakeholders.

## New family of tiny crystals glow bright in LED lights

Scientists are using X-ray diffraction to further understand crystals that could improve warm-white LED performance



Minuscule crystals that glow different colours may be the missing ingredient for white LED lighting that illuminates homes and offices as effectively as natural sunlight.

LEDs offer substantial energy savings over incandescent and fluorescent lights and are easily produced in single colours such as red or green commonly used in traffic lights or children’s toys.

Developing an LED that emits a broad spectrum of warm white light on par with sunlight has proven tricky. However, LEDs, which produce light by passing electrons through a semiconductor material, are often coupled with phosphors that glow when excited by radiation from the LED.

“But it’s hard to get one phosphor that makes the broad range of colours needed to replicate the sun,” notes John Budai, a scientist in Oak Ridge National Laboratory’s (ORNL’s) Materials Science and Technology division. “One approach to generating warm-white light is to hit a mixture of phosphors with ultraviolet radiation from an LED to stimulate many colours needed for white light.”

Budai is working with a team of scientists from University of Georgia and Oak Ridge and Argonne national laboratories to understand a new group of crystals that might yield the right blend of colours for white LEDs as well as other uses.

Zhengwei Pan’s group at UGA grew the nanocrystals using europium oxide and aluminium oxide powders as the source materials because the rare-earth element europium is known to be a dopant, or additive, with good phosphorescent properties.

“What’s amazing about these compounds is that they glow in lots of different colours - some are orange, purple, green or yellow,” Budai explains. “The next question became: why are they different colours? It turns out that the atomic structures are very different.”

Budai has been studying the atomic structure of the materials using x-rays from Argonne’s Advanced Photon Source. Two of the three types of crystal structures in the group of phosphors had never been seen before, which can probably be attributed to the crystals’ small size, Budai claims.

“Only the green ones were a known crystal structure,” Budai says. “The other two, the yellow and blue, don’t grow in big crystals; they only grow with these atomic arrangements in these tiny nanocrystals. That’s why they have different photoluminescent properties.”

X-ray diffraction analysis is helping Budai and his collaborators work out how the atoms are arranged in each of the different crystal types. The different-coloured

phosphors exhibit distinct diffraction patterns when they are hit with x-rays, enabling researchers to analyse the crystal structure.

“What that means in terms of how the electrons around the atoms interact to make light is much harder,” Budai says. “We haven’t completely solved that yet. That’s the continuing research. We have a lot of clues, but we don’t know everything.”

The knowledge gained through their atomic-scale analysis is helping the research team improve the phosphorescent crystals. Different factors in the growth process, temperature, powder composition, and types of gas used, can change the final product. A fundamental understanding of all the parameters could help the team to perfect the recipe and improve the crystals’ ability to convert energy into light.

Advancing the material’s luminescence efficiency is key to making it useful for commercial LED products and other applications; the new nanocrystals may turn out to have other practical photonic uses beyond phosphors for LEDs. Their ability to act as miniature “light pipes” when the crystal quality is high enough could lend them to applications in fibre-optic technologies, Budai says.

You can keep growing the crystals and measuring them, or you can understand why it’s doing what it’s doing, and figure out how to make it better. That’s what we’re doing—basic research. We have to figure out nature first.”

The team’s most recent study is published as the inside front cover article in the April 25 issue of *Advanced Functional Materials* as “New Ternary Europium Aluminate Luminescent Nanoribbons for Advanced Photonics.”

Budai and use of the Advanced Photon Source at Argonne were supported by DOE’s Office of Science. Zhengwai Pan was funded by the National Science Foundation.

The Advanced Photon Source at Argonne National Laboratory is one of five national synchrotron radiation light sources supported by the U.S. Department of Energy’s Office of Science. The program is designed to carry out applied and basic research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels, provide the foundations for new energy technologies, and support DOE missions in energy, environment, and national security.

## IMRE uses LayTec tool for 200mm GaN-on-silicon

The EpiCurve Triple TT in-situ monitoring system is being used to develop epiwafers for InGaN/GaN LEDs and GaN power electronic devices

In his invited talk at the LED Technology Forum in Singapore Sudhiranjan Tripathy of IMRE (Institute of Materials and Research Engineering, A\*STAR revealed the latest results of GaN growth on 200 mm diameter silicon.

The conference took place between 7th and 10th May.

Tripathy’s team uses LayTec’s *in-situ* monitoring system EpiCurveTriple TT to develop epiwafers for InGaN/GaN LEDs and GaN power electronic devices.

EpiCurve Triple TT is ideally suited for 200 mm real time wafer characterisation because of its 3 sensor heads for radial analysis of growth conditions. It provides wafer bow and temperature measurements, as well as simultaneous detection of growth rate and surface morphology.

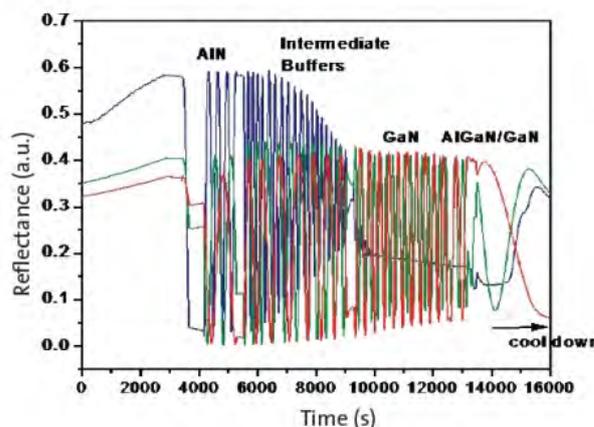


Fig. 1: Reflectance monitoring of AlGaIn/GaN HEMT structure grown on 1.0 mm thick 200 mm diameter Si (111) at IMRE: blue - 405 nm, green - 633 nm, red - 950 nm

Fig. 1 shows reflectance profiles at 3 wavelengths: 950 nm for emissivity correction of pyrometry, 633 nm for analysis of thick layers e.g. GaN buffer, and 405 nm for thin layers. Fig. 2 demonstrates how the 405 nm reflectance is used for individual *in-situ* tuning of each well and barrier within the multiquantum wells stack.

The *in-situ* signal (Fig. 2 - left) perfectly corresponds with the multi-quantum wells (MQWs), which can be seen in the scanning transmission electron microscopy (sTEM, Fig. 2 - right).

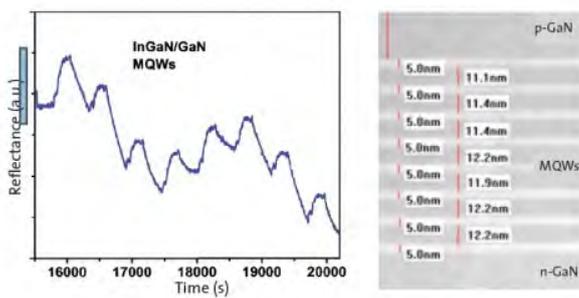


Fig. 2: 405 nm reflectance (left) of InGaN/GaN MQW stacks and the corresponding STEM image of the MQWs (right).

According to Tripathy's team, LayTec *in-situ* metrology is a key element for identifying the epitaxial process potentials. In comparison to the time consuming, destructive *ex-situ* cross section transmission electron microscopy analysis, the *in-situ* tool provides real time information on growth thickness and homogeneity already during growth.

LayTec says its system has reduced significantly IMRE's R & D cycles for epitaxial growth optimisation and enables faster industrialisation of the GaN-on-Silicon technology.

## Electron Microscopy solves key puzzle of LED efficiency

Scientists have used electron microscopy imaging techniques on indium gallium nitride (InGaN) LEDs to settle the controversy of indium clustering and raise new experimental possibilities

From the high-resolution glow of flat screen televisions to light bulbs that last for years, LEDs continue to transform technology.

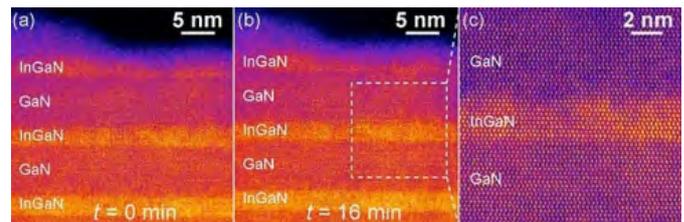
The celebrated efficiency and versatility of LEDs, and other solid-state technologies including laser diodes and solar photovoltaics, make them increasingly popular. Their full potential, however, remains untapped, in part because the semiconductor alloys that make these devices work continue to puzzle scientists.

A contentious controversy surrounds the high intensity of one leading LED semiconductor, InGaN, with experts split on whether or not indium-rich clusters within the material provide the LED's remarkable efficiency.

Now, researchers from the Massachusetts Institute of Technology (MIT) and the U.S. Department of Energy's (DOE) Brookhaven National Laboratory say they have demonstrated definitively that clustering is not

the source. These results are claimed to advance the fundamental understanding of LED technology and open up new research pathways.

"This discovery helps solve a significant mystery in the field of LED research and demonstrates breakthrough experimental techniques that can advance other sensitive and cutting-edge electronics," says MIT professor, Silviya Gradečak. "The work brings us closer to truly mastering solid-state technologies that could supply light and energy with unprecedented efficiency."



These images of the InGaN samples, produced by CFN's low-voltage scanning transmission electron microscope, reveal a lack of structural changes over time. After 16 minutes of scanning, no damage or decomposition is visible, and the higher magnification (c) exhibits none of the clustering previously thought to be central to LED efficiency

### Building a Better Bulb

Incandescent lights, the classic bulbs that use glowing wires of tungsten or other metals, convert only about five percent of their energy into visible light, with the rest lost as heat. Fluorescent lights push that efficiency up to about 20 percent, still wasting 80 percent of the electricity needed to keep homes and businesses bright. In both of these instances, light is only the by-product of heat-generating reactions rather than the principal effect, making the technology inherently inefficient.

"Solid-state lights convert electric current directly into photons," explains Eric Stach, leader of the Electron Microscopy Group at Brookhaven Lab's Centre for Functional Nanomaterials (CFN). "LED bulbs use semiconductors to generate light in a process called electroluminescence. The efficiency of this process could, in theory, be nearly perfect, but the experimental realisation has not reached those levels. That disconnect helped motivate this study."

For this study, the scientists looked at the LED compound InGaN, which is particularly promising for practical applications. InGaN alloys contain dislocations, structural imperfections that could inhibit electricity flow and light production, but somehow the alloy performs exceptionally well. To understand the light-emitting reactions, physicists needed to understand what was happening on the atomic scale. After researchers started to investigate, however, not everyone reached the same

conclusions.

#### Controversial Clusters

“Years ago, a team of researchers used electron microscopes to examine InGaN samples, and they identified a surprising phenomenon, the material appeared to be spontaneously decomposing and forming these isolated indium-rich clusters,” Stach says. “This behaviour could explain the efficient light emission, as the clusters might help electrons avoid the structural problems in the InGaN. But then things became really interesting when another group proposed that the electron microscope itself caused that clustering decomposition. We had a real divide in the semiconductor field.”

Rather than using light to examine materials, electron microscopes bombard samples with finely tuned beams of electrons and detect their interactions when they pass through a sample to reveal atomic structures. To achieve high enough resolution to examine the InGaN alloys, the electron microscopes used in the older experiments needed high-voltage beams. The controversy revolved around whether or not the experiment itself produced the clusters, rather than discovering the mechanism behind efficient light emission.

#### Improved Imaging

“The state-of-the-art instruments available at Brookhaven Lab’s CFN changed the way we could test these promising materials,” Gradečak says. “The CFN’s aberration-corrected scanning transmission electron microscope (STEM) opened a new and non-destructive window into the LED samples. For the first time, we could get Ångstrom-level details, that’s one tenth of one nanometre, without the risk of the device affecting the sample.”



*This scanning transmission electron microscope’s non-destructive imaging of specific InGaN samples clarified a decade of research, demonstrating conclusively that*

*indium-rich clustering does not drive the efficient light emission*

The researchers combined the leading STEM techniques with high-resolution electron energy loss spectroscopy (EELS), which measured the energy lost by electrons as they passed through the sample. Kamal Baloch of MIT actually applied these imaging techniques to the same samples that first launched the controversy over clustering, helping further settle the issue.

#### Beyond Lighting - InGaN in Action

The InGaN alloy is of extreme interest to scientists and inventors in the semiconductor and solid-state lighting fields. It has the ability to emit light over a wide range of wavelengths, manifesting as different colours, simply by changing the relative amounts of indium and gallium in the material.

Scientists at the Centre for Excitonics are exploring the fundamentals of light emission in this material, as well as pushing the frontiers of the exciting field of excitonics, where light and electrons interact both to store energy and mediate its transfer in a wide range of materials. In the case of InGaN alloys, this deeper understanding of excitonics can impact many real-world devices, including:

*Blue and green LEDs*

*Ultra-high-efficiency solar photovoltaics*

*Green and blue diode lasers (e.g. laser pointers, Blu-ray writers)*

*High-power, high-voltage electronics*

*Phased radar arrays*

*Ultraviolet LEDs for medical and industrial applications*

“We found that the indium-rich clusters do not actually exist in these samples, even though they remain efficient light emitters,” Baloch comments. “While clustering may still occur in other samples, which may be prepared in different ways, the important point is that we’ve established a foolproof method for investigating InGaN materials. We can use these non-destructive imaging techniques to explore the fundamental relationship between cluster formation and light emission to help unlock the secrets of this amazing alloy.”

Beyond the advanced imaging instruments, researchers used the expertise of Brookhaven Lab physicist Kim Kisslinger, who specialises in nanoscale sample preparation. The InGaN samples were reduced to a thickness of just 20 nm, an essential step in priming the materials for STEM and EELS experimentation. The samples were also painstakingly cleaned and polished to eliminate artifacts that might impact image resolution.



CFN's Kim Kisslinger, seen here with a focused-ion beam instrument, reduced the InGaN samples to a thickness of just 20 nm to prepare them for electron microscopy

The research was supported by the Centre for Excitonics, an Energy Frontier Research Centre funded by the U.S. Department of Energy's Office of Science. The work at Brookhaven Lab's Centre for Functional Nanomaterials was also supported by DOE's Office of Science, with additional work carried out at the MIT Centre for Materials Science Engineering.

"The Centre for Excitonics gave us the freedom and funding to look at this fundamental question, knowing that these explorations will ultimately push the limits of LED technology," Gradečak says. "This was a strong collaboration between MIT and Brookhaven's CFN, demonstrating the concentration of expertise and instrumentation that really pushes science and technology forward."

Further details of this work has been published in the paper, "Revisiting the "In-clustering" question in InGaN through the use of aberration-corrected electron microscopy below the knock-on threshold," by Kamal H. Baloch *et al* in *Applied Physics Letters*, 102, 191910 (2013). <http://dx.doi.org/10.1063/1.4807122>

## 3M and Nanosys stunningly enhance LCDs with quantum dots

Pumped with a blue source, such as the gallium nitride (GaN) LED, quantum dots can be made to emit at any wavelength beyond the pump source wavelength with over 90 percent quantum yield

3M has announced it is in the final stages of scale-up for its new 3M Quantum Dot Enhancement Film (QDEF).

The new film allows up to 50 percent more color than current levels in liquid crystal display (LCD) devices.

3M has teamed up with Nanosys, to produce the 3M

QDEF solution specifically to deliver more colour, and to make devices such as smart phones, tablets and televisions, lighter, brighter and more energy efficient.

Current LCDs typically are limited to displaying 35 percent or less of the visible color spectrum. This means the viewing experience on an LCD can be vastly different than what a person sees in the real world. Wide colour gamut displays will allow consumers to enjoy more visceral, more immersive and truer-to-life colour.



Comparison of LCDs without (left) and with (right) 3M's QDEF solution. (Photo: 3M)

"One of the many advantages of the new 3M QDEF solution is the film's ability to deliver richly-saturated colours, while minimising power consumption - a difference you can clearly see," says Ty Silberhorn, vice president and general manager, 3M Optical Systems Division. "We will have qualification material available to customers for design cycles starting late second quarter this year."

Over the years, 3M light management technologies have made LCDs thinner, lighter and more energy efficient. Colour performance of LCDs industry-wide has gone largely unchanged until now. 3M research data shows that devices with 3M QDEF-enabled wide colour gamut will be noticeably different from other standard LCD devices, prompting the human eye to dwell on the display longer than less-saturated displays.

QDEF utilises the light emitting properties of quantum dots to create an ideal backlight for LCDs, which is one of the most critical factors in the colour and efficiency performance of LCDs.

Unlike conventional phosphor technologies such as YAG that emit with a fixed spectrum, quantum dots can actually convert light to nearly any color in the visible spectrum.

Pumped with a blue source, such as a GaN LED, they can be made to emit at any wavelength beyond the pump source wavelength with very high efficiency (over 90 percent quantum yield) and with very narrow spectral distribution (only 30 - 40nm FWHM.)

The real magic of quantum dots is in the ability to tune the colour output of the dots, by carefully controlling the size of the crystals as they are synthesised so that their spectral peak output can be controlled within 2nm to nearly any visible wavelength.

A quantum dot, which is 10,000 times narrower than a human hair, can be tuned to emit light at very precise wavelengths. This means display makers can create a highly-optimised backlight that only produces the exact wavelengths of red, green and blue light needed by an LCD for optimal colour and energy performance.

Trillions of these quantum dots protected by barrier film fit inside an LCD backlight unit. The new film replaces one already found inside LCD backlights, which means the manufacturing process requires no new equipment or process changes for the LCD manufacturer.

“Improving colour performance for LCDs with simple, drop-in manufacturing solutions will create a stunning new visual experience for consumers,” comments Jason Hartlove, president and CEO, Nanosys, Inc.

“Working together with 3M and utilising their outstanding design and supply chain capabilities will allow our quantum dot technology to be widely deployed across all product segments, ensuring availability to all customers,” he adds.

## Soraa to ENERGY STAR: Light quality vital for LED adoption

The GaN on GaN LED specialist has asked the EPA not to repeat mistakes made on compact fluorescent lamps (CFLs)

To ensure the long-term success and widespread market adoption of LED lamps, Soraa last week urged the U.S. Environmental Protection Agency’s (EPA) ENERGY STAR program to address light quality.

In particular, the firm is concerned about colour rendering, in its new lamp specification.

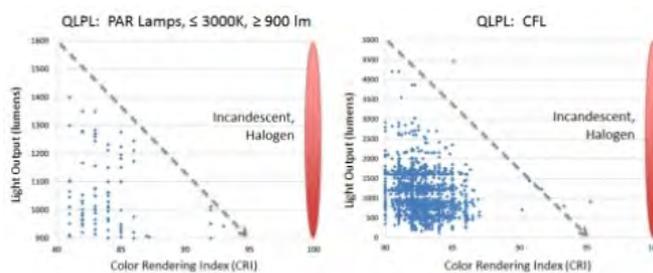
Support for higher colour rendering has been expressed by the California Lighting Technology Centre; Shuji Nakamura and Steven DenBaars; the International Association of Lighting Designers (IALD); Northeast Utilities Companies (NSTAR); and lighting designer Chip Israel; who all filed formal comments on EPA’s Draft 3 product specification for LED lamps.

“Poor light quality ruined many consumers’ confidence

in compact fluorescents,” says Mike Krames, CTO of Soraa. “The ENERGY STAR qualification must be associated with LED lamps that provide a better quality of light; otherwise, the program will start to lack credibility with end-users and the low adoption rate history of CFLs will be repeated by LED lamps.”

In comments filed with the EPA on May 17th, Soraa told EPA that while ENERGY STAR is not a mandatory standard; the agency must recognise that it has become a de facto standard for utility rebate dollars critical to lowering the initial cost of LED products.

In the absence of a second high colour rendering index (CRI) tier, it is likely that, similar to the historical situation with CFLs, the vast majority of lamp products will be engineered to perform close to the lower boundaries of quality requirements as set in the ENERGY STAR lamp specification for cost reasons, as shown in the figure below.



*Light output vs. colour rendering index (CRI) for both PAR Lamps (left) and CFL (right) from the ENERGY STAR Qualified Lighting Product List (QLPL), compared to conventional light sources (red ovals). The current standards drive the industry to predominantly produce modest colour quality lamps, which do not address the colour quality barrier to adoption*

Left unaddressed, this lack of high colour quality lighting products will lead to a stalling in consumer adoption of energy efficient lighting technology, similar to what has been observed to date with CFLs.

“To persuade consumers to purchase LEDs instead of incandescent lamps, LED lamps must be seen as high-quality products worth the initial higher price differential. Therefore, LED lamps must closely replicate the colour rendering of the incandescent and halogen lamps that they replace,” explains Ravi Parikh, Energy Services Specialist at Burlington Electric in Vermont.

“The Soraa VIVID is such a product, providing superior colour quality while improving energy efficiency. As a utility, we are always willing to consider higher incentives for projects utilising lamps such as Soraa’s. We want to ensure customer satisfaction by reduced energy bills and

maintained - if not, improved - quality of light. There is no need to sacrifice quality for efficiency. It is critical we understand the value in both.”

To provide a more balanced portfolio of ENERGY STAR lamp products on the market and mitigate colour quality as a barrier to wider adoption of energy efficient lighting products, Soraa proposed to the EPA a second high CRI tier with differential efficacy requirements taking into account the inherent lumen per watt trade-off as a function of CRI for phosphor converted white LEDs.

Soraa proposed to keep the existing minimum efficacy requirements, but raise the colour quality to a minimum CRI 90. For lamps with CRI between 80 and 90, Soraa proposes to increase the luminous efficacy requirements.

Soraa says its proposal will increase overall energy savings through enhanced adoption of higher light quality lamps as well as through higher energy efficiency in lamps of modest light quality.

## Oxford Instruments hosts Asian seminars in the Far East

The talks included GaN-on-silicon, HB-LED, SiC and III-V developments

Oxford Instruments Plasma Technology has just completed its series of Asian seminars in Beijing, China and Hsinchu, Taiwan, attracting a record total attendance of over 250 people.



The seminar in Beijing was co-hosted by the Institute of Semiconductors, Chinese Academy of Sciences (IOS-CAS) one of the most important bases for the research and development of semiconductor science and

technology in China. Its counterpart in Taiwan was co-hosted by ITRI, one of Taiwan's leading non-profit R&D organisations with over 5,800 employees.

Both seminars featured a range of International and national speakers including Yang Fuhua from IOS-CAS in China and Chyi, Jen-Inn, Executive Vice President, National Applied Research Laboratories in Taiwan.

The talks covered a number of key areas including GaN on silicon power device development, SiC wide bandgap semiconductors for power electronics applications and MEMS devices, processes and trends.

Shao-Chung Hsu, Executive Director of ITRI South Campus gave a welcome address at ITRI, and commented, “At ITRI we actively encourage our collaborations with leading industrial companies, and are delighted to join Oxford Instruments this week and hold such an informative conference. Oxford Instruments has an excellent cleanroom facility established here at ITRI so it is fitting for us to host an event covering the wide range of applications that the Oxford Instruments systems can offer including MEMS, HBLED, ALD and III-V. “

He continued, “Talks about the recent progress in their research and development and future trends in the fabrication and applications in micro and nano structures, gave the audience from academia and industry much opportunity for discussion. We hope to hold more events like this with Oxford Instruments at ITRI.”

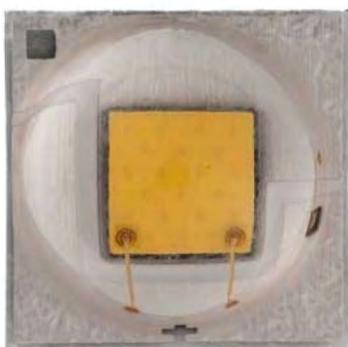
Frazer Anderson, Business Group Director at Oxford Instruments Plasma Technology introduced the company at both seminars and summarises the company's pleasure at the events' success last week,

“These technical seminars in China and Taiwan gave us and our audiences a great opportunity to spend time being updated by a wide range of eminent speakers, in a relaxed atmosphere where we can share experiences and learn more from our peers. As a company our ethos is to use innovation to turn smart science into world class products, and by working closely with partners at the top of their field and learning about their evolving requirements, their research and technological developments, we hope to achieve this,” he said.

## Cree releases brightest highest-efficacy colour LEDs

The silicon carbide (SiC) based LEDs are suited to architectural, vehicle and display lighting and come in a range of colours

Cree has announced the commercial availability of its XLamp XP-E2 colour LEDs



*XLamp XP-E2 LED*

The new XP-E2 colour LEDs deliver up to 88 percent higher maximum light output compared to alternative high-power colour LEDs.

This enables lighting manufacturers to more cost-effectively address a wide spectrum of applications, such as architectural, vehicle and display lighting.

Built on Cree's SC<sup>3</sup> technology next-generation LED platform, the new XP-E2 colour LEDs deliver higher lumens-per-watt and lumens-per-dollar compared to the original XP-E colour LEDs to lower system costs for existing XP-E colour designs.

The latest XP-E2 colour LEDs leverage the same XP footprint (3.45 mm x 3.45 mm) and are optically compatible with the original XP-E LED. This provides drop-in-ready performance enhancements to shorten design cycle and improve customer time to market.

"We are excited that Cree is offering higher-performance color LEDs in the XP footprint," says Greg Campbell, executive vice president and chief technology officer, Lumenpulse. "The brighter XP-E2 colour LEDs enable Lumenpulse to continue to provide innovative, high-performance LED lighting systems."

XLamp XP-E2 colour LEDs deliver up to 1409 mW for royal blue, 109 lumens for blue, 253 lumens for green, 203 lumens for amber, 193 lumens for red-orange and 155 lumens for red, all at maximum drive currents in the 3.45 mm x 3.45 mm footprint.

Samples are available now, and production quantities are available with standard lead times. Cree XLamp XP-E2 colour LEDs are available in red, red-orange, amber, green, blue and royal blue.

## Former Osram GM joins GaN-on-silicon LED innovator Aledia

New board member Bernhard Stapp brings more than a dozen years of executive experience in LED lighting technologies to Aledia

Aledia has announced that solid-state lighting (SSL) industry veteran Bernhard Stapp is now on its board of directors.



*Bernhard Stapp*

Aledia is a developer of WireLED, a new microwire-based 3D LED technology that dramatically cuts manufacturing costs compared to conventional planar (2D) LEDs.

Most recently he has been in senior management positions at Osram.

As general manager and senior vice president of Osram AG's SSL unit, Stapp was responsible for the company's professional LED and OLED business.

Earlier, as SSL vice president and general manager at Osram Opto Semiconductors, he launched and managed the general-lighting LED business and oversaw launch of the world's first OLED lighting products.

Prior to that, Stapp was vice president and CTO of the semiconductor company, where he oversaw global LED, laser and OLED R&D. Earlier in his career, he held a variety of management positions in Siemens AG's Corporate Technology division.

"Aledia's mission is to bring fundamental change to the world's lighting markets by making LED technology substantially more affordable and more versatile, with better performance and fewer limitations," says Giorgio

Anania, Aledia's co-founder, president and CEO.

"Bernhard has been a key player at the heart of the global LED industry since its inception, and also has an outstanding technical background. His unique perspective on this industry's future will be invaluable as Aledia moves into the next stage of its evolution," he finishes.

WireLED, Aledia's 3D microwire GaN-on-silicon technology was developed at the CEA-Leti's nanotech research institute in Grenoble.

It addresses the basic technical and economic challenges facing LED lighting by allowing production of LEDs on inexpensive industry-standard 200mm silicon wafers using standard semiconductor processes and tools.

"Aledia's technology is, quite simply, a breakthrough for the entire LED sector," says Stapp. "It can meet the industry's critical requirement for cost-reduction, while using far simpler production processes and much less material than conventional approaches. I am very excited about the opportunity to join this team."

## A new era of atomic-scale semiconductor devices

Scientists have demonstrated the semiconductor molybdenum sulphide can be grown in layers only one atom thick without compromising its properties

Researchers at North Carolina State University have developed a new technique for creating high-quality semiconductor thin films on the atomic scale where the films are only one atom thick.

The technique can be used to create these thin films on a large scale, sufficient to coat wafers that are two inches wide, or larger.

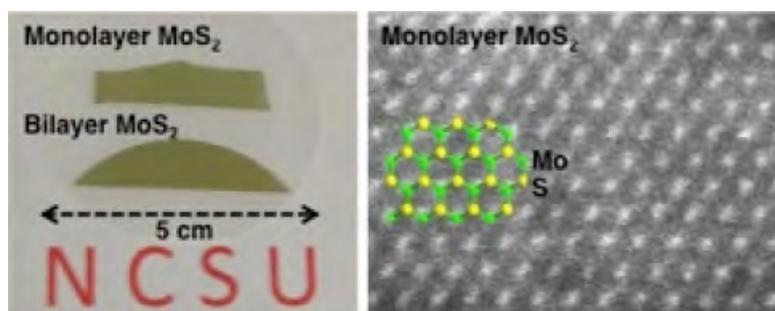
"This could be used to scale current semiconductor technologies down to the atomic scale, lasers, LEDs, computer chips, anything," says Linyou Cao, an assistant professor of materials science and engineering at NC State and senior author of a paper on the work. "People have been talking about this concept for a long time, but it wasn't possible. With this discovery, I think it's possible."

The researchers worked with molybdenum sulphide (MoS<sub>2</sub>), an inexpensive semiconductor material with electronic and optical properties similar to materials already used in the semiconductor industry.

However, MoS<sub>2</sub> is different from other semiconductor materials because it can be grown in layers only one atom thick without compromising its properties.

In the new technique, researchers place sulphur and molybdenum chloride powders in a furnace and gradually raise the temperature to 8500C, which vaporises the powder. The two substances react at high temperatures to form MoS<sub>2</sub>. While still under high temperatures, the vapour is then deposited in a thin layer onto the substrate.

"The key to our success is the development of a new growth mechanism, a self-limiting growth," Cao says.



MoS<sub>2</sub> structure

The researchers can precisely control the thickness of the MoS<sub>2</sub> layer by controlling the partial pressure and vapour pressure in the furnace. Partial pressure is the tendency of atoms or molecules suspended in the air to condense into a solid and settle onto the substrate. Vapour pressure is the tendency of solid atoms or molecules on the substrate to vaporise and rise into the air.

To create a single layer of MoS<sub>2</sub> on the substrate, the partial pressure must be higher than the vapour pressure. The higher the partial pressure, the more layers of MoS<sub>2</sub> will settle to the bottom.

If the partial pressure is higher than the vapour pressure of a single layer of atoms on the substrate, but not higher than the vapour pressure of two layers, the balance between the partial pressure and the vapour pressure can ensure that thin-film growth automatically stops once the monolayer is formed. Cao calls this "self-limiting" growth.

Partial pressure is controlled by adjusting the amount of molybdenum chloride in the furnace - the more molybdenum is in the furnace, the higher the partial pressure.

"Using this technique, we can create wafer-scale MoS<sub>2</sub> monolayer thin films, one atom thick, every time," Cao explains. "We can also produce layers that are two, three or four atoms thick."

Cao's team is now trying to find ways to create similar thin films in which each atomic layer is made of a different material. Cao is also working to create field-effect transistors and LEDs using the technique. Cao has filed a patent on the new technique.

## Verticle reveals copper-based hexagonal UV-LED chip

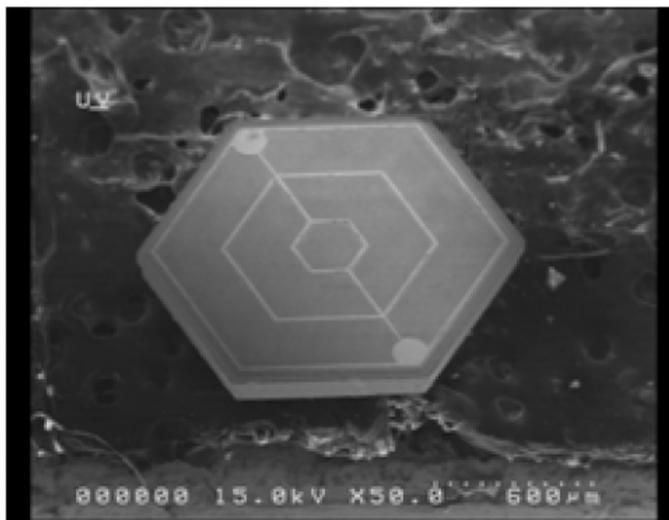
The firm has extended its product line in gallium nitride (GaN) based UV-LEDs

Verticle's new hexagonal shaped UV chip incorporates a copper substrate to enable a higher current.

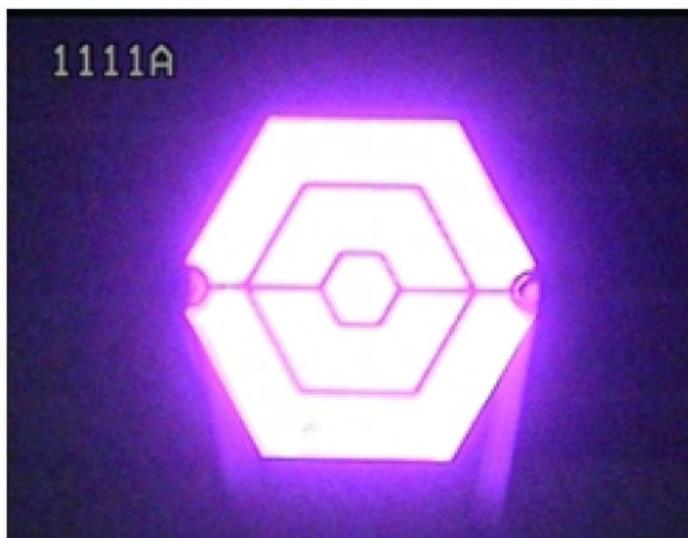
Despite many advantages, the main drawback of UV-LEDs is lower optical power due to lower internal quantum efficiency (IQE).

Since improving the IQE of UV epitaxial wafers is a long-term prospect, an alternative way to boost UV-LED power is to drive more current in.

However, heat generation is a big issue with high current drive. What's more, aluminium containing UV epitaxial wafers are more resistive than blue, meaning thermal management of UV-LEDs is more critical. This makes one of the main challenges lowering the junction temperature in UV-LEDs.



An SEM image of the hexagonal UV-LED chip



UV light emitting from the chip

In order to operate at higher current injection conditions and dissipating heat more efficiently, Verticle's UV-LED chip uses a copper substrate. According to the firm, as shown in the figure below, its copper based vertical chip's thermal resistance ( $R_{th}$ ) is 2K/W lower than for a GaN-on-silicon vertical chip.

*Thermal resistance and junction temperature of GaN-on-silicon and GaN-on-copper vertical LEDs as a function of injection current (at 250C).*

As a result, Verticle maintains that the junction temperature ( $T_j$ ) of GaN-on-copper is lower than for GaN-on-silicon. Also, the junction temperature difference is 20C at 350 mA current injection between two chips. And the difference becomes larger (60C) at a 1A current injection.

What's more, Verticle claims its UV-LED chip can be driven at a higher current than other vertical chips constructed with different substrate materials.

Verticle also says its GaN-on-copper UV-LED chips do not saturate over 1A, while GaN-on-tungsten and GaN-on-sapphire UV-LED chips start to saturate after 500mA. This means that the GaN-on-copper chips have a higher heat dissipation capability compared to GaN on other substrates.

This could mean that copper based UV-LED chips have distinct advantages for applications where high current injection and good thermal properties are required.

A graph illustrating the firm's hexagonal UV-LED chip performance is shown below. Data was taken for a 45 mm size chip with radiant fluxes measured at 416mW at 350mA current injection, 787mW at 700mA, and 1.025mW at 1A for the 392 nm wavelength, respectively.

*Radiant flux vs. current: 1) GaN-on-copper vertical UV-LED, 2) GaN-on-tungsten vertical UV-LED, and 3) GaN-on-sapphire lateral UV-LED. Bare UV-LED chips were attached on 5050 metal lead frame without molding. To eliminate wavelength dependency on radiant flux, 390 ~ 395nm UV-LED chips were used.*

Verticle believes an additional benefit of its hexagonal chip is a higher extraction efficiency once it is packaged with a circular lens. The reason for this is that the hexagonal chip has a near circular beam profile when it is packaged with a circular lens. So there is less of a dark spot than there is in rectangular chips.

This makes Honeycomb LEDs useful for optic design with a circular lens system where a near circular beam profile is required for various package and module applications.

Verticle's hexagonal UV-LED chip samples are available upon request from the company's website.

Verticle Inc. is located in the Silicon Valley, California with production facilities in Korea. The firm specialises in manufacturing vertical type LED chips using a patented copper substrate and Chemical Chip Separation Technology.

## SETi & USDA's UVB LED technology extends food life

Scientists have demonstrated an increased shelf life and improved nutritional quality of fresh produce with a new storage technology using ultraviolet aluminium gallium nitride (AlGaIn) LEDs

In an exciting development, a combined team of scientists from Sensor Electronic Technology, Inc. (SETi) and the Food Components and Health Laboratory of the US Department of Agriculture (USDA) have found a way to extend the shelf life of fresh fruit and vegetables stored in home refrigerators.

This 3-year program, which investigated the effects of light from certain types of UV LEDs, has led to more than double the shelf life of fresh produce, while retaining the nutritional quality and appearance.

The technology is currently being commercialised for the home appliance market.

Remis Gaska, President and CEO of SETi says, "Findings of this exciting program are expected to have a major impact on the appliance business to extend the shelf life and preserve nutritional value of the fresh

produce. We look forward to the prospect of UV LEDs in residential refrigerators impacting on everyday life and reducing waste through spoilage."

Steven Britz, Research Plant Physiologist, Agricultural Research Service of USDA adds, "We are exploring the possibility that the UV effect involves the induction of defence mechanisms in the fruit itself in addition to inhibition of mold growth, since evidence indicates parts of the UV spectrum retards decay."

## QD Vision breaks QLED efficiency barriers

The firm's CdSe-CdS emitters are suited to applications such as electronic displays and solid-state lighting

QD Vision, a manufacturer of 'Color IQ' optical components for LCD applications, says it has made a breakthrough in next generation quantum dot light emitting devices (QLEDs), which are currently in the advanced development stage.

QLEDs are a quantum dot-based light emitting technology, which in the future will be used in applications such as electronic displays and solid-state lighting.



*Semiconductor nanocrystal technology that emits light very precisely. So when it's used in LCD screens like TVs, you see a more dynamic range of colours and the true, natural palette encoded in the picture. QD Vision says Color IQ adds up to 50 percent more colour into the TV picture*

The firm's QLEDs are composed of an inverted organic-inorganic hybrid device structure and colloidal CdSe-CdS (core-shell) quantum-dot emitters. The strong electronic coupling of quantum dots to an adjacent layer of ZnO nanocrystals (which form the electron transport layer) facilitates charge transfer, which is responsible for both injecting electrons and maintaining an optimal charge

balance for the quantum dot emitters.

QD Vision's latest QLED performance results have been published in the 21st April 2013 issue of *Nature Photonics*. In the article, QD Vision reports achieving 18 percent External Quantum Efficiency which puts QLEDs near the fundamental efficiency limit of the technology.

The firm claims these results are double the efficiency of previously reported QLED devices.

QD Vision says its current and luminous power efficiency are better than the best evaporated OLED result of the same colour coordinate, and significantly better than what solution-processed OLEDs have thus far achieved.

"This paper clearly demonstrates the fundamental efficiency advantage that QLEDs have over any other emissive display technology. Achieving this milestone is a great breakthrough and the result of years of hard work and dedication to achieving what others may have thought impossible," says QD Vision co-founder Seth Coe-Sullivan.

While at an earlier stage of development and commercialisation than QD Vision's Color IQ products, QLED performance is already suitable for use in certain products that require precision colour solutions in an ultra-slim form factor. These include monochrome visible and infrared displays, and lighting devices for machine and night vision applications.

Further details of this work have been published in the paper, "High-efficiency quantum-dot light-emitting devices with enhanced charge injection," by Benjamin S. Mashford *et al* in *Nature Photonics* (2013), 407-412. DOI:10.1038/nphoton.2013.70

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## Rubicon to showcase optical-grade sapphire products

The provider of sapphire substrates and products to the LED, semiconductor, and optical markets will exhibit its products at the Laser World of Photonics in Munich, Germany 21st Laser World of Photonics Show

Rubicon Technology will show off its line of optical products for use in defence and aerospace, instrumentation and analytical processing, sensors and detectors, semiconductor process equipment, and medical and laser applications at the 21st Laser World of Photonics International Trade Fair.

Sapphire can be used as a component in electro-optic

products used to detect or measure the presence or features of light in a number of optical applications. Rubicon provides a wide range of sapphire products that can be integrated into existing opto-electronic applications including sapphire cores, ingots, windows and blanks.

"As opto-electronic technology and applications evolve, the demand for optical-grade, high-quality sapphire has grown," says Raja M. Parvez, President and CEO, Rubicon Technology. "Based on sapphire's unique strength and hardness, chemical inertness, and transparency in the visible and IR spectrum, there's growing interest in using sapphire in products that are used to detect or measure light. Sapphire becomes very desirable in extreme environments such as military and industrial applications where material durability is just as important as optical clarity."

Until now, existing methods used to produce optical-grade sapphire windows haven't met demands for thickness and size in certain military and other applications. The company recently developed a new horizontal growth process to produce monolithic sapphire sheets large enough for use in next generation optical windows for military and industrial applications.

Rubicon will have a number of optical sapphire products of different sizes and orientations on display in Hall B2, Stand #163 at Laser World of Photonics, including sapphire cores, ingots, windows, domes and blanks. Rubicon will also be displaying large diameter wafers ranging in size from 4, 6 and 8 inches.

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## Philips halves LED count in retrofit lamps

Lumileds' latest innovation in mid-power III-nitride LEDs achieves up to 140 lm/W efficacy

Philips Lumileds has launched the LUXEON 3535 2D, which combines two LED chips in one package.

The device enables reduction in LED count and cost of designing retrofit lamps, consumer downlights and diffuse industrial lamps.



LUXEON 3535 2D LED module

Efficacy of 140 lm/W is achieved for cool white light at 4000K and minimum 80 CRI.

“This is an exciting breakthrough, because lighting designers can take advantage of a high lumen package with high efficacy while using significantly fewer chips per fixture,” says Rahul Bammi, VP of Product Management at Philips Lumileds. “For example, a 50W PAR20 lamp can be achieved using only 4 LEDs. Alternatively, a 40W A19 lamp that previously required 14 LEDs can now be created using only 6.”

The new mid-power LEDs are offered across a full spectrum of correlated colour temperatures (2700K-6500K) with a minimum CRI of 80. Versions with CRI 70 for outdoor applications and CRI 90 for high end indoor applications are planned for future release.

The LUXEON 3535 2D line operates at 0.5 - 1W, delivering up to 130 lumen in the compact 3535 form factor. Rated at 100mA, the LUXEON 3535 2D can be driven up to a maximum of 200mA.

The LUXEON 3535 2D supports ENERGY STAR certification requirements up to 25,000 hours at 85°C and 150mA.

#### Low-power LEDs

Apart from expanding its mid-power range, Philips Lumileds has also introduced its first low-power LED solution, the LUXEON 4014.



#### LUXEON 4014

This rectangular LED is a high efficacy LED that was designed to specifically address linear and omnidirectional lighting applications such as under-cabinet and cove, refrigerator lighting and the retrofit LED market. Delivered in a 4.0 x 1.4 x 0.7 mm footprint, the LUXEON 4014 line can achieve an efficacy of 160 lm/W at 4000K and CRI of 80.

## PhotonStar leisure retrofit project wins Greenbuild Award

The firm's nitride LEDs have been used in the Arcola theatre to improve overall efficiency and quality

PhotonStar's most sustainable project, the Arcola Theatre in Hackney, UK, has been awarded the Leisure Retrofit award in the 2013 Greenbuild Awards.



The Arcola theatre is the forerunner in measurable sustainable practices within the arts community and is on the way to becoming the world's first carbon neutral theatre.

The theatre recently underwent complete sustainable refurbishment, a key element of which was the installation of PhotonStar LEDs throughout to improve the overall efficiency and quality.



Arcola has a strong focus on environmental performance,

regularly carrying out sustainability projects not only to increase efficiency but also to educate and inspire the community.

Aiming to celebrate true sustainability, the Greenbuild Awards recognise buildings in use that focus on actual measured performance rather than design intent or performance specifications.

The award for the best leisure retrofit project was given by a panel of distinguished industry leaders who were looking for the project that had reduced its environmental impact more effectively than its rivals.

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## SEMI highlights the need for InP and GaAs

The organisation says that the restriction of the use of indium phosphide and gallium arsenide would have a negative impact on the semiconductor industry and Europe as a whole. SEMI has also described a new directive which will bring down patent application costs

According to Heinz Kundert, president of SEMI Europe, being able to quickly identify and seize the potential offered by new technologies and new markets is critical in the semiconductor industry. Keeping track of public policy developments is equally important.

Decisions made in a national Ministry or an EU institution can have a direct impact on the industry.

A new EU patent procedure, to be introduced by mid-2014, will significantly reduce the cost and time for a company to obtain a patent valid across 25 European states. The outcomes of the current review of substances under European EHS rules, for example, may have an impact on industry's research priorities or its access to the EU market.

This article covers these topics: 7th SEMI Brussels Forum; EU Patent Protection; GaAs and InP under Review (REACH); RoHS Exemptions Expiring; Banned Substances under RoHS; EU Conflict Minerals Debate.

The SEMI Brussels Forum is one of Europe's leading policy events for semiconductor equipment and materials, providing a unique platform for top-level executives and EU representatives to exchange views and debate how to reinforce Europe's competitiveness in the global market.

The 7th SEMI Brussels Forum will discuss how Europe's industry and policy-makers can increase their impact - both individually and jointly to reinforce Europe's position.

How can industry build on its leading positions and expertise and optimise synergies? How can Europe balance its values and rules on free competition on one hand, with the need to provide for a global level playing field on the other?

SEMI says this is the only event that brings together top-level management and EU representatives to exchange views on how to reinforce Europe's competitiveness. More information can be accessed via the link [www.semi.org/eu/brusselsforum](http://www.semi.org/eu/brusselsforum).

### New EU Patent Procedure Offers Automatic Protection in 25 Countries and Brings Down Costs

The new 'EU Unitary Patent', to be made available by April 2014, is expected to reduce the administrative and financial burden of patent protection across the EU. Companies will be able to fill out a single application to the European Patent Office. Once granted, the patent is automatically valid across 25 countries (all EU member states except for Italy and Spain). A single court will be created (Unified Patent Court) with jurisdiction over infringement proceedings in any of these countries.

Companies will no longer need to apply before each national body for their patent to have effect in that territory, nor satisfy local language and administrative requirements or pay local fees. Nor will they need to defend their patents in different jurisdictions and receive different, sometimes conflicting, rulings.

This new system is also expected to significantly bring down the costs of obtaining a patent. The European Commission estimates that today, a 'classic' European patent (that needs to be validated individually in 27 Member States) costs EUR (€)36 000. The new unitary patent system will bring the costs down dramatically to around €5 000, or one-seventh of today's cost.

### GaAs and InP under Review for a Possible Restriction under REACH

A recent EU study collected information on the production, import and use of 44 substances, including GaAs and InP, in articles, as a first step towards assessing the need for a possible restriction on their use in the EU. Such a restriction (under Art. 68 REACH) could have an impact not only on European manufacturing but also on imports.

In a joint response with other industry associations, SEMI listed the applications where these compounds are used and the lack of risk to consumers when they are completely encapsulated. SEMI further highlighted the strategic importance of these compounds for micro- and nano-electronics.

Their restriction would have a negative impact not only on industry, but on Europe as a whole. It would curb the global competitiveness of the European semiconductor manufacturing supply chain and it would deprive the EU of the industry base and products Europe needs to achieve its strategic goals for the global digital market.

GaAs and InP are the first III-V compounds being examined under the REACH microscope and SEMI is actively monitoring developments. In its upcoming advocacy activities, SEMI will collect information on risk management measures the industry has in place to avoid exposure to workers and the environment – if your company can contribute, please contact [gourania@semi.org](mailto:gourania@semi.org).

**EU RoHS Update: Exemptions are Expiring; More Substances to be Banned under RoHS**

The EU RoHS directive currently bans six substances from being used in electric and electronic equipment. Certain products of SEMI members are not covered by the Directive, such as PV panels going into fixed installations, large-scale stationary industrial tools (LSIT) and large-scale fixed installations. SEMI members also benefit from exemptions to the Directive, which allow for specific uses of the banned substances in specified quantities and for a limited period of time.

- A number of exemptions for specific applications will expire in July 2016. These exemptions can be renewed but applications for renewal need to be submitted by end of 2014. Now is therefore the time for industry to review the list of exempted applications, determine which ones are still needed and start pooling resources to draft the renewal application.

- Additional substances will be banned under RoHS by 22nd July 2014. An EU-funded study is currently underway to develop a methodology for evaluating the risk posed by hazardous substances and to determine whether they should be banned. By the end of 2013, this study will also propose additional substances that should be restricted. The European Commission will then decide on banning these substances under RoHS, the transition periods allowed for the manufacturing supply chain to adjust and start considering necessary exemptions.

The SEMI RoHS working is actively contributing to the drafting of the review methodology. For further information and to contribute to this work, please contact Sanjay Baliga at [sbaliga@semi.org](mailto:sbaliga@semi.org)

**EU Conflict Minerals Debate is Launched – Potential Impact on Industry's Sourcing of Raw Materials from Conflict Zones**

The EU is now also considering whether it needs to adopt EU measures to support responsible sourcing from conflict-affected or high-risk areas. It is not yet clear what minerals or what countries a possible EU initiative would focus on, nor whether its nature would be voluntary or binding. The question is also raised whether EU measures should address specific end-products or downstream industry sectors.

A number of initiatives on conflict minerals already exist, including the OECD guidelines on due diligence and the EU is looking to build on these and reinforce transparency through the supply chain. In the U.S., the Dodd-Frank act requires companies to report annually whether they or their suppliers are using conflict minerals (tin, tungsten, tantalum and gold originating from the Democratic Republic of Congo or an adjoining country) and the EU is seeking feedback on how these provisions are working in practice.

The adoption of an EU legislative measure would have significant implications for SEMI members, creating a traceability requirement across the entire manufacturing supply chain. The consultation is available online here – deadline for submissions is 26 June 2013. For further information, please contact [gourania@semi.org](mailto:gourania@semi.org)

Further information on SEMI advocacy activities in Europe and on the SEMI Europe Advocacy Partners program can be obtained from Rania Georgoutsakou ([gourania@semi.org](mailto:gourania@semi.org); +32 2 609 5334) or Heinz Kundert ([hkundert@semi.org](mailto:hkundert@semi.org)).

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## ARC Energy selects Elmet to supply components for sapphire

Elmet Technologies is now manufacturing refractory metal crucibles and furnace components for ARC Energy's CHES sapphire growth furnaces

ARC Energy has selected Elmet Technologies as a preferred supplier of crucibles and furnace components for ARC Energy Controlled Heat Extraction System (CHES) furnaces.

After an intensive qualification and review process, ARC Energy is confident that Elmet has the capacity and expertise to produce high-quality replacement crucibles and components in support of CHES furnace operators world-wide.

ARC Energy CHES furnaces grow high quality synthetic sapphire up to 260mm diameter.

Synthetic sapphire is a critical building block for LED light manufacturing, high performance glass for mobile devices, silicon-on-sapphire (SOS) semiconductor substrates, military grade windows, and other applications.

“At ARC Energy, we strive to provide our customers with innovative, efficient furnaces for large diameter 6” sapphire,” says Rick Schwerdtfeger, co-founder and chief technology officer for ARC Energy. “By partnering with Elmet, we feel secure knowing our customers have access to quality crucibles and furnace components manufactured to the highest standards in the industry.”

“The market for synthetic sapphire is increasing rapidly, and Elmet is continually investing to support the growing demand for sapphire crucibles and precision-formed furnace components,” explains Sandeep Jain, senior VP of sales and marketing for Elmet. “We have unique capabilities on which the sapphire industry can capitalise to keep up with the demand for their products.”

Headquartered in Nashua, N.H., the Advanced RenewableEnergy Company, LLC (ARC Energy), was founded in 2007 to commercialise cutting-edge technologies for LED and other clean energy markets.

Established in 1929, Elmet is a global supplier of high performance materials with a specialisation in molybdenum and tungsten.

With 400,000 square-feet at three manufacturing sites in Maine, Georgia, and China, Elmet produces mill, machined, and fabricated products for sapphire growth, FPD manufacturing, medical imaging, high temperature furnace, and many other industries.

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## Osram`s IR LED sensor simplifies smartphone design

The digital SFH 7776 sensor contains a GaAs (gallium arsenide) based infrared LED and two detectors. It registers the ambient brightness in order to control the display backlighting and also deactivates the touch function on the display as soon as you hold a phone up to your ear

Osram Opto Semiconductors has expanded its portfolio of proximity and ambient light sensors with an extremely powerful version with low power consumption.

The compact SFH 7776 sensor registers the ambient brightness even behind dark smartphone covers and prevents unintentional responses from the touch screen

during telephone calls. This makes it even easier for smartphone designers to control the backlighting and touch functions of displays.



*The SFH 7776 combined proximity and ambient light sensor*

The digital SFH 7776 sensor contains a GaAs based infrared LED (IRED) and two detectors and performs two different functions. It registers the ambient brightness in order to control the display backlighting so that it can always be easily read but consumes as little power as possible.

It also deactivates the touch function on the display as soon as you hold the phone up to your ear during a phone call. To do this the sensor emits infrared light that is reflected by approaching objects, such as your ear.

With a working range of up to 16 centimetres and its small size, the SFH 7776 has been designed specifically for use in smartphones and other mobile devices. Thanks to the excellent sensitivity of the detector the component does not need lenses to bundle the emitted infrared light. As a result, it has an impressively small height of only 1.35 millimetres. With its black casing the sensor is virtually invisible even behind transparent phone covers. Its low power consumption is also an important factor in terms of its suitability for mobile devices – in standby mode it only needs 0.8 mA.

### Behind dark covers

The SFH 7776 is extremely sensitive to ambient light. With a detection limit of 0.002 lux (lx) it can even be used behind dark casing panels. Designers can place the sensor anywhere and do not need a special translucent window.

“The SFH 777x series gives our customers a complete family of multifunctional sensors for an extremely wide range of phone covers,” says Dirk Sossenheimer, responsible for intelligent sensor applications at Osram Opto Semiconductors.

What’s more, the SFH 7776 is designed so that the ambient light sensor doesn’t react to short-term fluctuations in the brightness of various lamp types,

caused for example by changes in the power supply frequency. This ensures that the display backlighting remains constant.

No crosstalk with the proximity sensor

Crosstalk – an effect in which the emitted infrared light is reflected by the smartphone casing directly onto the receiver – is eliminated by the SFH 7776 in the component itself. Designers no longer need to provide separate optical barriers between the IRED and the detector, which makes it much easier to create robust, uncomplicated solutions for different setups.

Since the SFH 7776 covers the complete working range from 0 to 16 mm it would even react to direct contact (“zero distance detection”). The touch function of the display is therefore reliably deactivated even in marginal situations.

“Overall, the SFH 7776 overcomes various challenges in terms of proximity and ambient light detection in the component itself, so designers can integrate the product in smartphones relatively easily”, adds Dirk Sossenheimer.

Technical data SFH 7776: Dimensions 4 x 2.1 x 1.35 mm

Current draw in standby mode 0.8  $\mu$ A

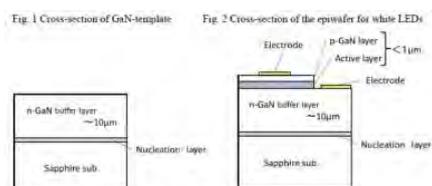
Sensitivity of the ambient light signal 0.002 to 68,000 lx

Working distance of proximity sensor max. 16 cm

## Hitachi Cable launching GaN template for LEDs

At CS Mantech 2013, Hitachi Cable will present its gallium nitride based templates grown on sapphire

Hitachi Cable has developed a new mass-production technology for GaN-templates as shown in Figures 1 and 2 below.



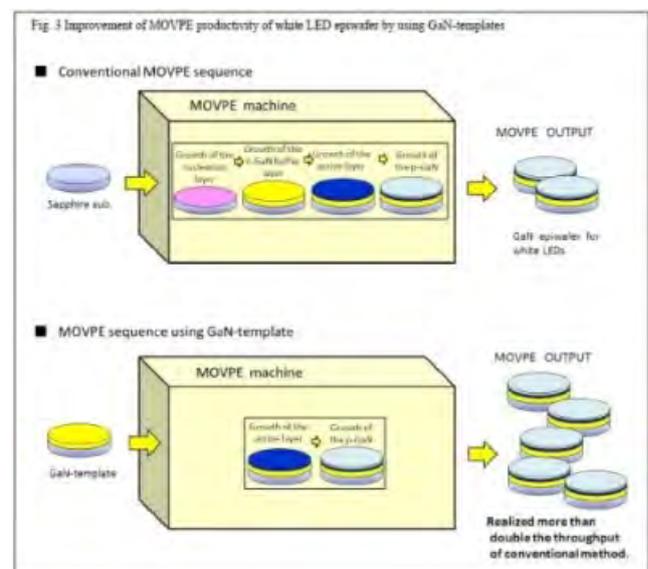
The process allows high-quality GaN single-crystal thin film to be grown on a sapphire substrate and the company plans to start selling these templates.

Using this product as a base substrate for an epitaxial wafer for white LEDs the company claims it makes it possible to drastically improve productivity of white LED epiwafers and the LED properties.

Therefore, this product is expected to become an effective solution to improve the position of white LED manufacturers in the industry, where there is severe competition.

The demand for white LEDs is rapidly expanding and they have come to be used in backlight unit in liquid crystal displays (LCDs) and ordinary lighting devices in recent years thanks to their energy efficiency and long service life.

The structure of an white LED epiwafer consists of a thin active layer and a *p*-type GaN layer with a total thickness of about 1 $\mu$ m over an *n*-type GaN layer with a thickness of about 10 $\mu$ m, grown on a sapphire substrate as shown in Figure 3 below.



All these crystal layers are produced by the MOVPE processes. The MOVPE method is suitable for growing active layers which require atomic-level control of the film thickness.

Meanwhile, a disadvantage of this method is that it takes a long time to grow a high-quality and thick *n*-type GaN layer. White LED epiwafers can be grown about once or twice a day at the most, and thus there is a need for a high-efficiency production method.

To solve this problem, Hitachi Cable developed a GaN-template used as a base substrate for growth in the MOVPE method.

The GaN template consists of an *n*-type GaN layer grown on a sapphire substrate. Using a GaN-template means

LED manufacturers do not need to grow an *n*-type GaN buffer layer and this reduces the time required for growth by about half compared with conventional methods.

Hitachi Cable says its GaN-templates are also suitable for high-output LEDs which require large currents because they allow both low resistance and high crystal formation.

The firm has developed single-crystal free-standing GaN substrates used for blue-violet lasers and developed unique HVPE-growth technology and machines for mass-production of GaN substrates.

Based on this technology, Hitachi Cable developed new high-efficiency production technology and machines for mass-production of high-quality GaN-templates.

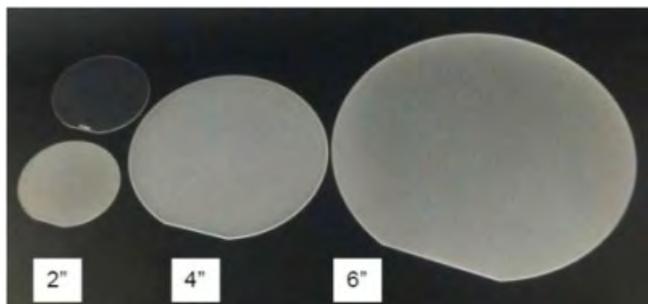
The main characteristics of the GaN-template are as follows.

High crystal quality and high surface quality based on growth technology established in the development of free-standing GaN substrates

Low resistance *n*-type GaN buffer which is suitable for high-output wafers and bonding-type LEDs

Templates on flat-surface sapphire substrates and various types of PSS are available

Wafers with 2 to 6 inches in diameters are available, with an 8-inch version now planned for development. Photos of the substrates currently available are shown below.



With this new GaN-template added to the lineup of GaN substrates and GaN epiwafers that it has been selling, Hitachi Cable aims to strengthen and expand its GaN product group and offer compound semiconductor products which respond to the various needs of clients.

## ZnO technology could revolutionise LEDs and UV lasers

To make lasers and LEDs both *n*-type and *p*-type materials are used. Researchers have claimed that shedding excess energy at the *p*-*n* junction is what produces light in both these types of devices

Scientists from North Carolina State University say they have solved a long-standing materials science problem.

They claim that it is possible to create new semiconductor devices using zinc oxide (ZnO).

The development could pave the way for efficient ultraviolet (UV) lasers and LED devices for use in sensors and drinking water treatment, as well as new ferromagnetic devices.

“The challenge of using ZnO to make these devices has stumped researchers for a long time, and we’ve developed a solution that uses some very common elements: nitrogen, hydrogen and oxygen,” says Lew Reynolds, co-author of a paper describing the research and a teaching associate professor of materials science and engineering at NC State.

“We’ve shown that it can be done, and how it can be done and that opens the door to a suite of new UV laser and LED technologies,” continues Judith Reynolds, a research scientist at NC State and lead author of the paper.

To make laser and LED technologies, you need both “*n*-type” materials and “*p*-type” materials. *N*-type materials contain an abundance of free electrons. *P*-type materials have “holes” that attract those free electrons.

But the holes in the *p*-type materials have a lower energy state, which means that electrons release their excess energy in the form of light as they travel from the *n*-type material to the *p*-type material.

The shedding of excess energy at the *p*-*n* junction is what produces light in lasers and LED devices.

Scientists have been interested in using ZnO to create these devices because ZnO produces UV light, and because it can be used to make devices with relatively fewer unwanted defects than other UV emitters. This means the resulting lasers or LEDs would be more energy efficient.

However, in the past, researchers have found it hard to consistently produce stable *p*-type materials out of ZnO.

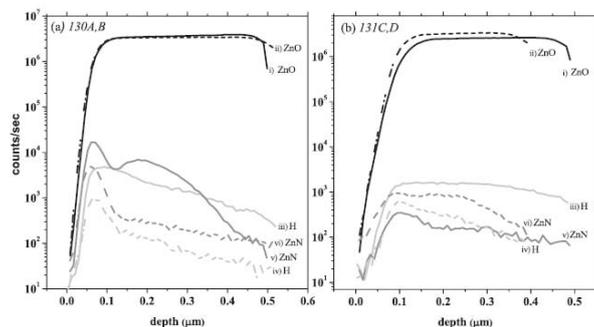
Now the scientists at NC State say they have solved that problem by introducing a specific “defect complex,” using a unique set of growth and annealing procedures in the ZnO.

The table below shows conditions used for the research.

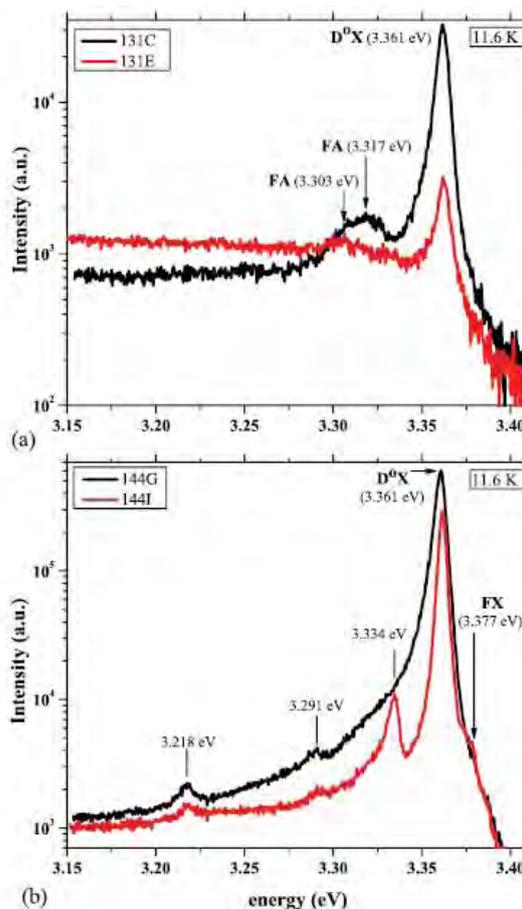
TABLE I. Summary of process conditions for thin films of ZnO.

Sample I.D	450 °C <i>in situ</i> anneal		Post-growth cooldown		800 °C <i>ex situ</i> anneal	
	<i>t</i> (s)	N <sub>2</sub>	N <sub>2</sub> O	<i>t</i> (s)	Ambient	
130A	0	Y	Y	0		
130B	0	Y	Y	60	N <sub>2</sub>	
131C	300	N	Y	0		
131D	300	N	Y	30	N <sub>2</sub>	
131E	300	N	Y	30	O <sub>2</sub>	
131F	300	N	Y	300	O <sub>2</sub>	
144G	0	Y	N	0		
144H	0	Y	N	30	N <sub>2</sub>	
144I	0	Y	N	30	O <sub>2</sub>	

The defect complex looks different from a normal ZnO molecule. The zinc atom is missing and a nitrogen atom (attached to a hydrogen atom) substitutes for the oxygen atom. These defect complexes are dispersed throughout the ZnO material and serve as the “holes” that accept the electrons in *p*-type materials.



SIMS depth profiles of ZnO, H, and ZnN collected for N-doped ZnO films of (a) *n* type sample 130A before (solid lines) and 130B after (dashed lines) an 800 C, 60s *ex situ* anneal in N<sub>2</sub> and (b) *p*-type sample 131C before (solid lines) and 131D after (dashed lines) a 30s *ex situ* anneal in N<sub>2</sub>



11.6K PL spectra of (a) 131C, 131E, and 144G, 144I before and (b) after the *ex situ* 800C O<sub>2</sub> anneal

This research illustrates how to create *p*-type materials from ZnO, but the defect complex allows the ZnO *p*-*n* junction to function efficiently and produce UV light at room temperature.

More details of this work are published in the paper, “Shallow acceptor complexes in *p*-type ZnO,” by Judith Reynolds *et al* in *Applied Physics Letters*, 102, 152114 published online on 19th April 2013. <http://dx.doi.org/10.1063/1.4802753>

This research was supported by the Defence Advanced Research Projects Agency.

## Cause of LED efficiency droop may be revealed

Auger recombination could be responsible for the LED droop phenomenon

Researchers at the University of California, Santa Barbara and colleagues at the École Polytechnique in France say they have identified Auger recombination as

the mechanism that causes LEDs to be less efficient at high drive currents.

Until now, scientists had only theorised the cause behind LED “droop.”

This is a mysterious drop in the light produced when a higher current is applied. The cost per lumen of LEDs has held the technology back as a viable replacement for incandescent bulbs for all-purpose commercial and residential lighting.

This could all change now that the cause of LED efficiency droop has been explained according to researchers James Speck and Claude Weisbuch of the Centre for Energy Efficient Materials at UCSB, an Energy Frontier Research Centre sponsored by the U.S. Department of Energy.

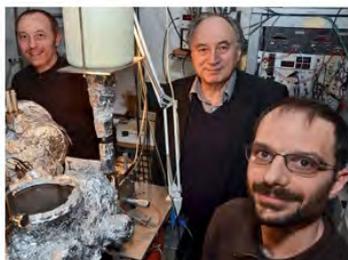
Knowledge gained from this study is expected to result in new ways to design LEDs that could have significantly higher light emission efficiencies. LEDs have enormous potential for providing long-lived high quality efficient sources of lighting for residential and commercial applications.

The U.S. Department of Energy recently estimated that the widespread replacement of incandescent and fluorescent lights by LEDs in the U.S. could save electricity equal to the total output of fifty 1GW power plants.

“Rising to this potential has been contingent upon solving the puzzle of LED efficiency droop,” comments Speck, professor of Materials and the Seoul Optodevice Chair in Solid State Lighting at UCSB. “These findings will enable us to design LEDs that minimise the non-radiative recombination and produce higher light output.”



Justin Iveland (left) and Professor James Speck  
Credit: UCSB



From left: Jacques Peretti, Claude Weisbuch,  
and Lucio Martinelli  
Credit: Ecole Polytechnique, Ph. Laviolle

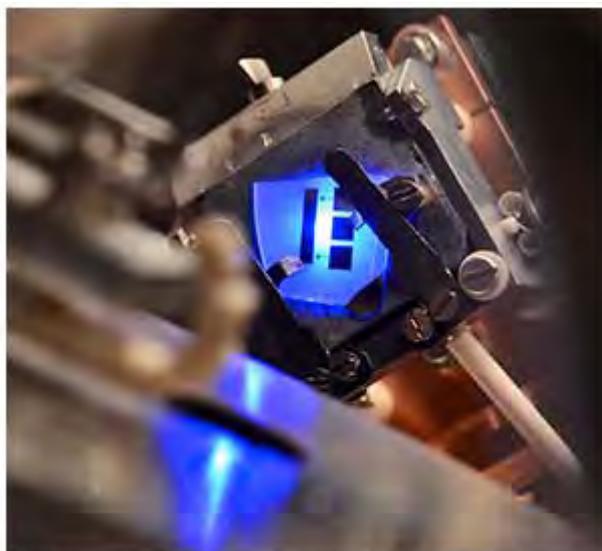
“This was a very complex experiment - one that illustrates the benefits of teamwork through both an international collaboration and a DOE Energy Frontier Research Centre,” points out Weisbuch, distinguished professor of Materials at UCSB. Weisbuch is also a faculty member at the École Polytechnique in Paris and enlisted the support of his colleagues Lucio Martinelli and Jacques Peretti to conduct this research.

UCSB graduate student Justin Iveland was also a key member of the team working both at UCSB and École Polytechnique.

In 2011, UCSB professor Chris van de Walle and colleagues theorised that a complex non-radiative process known as Auger recombination was behind nitride semiconductor LED droop, where injected electrons lose energy to heat by collisions with other electrons rather than emitting light.

Speck, Weisbuch, and its research team claim a definitive measurement of Auger recombination in LEDs has now been accomplished.

The experiment used an LED with a specially prepared surface that allowed the researchers to directly measure the energy spectrum of electrons emitted from the LED. The results showed a signature of energetic electrons produced by the Auger process.



LED emitting light under forward bias in an ultra high vacuum chamber allowing simultaneous electron emission energy

Credit: Ecole Polytechnique, Ph. Laviolle

The results of this work are to be published in the journal *Physical Review Letters*. A similar version of the publication can be seen at <http://arxiv.org/abs/1304.5469>.

This research was funded by the UCSB Centre for Energy Efficient Materials, an Energy Frontier Research

Centre of the US Department of Energy, Office of Science. Additional support for the work at École Polytechnique was provided by the French government.

## Epistar & Intermolecular collaborate with LED IP licensing

The companies will work together to accelerating R&D of new materials and manufacturing processes for LEDs using Intermolecular's technology

Intermolecular and Epistar have signed a collaborative development program (CDP) and royalty-bearing IP licensing agreement to increase the efficiency and reduce cost of Epistar's LED devices.

Under this agreement, Epistar and Intermolecular engineers will try to leverage Intermolecular's High Productivity Combinatorial (HPC) technology platform to dramatically accelerate development and manufacturing qualification of novel materials and processes for advanced LED products.

"After a rigorous review of Intermolecular's capabilities through an initial collaboration engagement, we have seen how their combinatorial approach to materials innovation and device integration can augment Epistar's leadership in LED technology," says M. J. Jou, president of Epistar. "Collaboration with our industry partners has been critical to our world-leading R&D and manufacturing strategy. We are confident that leveraging Intermolecular's team and technology platform will further increase our competitive advantage."

The commercial LED market is highly competitive, and new technologies created by R&D are needed to both improve light output and to reduce costs. A multi-functional team of technologists from Epistar and Intermolecular will work together using the HPC Platform to accelerate the pace of R&D ten times or more compared to what can be achieved in a conventional LED lab.

"We are very excited to partner with Epistar, a global leader in LED manufacturing," comments Sandeep Nijhawan, senior vice president and general manager of Intermolecular's clean energy group. "Entering into a strategic engagement with a top-tier LED company like Epistar validates the applicability and disruptive potential of the HPC technology platform for LEDs, a market that continues to have tremendous room for growth and technology innovation."

Intermolecular's mission is to improve R&D efficiency in

the semiconductor and clean energy industries through collaborations that use its HPC platform, which allows R&D experimentation to be performed at speeds up to 100 times faster than traditional methods.

## Osram unveils five new colour versions for LED Duris P 5

The company has revealed new design options with indium gallium nitride and indium gallium aluminium phosphide mid-power LEDs

Osram Opto Semiconductors now offers the mid-power LED Duris P 5 in colour.

The five new versions have impressively high luminous efficacy from a compact form factor, already known from the white version. The LEDs are ideal for architecture lighting and for the hospitality sector, in other words hotels and restaurants.

The five colour versions of Duris P 5 are "deep blue" (450 nm), "blue" (470 nm), "true green" (528 nm), "yellow" (590 nm) and "red" (615 to 625 nm).

At the heart of the different colours are state-of-the-art chip technologies from Osram, based on either the InGaN material system or InGaAlP depending on the wavelength.



*Osram Duris P 5 LED*

Low forward voltages and optimised light extraction result in high luminous efficacies for all types. The "deep blue" version, for example, delivers a light output of 140 mW (at 100 mA and 250C), corresponding to a typical efficiency of 48 percent. Efficiency is defined as the ratio of the amount of light produced to the amount of power consumed.

As members of the mid-power class, the colour versions of Duris P 5 are ideal for linear, area or omnidirectional lighting applications in which the light has to be

distributed as uniformly as possible.

Colour mixing is also much easier in applications involving several colours.

More design options for professional lighting “The colour Duris P 5 versions will give our customers even greater freedom in designing luminaires. A good example is the combination of white and coloured mid-power LEDs within a luminaire”, says Martin Wittmann, Product Manager Marketing SSL at Osram Opto Semiconductors, and adds, “The use of the Duris power class also reduces system costs while at the same time improving the distribution of light and simplifying thermal management.”

Like the white versions in the P 5 family, the coloured Duris versions are capable of withstanding extremely harsh conditions. The innovative package technology offers greater corrosion stability compared to conventional mid-power LEDs. The component dimensions measure just 2.6 by 2.2 mm also allow good optical control in connection with secondary optics.

In addition to architectural lighting and signage applications, the new Duris colour versions can be used in LED lamp and luminaire modules with “remote phosphor” technology. In this case, the converters needed to generate white light are not attached directly to the chip but are illuminated by “deep blue” LED from a certain distance, causing them to luminesce.

Technical information for Duris P 5 (Gx DASPA1.xx):

Type	Color	Wavelength	Typical light output (100mA/25°C)	Typical forward voltage (100mA/25°C)	Typical efficacy / efficiency (100mA/25°C)
GD	deep blue	439 nm - 461 nm	140 mW	2.95 V	48%
DASPA1.14	blue	459 nm - 476 nm	8 lm	3.20 V	25 lm/W
GB	blue	459 nm - 476 nm	8 lm	3.20 V	25 lm/W
DASPA1.13	blue	459 nm - 476 nm	8 lm	3.20 V	25 lm/W
GT	true green	513 nm - 543 nm	26 lm	3.25 V	80 lm/W
DASPA1.13	green	513 nm - 543 nm	26 lm	3.25 V	80 lm/W
GY	yellow	583 nm - 595 nm	14 lm	2.15 V	65 lm/W
DASPA1.23	yellow	583 nm - 595 nm	14 lm	2.15 V	65 lm/W
GR	red	612 nm - 630 nm	16 lm	2.05 V	78 lm/W
DASPA1.23	red	612 nm - 630 nm	16 lm	2.05 V	78 lm/W
Max. conducting current (Ts=25°C)			250 mA		
Typical thermal resistance (junction/solder pad)			18 K/W		
Size			2.6 x 2.2 mm		

This remote phosphor technology results in uniform distribution of light and high luminous efficacy.

The colour Duris P 5 versions will be premiered at the Osram booth #1001 at Lightfair 2013 taking place in Philadelphia between April 23rd and 25th, 2013.

## Everlight has 1000 granted patents

The company has established a strong patent portfolio related to III-nitride LEDs and phosphors

LED package manufacture Everlight Electronics now holds more than 1,600 patents and patent applications.

What’s more, Everlight obtained its 1000th granted patent in March this year.

Everlight’s patent portfolio covers LED chips, phosphors, LED package design, LED luminaires, and many other diverse LED applications. Everlight believes that only with constant dedication in technical development, product innovation, and establishing a strong patent portfolio could make the firm one of the top players in the LED industry.



Everlight COB LED

Throughout the years, Everlight entered into mutually beneficial licensing agreements with many top-of-the-line LED providers so as to ensure the interests for both Everlight and its customers, while providing more competitive products and services to its clients.

Everlights Electronics Co., Ltd. was founded in 1983 in Taipei, Taiwan. The company provides a diverse product portfolio consisting of High Power LEDs, Lamps, SMD LEDs, Lighting Components, LED Lighting Modules, Digital Displays, Optocouplers and Infrared Components for various applications.



EVERLIGHT

Everlight Electronics headquarters

## Bridgelux to sell Toshiba its GaN-On-silicon related assets

The LED specialist has agreed to provide Toshiba with its technology/chip licensing and manufacturing collaboration

Bridgelux and Toshiba have signed an agreement under which Bridgelux will sell to Toshiba its GaN-on-silicon technology and related assets.

The companies aim to strengthen and extend their strategic technology collaboration, through an expanded licensing and manufacturing relationship.

In January, 2012, Bridgelux and Toshiba entered into a Joint Development and Collaboration Agreement for the development of GaN-on-silicon LED technologies.

The success of that relationship was demonstrated by Toshiba's announcements of the achievement of the performance of its 8" GaN-on-silicon LED wafers and mass production of white LEDs.

Both of these milestones were achieved using Bridgelux's crystal growth and LED device processes as well as Toshiba's advanced silicon processes and manufacturing technologies.

The enhanced strategic relationship could provide a new business opportunity through the expanded collaboration for next generation LED chips and packages, or platforms, based on the jointly developed GaN-on-silicon technology, as well as a manufacturing arrangement securing Bridgelux a source of supply for GaN-on-silicon-based LED chips.

"Our agreement with Toshiba marks a tremendous milestone in our long history of working closely together, allowing Bridgelux to capitalise on our strong core LED technology platform, providing us with significant new capital for growth, and reducing our capital requirements," says Brad Bullington, Chief Executive Officer of Bridgelux.

"This agreement also allows us to focus on what we do best, and what we think the market needs most at this point in time: commercialising, productising and bringing to market LED-based solid state lighting technologies alongside a proven global scale semiconductor manufacturing partner. We are one step closer to becoming the world's leading solid state lighting technology architecture company," he explains.

"We are so excited with this deal that gaining GaN-on-

silicon technology and related assets will contribute to drastically strengthening our LED business, and bring us a high performance and competitive product line-up. We fully expect our new Livermore team to play a leading role within Toshiba in the development and rapid market penetration of GaN-on-Silicon LED chips," says Makoto Hideshima, Executive Vice President of Semiconductor and Storage Products Company, Corporate Vice President of Toshiba.

"Entering a new phase of our relationship with Bridgelux, we will be able to accelerate the scaled manufacturing of 8" GaN-on-silicon LED wafers, which will position both companies for strong growth in our respective LED businesses. The GaN-on-silicon technology that we acquire will also bring us a breakthrough for Power Devices development and production."

The GaN-on-silicon assets included in the sale, and the related Bridgelux employees, will remain on site at Bridgelux's headquarters in Livermore after the transaction closes to assure continued technical and business collaboration between the companies.

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## NPD: LEDs to grab quarter of global lighting market

LEDs are expected to sell 16 million units in 2012 to a forecasted 33 million in 2013, and will nearly triple by 2016

Demand for LED lighting is growing rapidly thanks to significant expansion in manufacturing capacity, falling prices, environmental concerns, and government incentives.

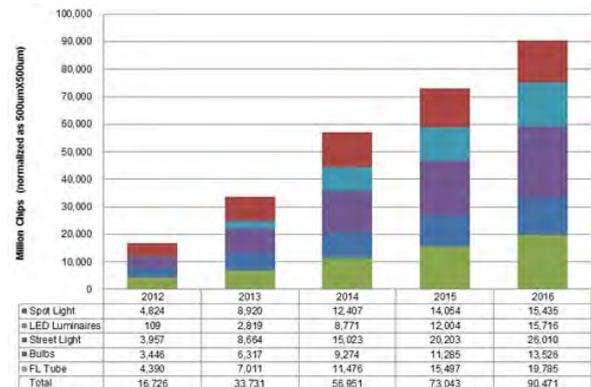
According to the "NPD DisplaySearch LED Lighting Market and Forecast Report", this new opportunity for LED lighting applications will double the market, from 16 million units in 2012 to a forecasted 33 million in 2013, and will nearly triple by 2016.

As a result, the demand for all LED lighting products, including spot lights, LED luminaires, street lights, LED light bulbs and fluorescent tubes, will reach 90 million in 2016, increasing the global penetration for LED lighting applications to 26 percent in 2016, up from only 5 percent in 2012.

This increase is due in large part to continued growth in commercial applications, government incentive programs, and consumer demand for energy-saving technology. The highest growth will be in LED-based tubes that replace fluorescent (FL) tubes used in commercial applications, LED-based street lights, and

LED luminaires—innovative designs that produce light across various shapes and sizes.

*Demand in LED Lighting Applications*



Source: NPD DisplaySearch LED Lighting Market and Forecast Report

“LEDs are playing a leading role in the lighting industry, driven primarily by government incentive policies and consumer demand for more efficient light sources with advanced technologies such as wireless and colour control,” notes Steven Sher, Analyst, NPD DisplaySearch. “This increased demand will manifest over the next three years, as consumers look to replace their traditional light bulbs with more efficient LED lighting options.”

## Japan and China Lead LED Lighting Demand

Japan has been the largest market for LED lighting applications since 2011, and NPD DisplaySearch projects this dominance will continue through 2016, driven by the adoption of LED bulbs, spot lights, fluorescent tubes, and luminaires. LED lighting growth in China will be higher than other regions from 2012 to 2016 due to government policies such as the 12th Five-Year Plan, which is already driving demand for LED street lights. North America and Europe are also experiencing increased demand for LED lighting applications through 2016, particularly for LED fluorescent tubes.

## LED Lighting Demand by Region



The market opportunity for LED lighting is playing out in the context of a stagnant market for LEDs in LCD backlighting, currently the largest application for LEDs. In 2014, general illumination will pass display backlighting as the largest application for LEDs.

What’s more, the market for LED chips has been in oversupply as LED makers have invested heavily in MOCVD equipment, particularly in China. The surplus has caused competition to intensify and prices to drop dramatically, leading to higher LED penetration in lighting, but lower profits for LED makers.

This has led many LED makers to pursue vertical integration, in which the LED chip makers integrate the chip, phosphor, and control circuits to make lighting engines, and in which LED package makers integrate the lamp assembly. Success in the lighting market requires technical integration, but also optical design and the development of brand and channel strategies.

## Simplifying LED applications online

Luger Research is working with Arrow and Transim to introduce a new design tool for LEDs

Luger Research, a publisher of LED professional and organiser of the LED professional Symposium + Expo is supporting designers and engineers.

The company is cooperating with Arrow and Transim to introduce a new design tool.

Luger’s cloud-based application platform is designed to complete LED lighting system solutions in minutes.

This integrated design environment combines multiple modules including light sources, secondary optics, power supplies, connectors, heat sinks and boards to develop a system solution.

With built-in design guidelines, powerful simulation

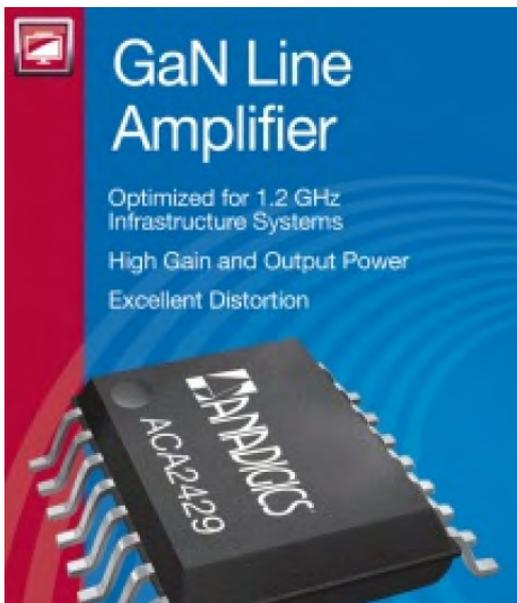
and analytical engines, and a comprehensive BOM module, engineers can get quick results and access to a wide portfolio of products from leading component manufacturers, all in a convenient and intuitive online environment.

## Telecoms

### Anadigics announces GaN amp for 1.2 GHz CATV systems

The firm's gallium nitride power doublers provide excellent output power, linearity, and bit error rate performance for CATV system amplifier and deep fibre node applications

Anadigics has introduced the ACA2429 GaN power doubler surface mount IC supporting operation up to 1.2 GHz.



The company's GaN line amplifiers combine Anadigics' MESFET technology with a GaN output stage in a proven package to deliver exceptional performance and reliability in CATV infrastructure applications.

With a combination of high gain, output power, and linearity coupled with low current consumption and bit error rate (BER), Anadigics' GaN line amplifiers can be used as output power doublers for system amplifiers and deep fibre nodes.

This level of performance provides a power efficient

"green" solution that saves energy and ensures distortion free video and audio in an advanced fully-loaded spectrum.

"New high speed HFC networks are demanding higher gain, output power and operating frequencies to provide additional video capabilities and increased data speeds," says Tim Laverick, vice president of Infrastructure Products at Anadigics.

"These systems continue to require exceptionally linear amplification at greater gain and output power levels than 1 GHz systems to ensure quality and reliability. Anadigics has responded to this challenge by developing GaN line amplifier solutions that combines our field-proven, highly linear GaAs technology with a high power GaN output stage in our reliable surface mount package platform."

Anadigics' ACA2429 GaN power doubler provides 25 dB gain with +60 dBmV output power and 1.2 GHz bandwidth.

The new ACA2429 delivers this performance with 10 W of power consumption in a standard surface mount package. The firm's GaN surface mount line amplifiers offer exceptional composite triple beat (CTB), composite second order (CSO), cross modulation, and carrier-to-intermodulation noise (CIN) characteristics for optimal performance in a fully-loaded spectrum.

The Anadigics GaN line amplifiers have a high gain, output power and isolation and operate at 24V with 420 mA current consumption. With a positive slope cable equivalent, the devices have a very low bit error rate. The GaN output stage increases power efficiency and minimises the operating (bias) current and have a reliable 16-lead SOIC surface mount package.

Samples of the ACA2429 are available now for qualified programs.

### TriQuint's GaN & GaAs power doublers boost CATV performance

The firm has released GaAs (gallium arsenide) and gallium nitride products to speed up uninterrupted connectivity

TriQuint Semiconductor has released a new GaN integrated power doubler with superior performance for fast-growing CATV infrastructure.

The firm's new GaN MMIC amplifier offers high gain (24dB) and excellent composite distortion performance

(CTB/CSO), which is a critical characteristic in multi-carrier CATV environments.



TriQuint has also released its new GaAs power doubler that delivers the highest gain and output power among 'green' 12 Volt CATV amplifiers. The new amplifier provides RF output of +58dBmV/ch while consuming less than 8W, making it one of the highest output 12V GaAs solutions in the CATV industry. Thanks to its low power consumption and gain, it can replace the equivalent of two legacy devices.

"TriQuint continues to expand solutions for cable TV infrastructure. Early customer feedback has been very positive on high output amplifier products," comments James L. Klein, Vice President and General Manager for TriQuint's Infrastructure and Defense Products. "Today's homes, schools and businesses are looking to cable and fibre operators to provide high speed uninterrupted connectivity to ensure access for digital education and entertainment. TriQuint's GaN and GaAs product innovations are key enablers for the systems."

The growth of CATV technologies is important to delivering sought-after content, notes Directing Analyst for Broadband Access and Video, Jeff Heynen, of Infonetics Research.

"Cable operators are gaining significant traction with DOCSIS 3.0 in North America, Europe, Korea and Japan; they're in the early stages of rolling out video gateways that combine DOCSIS CPE with video transcoding capabilities to deliver whole-home, multi-screen service; we anticipate hearty growth for the devices over the next few years," says Heynen.

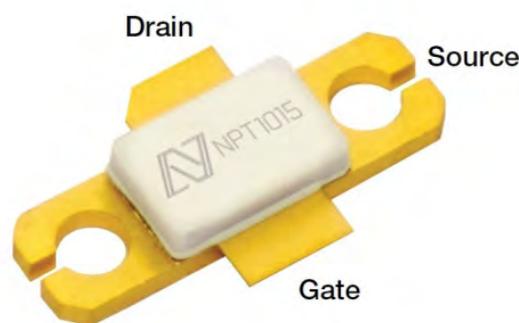
TriQuint says its innovative CATV / FTTH products deliver improved system-level performance. They are offered as surface-mount, 40-pin 5x7mm QFN packages which drive cost-effective direct-to-board assembly.

Samples and evaluation boards are now available; both devices are production-ready.

## Nitronex process creates industry's toughest GaN transistor

The firm has qualified its gallium nitride transistor for military and satellite communications, broadband, RADAR, wireless and point to point microwave applications

Nitronex, a designer and manufacturer of GaN based RF solutions for the defence, communications, cable TV, and industrial & scientific markets, has fully qualified the robust NPT1015 transistor.



The NPT1015 is a 28V, DC-2.5GHz, 50W power transistor with 15dB saturated gain and 65 percent peak drain efficiency at 2GHz.

The thermal resistance of the NPT1015 transistor is 1.9°C/W, which is among the lowest in the industry in this power class. This GaN technology is capable of surviving the industry's most severe robustness tests without significant device degradation.

Developed under an entirely new design process, the NPT1015 leverages Nitronex's existing 28V NRF1 process platform, which has been in volume production since 2009. One hundred NPT1015 devices from four wafers were subjected to a 15:1 VSWR at all phase angles with 90°C base plate temperature.

During VSWR testing, all devices operated in a saturated average power condition driven by a 4000 carrier 200MHz wideband signal with a 19.5dB peak-to-average ratio. The devices showed 100 percent survivability and only ~ 0.2dB average change in saturated output power.

"The NPT1015 is a robust next-generation product, as it incorporates significant thermal management improvements that increase breakdown and lowers thermal impedance. We are using these same techniques in our new 48V product line. Nitronex is very excited about the advancements in product robustness and reliability that put our GaN-on-Si devices on par or ahead of competitive products that primarily use GaN-on-

SiC,” says Greg Baker, president and CEO at Nitronex.

Nitronex says its patented SIGANTIC GaN-on-Silicon process is the only production qualified GaN process using an industry standard 4” silicon substrate. This results in a robust, scalable supply chain and positions Nitronex well for the growth expected from emerging GaN markets such as military communications, broadband, RADAR, commercial wireless, satellite communications and point to point microwave.

Fully qualified NPT1015 transistors are now available from stock to 12 weeks, and can be purchased through the Nitronex sales channel and distribution.

## Anadigics launches new family of InGaP 802.11 WiFi PAs

The firm's latest indium gallium phosphide power amplifiers are optimised for infrastructure and multimedia applications

Anadigics has unveiled a new family of 802.11ac power amplifiers (PAs) optimised for WiFi infrastructure and multimedia applications, including access points, routers, media gateways, set-top boxes, and smart TVs.

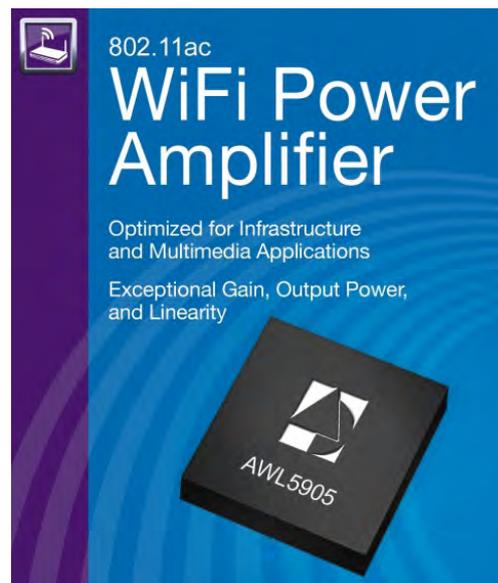
These PAs deliver a combination of high gain, output power, and linearity to maximise data throughput and ensure reliable transmission of high definition (HD) video at extended ranges.

The company's new 802.11ac solutions also feature greater integration compared with a typical power amplifier, reducing external component requirements and saving valuable PCB space.

“Anadigics continues to set the RF performance standard for WiFi applications,” says Dave Cresci, vice president of WiFi Products at Anadigics. “Our latest power amplifiers stand out as critical enablers in the expanding use of 802.11ac MIMO technology for WiFi infrastructure in both commercial and residential applications.”

Cresci adds, “They complement and build upon the success of our highly integrated front-end ICs by offering exceptional gain, output power and linearity to deliver higher data rates at greater ranges for an enhanced computing and multimedia user experience.”

Anadigics' new family of WiFi power amplifiers leverage the Company's exclusive InGaP-Plus technology and patented design architectures to offer world-class performance and integration.



*AWL5905 power amplifier*

The first product in this family is the AWL5905 power amplifier, which offers 29 dB of gain and is optimised for 5 GHz WLAN standards, including 802.11a/n/ac. The AWL5905 features an integrated detector that facilitates accurate power control over varying load conditions (3:1 VSWR), as well as a digital PA enable interface that improves ease of use and eliminates the requirement for an external buffer amplifier.

This level of integration includes internal RF matching and is provided in a compact, low-profile 4 mm x 4 mm x 0.8 mm surface-mount package that significantly reduces PCB space requirements. The AWL5905 also combines excellent efficiency and thermal performance, enabling manufacturers to develop multiple input multiple output (MIMO) solutions that consume less power and are more thermally efficient.

**Anadigics 802.11ac WiFi Power Amplifier Family Key Facts and Highlights:**

High gain and output power levels to ensure optimal performance in infrastructure and multimedia applications

Ultra-low EVM in the toughest 802.11ac modulation formats, enabling extremely high transmission data rates

High-accuracy, integrated power detector to ensure accurate power control over varying load conditions

CMOS-compatible enable voltage to improve ease of use

Compact 4 mm x 4 mm x 0.8 mm QFN package with RF ports internally matched to 50 Ohms and DC blocked to reduce PCB space requirements

Best-in-class power efficiency for improved thermal

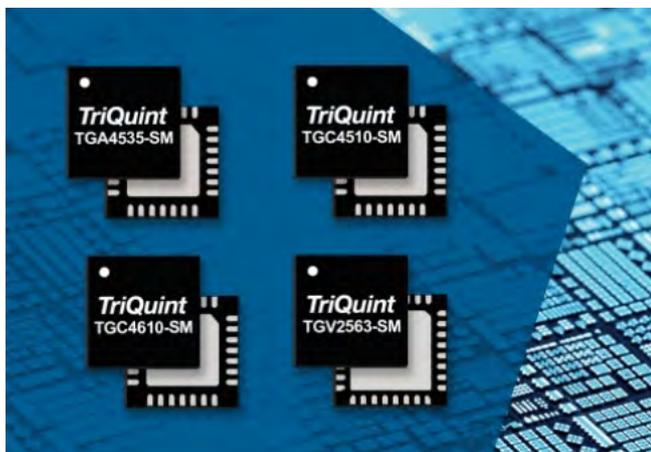
characteristics to support MIMO applications

Engineering samples of the AWL5905 are available now for qualified programs.

## TriQuint's GaAs chips simplify wireless backhaul microwave radios

The gallium arsenide radio frequency devices serve the 3G/4G cellular backhaul and related markets

TriQuint Semiconductor has introduced 12 new products and highlighted two complete RF chipset families for 15 and 23 GHz point-to-point (PtP) radios.



The firm's new GaAs based products include high-performance packaged amplifiers, up-converters / down-converters and voltage controlled oscillators (VCOs) as well as additional devices to support PtP RF requirements from 10-27 GHz.

Mobile network traffic generated by smartphones, tablets and other devices is increasing exponentially, making high-speed solutions that "backhaul" data across wireless networks essential to seamless connectivity.

Cisco's Virtual Networking Index notes that in 2012 global mobile data traffic grew by more than 70 percent compared to 2011 and predicts that it will grow at an annual rate of 66 percent through 2017.

James L. Klein, Vice President and General Manager for Infrastructure and Defence Products says, "Point-to-point radio plays a vital role in sustained mobile network growth. TriQuint's leadership in high frequency solutions now includes complete RF chipsets that simplify design and improve performance."

Microwave radios linking base stations and central switching hubs provide an excellent backhaul solution. The radios are comparatively easy to install and inexpensive to maintain. Especially at higher microwave and millimetre wave frequencies, they have broad channel bandwidths to enable very-high-speed data throughput.

TriQuint's new 15 and 23 GHz chipsets provide the OEM a single-source, surface-mount RF solution. These products are offered alongside TriQuint's larger family of PtP solutions which cover 10-16 GHz and 17-27 GHz.

### Technical Details

Point-to-Point Amplifiers

Description	Frequency Range (GHz)	Gain (dB)	P1dB (dBm)	Saturated Output Power (dBm)	OIP3 (dBm)	Voltage / Current (V / mA)	Package Style	Part Number
Power	12.4 - 15.7	27	+33	+34.5	+43	6 / 1.4	5x5mm QFN	TGA2533-
Power	21.2 - 23.6	22	+32	+34	+40	6 / 1.4	5x5mm QFN	TGA4535-
Power	17.7 - 19.7	21	+33	+34	+42.5	6 / 1.4	5x5mm QFN	TGA4534-
Power	24.2 - 26.5	20	+33	+34	+43	6 / 1.4	5x5mm QFN	TGA4536-

Point-to-Point Frequency Converters & Mixers

Description	Frequency Range (GHz)	Gain (dB)	LO / RF Isolation (dB)	IIP3 (dBm)	Voltage / Current (V / mA)	Package Style	Part Number
Ku-Band	10 - 16	17	25	15	5 / 300	5x5 QFN	TGC2510-SM
Ku-Band	10 - 16	14	40	3	4 / 160	5x5 QFN	TGC2610-SM
K-Band	17 - 27	13	40	19	5 / 340	5x5 QFN	TGC4510-SM
Upconverter	Ku-Band	17 - 27	15	40	3 / 230	5x5 QFN	TGC4610-SM

Point-to-Point Voltage Controlled Oscillators

Description	Frequency Range (GHz)	Power F0 (dBm)	100 dBz Phase Noise (dBc / Hz)	Voltage / Current (V / mA)	Package Style	Part Number
8.9 - 9.8 GHz VCO with Divide	8.9 - 9.8	9	-114	5 / 195	5x5 QFN	TGV2561-SM
9.5 - 10.3 GHz VCO with Divide	9.5 - 10.3	9	-113	5 / 195	5x5 QFN	TGV2562-SM
9.7 - 10.8 GHz VCO with Divide	9.7 - 10.8	9	-111	5 / 170	5x5 QFN	TGV2563-SM
10.3 - 11.1 GHz VCO with Divide	10.3 - 11.1	9	-111	5 / 175	5x5 QFN	TGV2564-SM
10.7 - 11.5 GHz VCO with Divide	10.7 - 11.5	9	-111	5 / 185	5x5 QFN	TGV2565-SM
11.3 - 12.3 GHz VCO with Divide	11.3 - 12.3	10	-111	5 / 180	5x5 QFN	TGV2566-SM
12.5 - 13.5 GHz VCO with Divide	12.5 - 13.5	7	-110	5 / 165	5x5 QFN	TGV2529-SM
12.6 - 13.8 GHz VCO with Divide	12.6 - 13.8	9	-110	5 / 180	5x5 QFN	TGV2584-SM
13.4 - 14.4 GHz VCO with Divide	13.4 - 14.4	9	-110	5 / 175	5x5 QFN	TGV2566-SM

Key 15 GHz Family 23 GHz Family PtP Solutions for 10-16 GHz and 17-27 GHz

## Europe to boost micro- and nanoelectronic industries

A new initiative is supporting research, development and innovation and improvement in the entire semiconductor ecosystem

The European Semiconductor Industry Association (ESIA) welcomes the European Commission's Communication "A European strategy for micro- and nanoelectronic components and systems".

The actions outlined in the Communication will strengthen the competitiveness and growth potential of the micro- and nanoelectronics industry in Europe, and build upon the European initiative on Key Enabling Technologies (KETs) and HORIZON 2020.

ESIA believes that this Communication takes a decisive

approach to reinforce the European semiconductor industry, and to increase its contribution to the wider European economy.

ESIA commends the acknowledgment that semiconductors play a crucial role in driving business transformation and responding to growing societal needs. This communication recognises the electronics industry as a key force to address the challenges the economy in the EU is facing.

ESIA fully supports the Commission's multi-level strategy including financial support for research, development and innovation (R&D&I), as well as the improvement and better use of relevant legislation. Given the very high diversity of the European market, ESIA is pleased to see the entire semiconductor ecosystem being addressed.

With a clear focus on R&D&I, market pull for new application areas, education and production, the strategy builds on the four pillars ESIA has been promoting as a basis for a dedicated European industrial policy for the micro- and nanoelectronics sector.

Rick Clemmer, ESIA President and CEO of NXP Semiconductors, states, "Pilot lines and prototyping are a welcome addition to the European R&D stimulation programme. But this concept should not be limited to semiconductor manufacturing as such. Joint semiconductor downstream application pilots will provide significant additional leverage in economic growth and employment in areas such as the Internet of Things and Smart Cities, including Intelligent Traffic Systems, Smart Buildings and Smart Grids."

Executing on this Communication has the potential to reverse the current trend in the European semiconductor market, which has seen production in Europe drop to less than 10% percent of world production in 2011.

"Leadership in innovation is key to developing a sustainable advantage for European industry and we need to build on the scientific excellence in Europe to turn great ideas into globally competitive technologies and related manufacturing," comments Carlo Bozotti, President and Chief Executive Officer of STMicroelectronics.

"With traditional strengths in analogue and power as well as more recent innovations in technologies, companies in Europe have the capability to continue to lead the development of the next wave of electronic products. The actions outlined in the Commission's Communication demonstrate a clear commitment to Europe's future," adds Bozotti.

Hendrik Abma, Director-General of ESIA, says, "ESIA welcomes the ambition and vision of the European

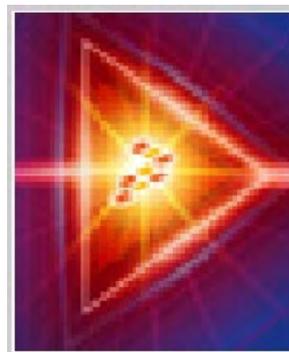
Commission's strategy. ESIA has consistently underlined the importance of the European semiconductor industry to the competitiveness and vitality of the European economy, as well as to tackling the grand societal challenges, such as energy efficiency and aging populations."

ESIA looks forward to the full implementation of the European Commission's strategy for micro- and nanoelectronic components and systems. ESIA is fully aware that the strategy's successful execution requires significant alignments among all stakeholders.

## Freescal reveals GaAs RF controller for Airfast Doherty amplifiers

The gallium arsenide MMIC based on E-pHEMT and InGaP HBT technology enables real-time digital adjustment of phase and amplitude to boost efficiency and linearity

Freescal Semiconductor has introduced an advanced GaAs monolithic microwave integrated circuit (MMIC) control circuit specifically designed to optimise the performance of Freescal Airfast Doherty amplifiers.



The MMDS20254H advanced Doherty alignment module (ADAM) enables more accurate alignment of phase and amplitude on the carrier and peaking paths of high-power Doherty amplifiers.

It therefore improves overall base station performance. The sophisticated technology also helps enhance power efficiency while boosting performance across the entire cellular frequency band.

"The process of optimising Doherty amplifiers can be challenging, time consuming and labour intensive," says Ritu Favre, senior vice president and general manager of Freescal's RF business.

“The highly sophisticated capabilities of our newest ADAM product demonstrate our deep understanding of the design challenges and issues facing RF engineers today. The MMDS20254H solution delivers the advanced technology and comprehensive support required to help RF engineers optimize the performance of Freescale’s industry-leading Airfast RF power portfolio,” adds Favre.

Fuelled by the widespread adoption of TD-LTE and W-CDMA, Doherty amplifiers have regained prominence as an industry standard, providing high power-added efficiency when amplifying the types of signals associated with these popular protocols.

Freescale’s MMDS20254H ADAM device offers exceptional linearity/efficiency tradeoffs, while improving output power. The solution includes a coupler, digitally selectable phase shifters and step attenuators, while operating from a single voltage supply. The MMDS20254H is suitable for transmit protocols such as W-CDMA and LTE, using frequencies from 1800 to 2200 MHz, and is controlled using a SPI interface.

Product information

Freescale’s MMDS20254H ADAM is a GaAs MMIC based on E-pHEMT and InGaP HBT technology. Housed in a RoHS-compliant industry-standard 6 mm QFN package, the device allows phase and peaking adjustments from 1800 to 2200 MHz.

The MMDS20254H ADAM has a constant 90 degree phase offset between port 2 and port 3 versus frequency (500 MHz bandwidth). Digital adjustment is possible to optimize power amplifier performance under different conditions, including power level, supply voltage and temperature.

Pricing and availability

The MMDS20254H is available now. A comprehensive evaluation kit including the ADAM evaluation board, SPI connector board, control software and quick start guide is available upon request to qualified customers.

## M/A-COM reveals tiny AlGaAs diode broadband shunt series

The aluminium gallium arsenide based PIN diode series delivers cost, time and space savings for high-power switching applications

M/A-COM Technology Solutions (MACOM) has launched a new family of broadband Shunt PIN Diodes for high-

power switching applications.

These devices are designed for customers who need a versatile, low cost, ultra-small Shunt PIN Diode element for land mobile radio, wireless infrastructure and test instrument applications.

Unlike the competition, MACOM’s compact 1.5 x 1.2 mm plastic package reduces board space while enabling broadband performance comparable to chip-scale devices. Typical applications include high-power switching through 6GHz with incident power up to 100W.



MACOM’s Shunt PIN Diode device

“This family of Shunt PIN Diodes offers an excellent combination of broadband performance, ease of use and low cost,” says Paul Wade, Product Manager. “These devices are ideal for customers looking for cost and space savings to implement into their solutions.”

The 3 terminal, low-pass filter structure inherent in MACOM’s devices provides superior low- and high signal performance compared to 2 terminal PIN diode devices, making the Shunt PIN Diodes ideal for high-power switching applications through 12 GHz with incident power up to 100W.

The table below outlines typical part number performance:

Parameters	Units	MADP-011027-	MADP-011028-	MADP-011029-
		14150T	14150T	14150T
Frequency	GHz	0.05-12	0.05-12	0.05-12
Capacitance (@-50V)	pF	0.24	0.24	0.31
Series Resistance	Ω	1.9	3.4	1.5
Breakdown Voltage	V	100 (min)	200 (min)	500 (min)
Power Dissipation	W	3.3	4.3(max)	7.5
Size	-	1.5 x 1.2	1.5 x 1.2	1.5 x 1.2
Process	-	Si	Si	Si

## InP PIC manufacturer Infinera announces \$135 million offering

Holder may require Infinera to repurchase their Notes at a purchase price equal to the principal amount thereof plus accrued and unpaid interest to, but excluding, the repurchase date

Infinera Corporation has announced the pricing of an offering of \$135 million aggregate principal amount of its 1.75 percent convertible senior notes due 2018 (the 'Notes').

The Notes are being offered in a private placement to qualified institutional buyers pursuant to Rule 144A under the Securities Act of 1933, as amended (the 'Act').

Infinera has granted the initial purchasers a 30-day option to purchase up to an additional \$15 million aggregate principal amount of the Notes on the same terms and conditions to cover overallocments, if any. Interest on the Notes will be paid semi-annually at a rate of 1.75 percent per year, and the Notes will mature on June 1st, 2018, unless earlier repurchased or converted.

Holder may require Infinera to repurchase their Notes upon a fundamental change at a purchase price equal to the principal amount thereof plus accrued and unpaid interest to, but excluding, the repurchase date. Infinera may not redeem the Notes prior to maturity.

The Notes will be convertible, subject to the satisfaction of certain conditions, into cash, shares of Infinera common stock or a combination thereof, at Infinera's option. The initial conversion rate per \$1,000 principal amount of Notes is equivalent to 79.4834 shares of common stock, which is equivalent to a conversion price of approximately \$12.58 per share of common stock, subject to adjustment in certain circumstances. This initial conversion price represents a premium of 37.5 percent relative to the last reported sale price on May 23rd, 2013 of Infinera's common stock of \$9.15.

Infinera expects to use the net proceeds of the offering for general corporate purposes, including working capital and potential strategic projects.

This announcement is neither an offer to sell nor a solicitation of an offer to buy any of these securities and shall not constitute an offer, solicitation, or sale in any jurisdiction in which such offer, solicitation, or sale is unlawful.

The Notes and the shares of common stock issuable upon conversion of the Notes, if any, will not be

registered under the Act or any state securities laws, and unless so registered, may not be offered or sold in the United States except pursuant to an exemption from the registration requirements of the Act and applicable state laws.

## GCS develops two InGaP HBT foundry processes

firm has launched a couple of indium gallium phosphide processes to address the VCO for point-to-point and 12V PA for small cell PA infrastructure markets

Global Communication Semiconductors, LLC. (GCS), a pure-play III-V compound semiconductor wafer foundry, has unveiled proprietary InGaP HBT D5 and P7 foundry processes.

"The D5 InGaP HBT process offers an advantage of a wider (2 x) frequency tuning range, in addition to maintaining the super low phase noise performance offered by our already successful D1 VCO process," comments Brian Ann, Chief Executive Officer of GCS.

"P7 InGaP HBT process, with a BVceo of 28v, was developed to address the small cell base station infrastructure PA requirement of 12V operation. The process can be used to develop linear PA with an output power of 1, 2, 4, 8, 10W, etc. As an example, a 2W PA has demonstrated a power density of 0.917mW/um<sup>2</sup> with a power added efficiency of over 65percent. These two new processes expand our InGaP HBT process portfolio to a total of seven processes which are sufficient to address any wireless infrastructure PA and VCO requirements," continues Brian Ann.

## Oxford Instruments hosts Asian seminars in the Far East

The talks included GaN-on-silicon, HB-LED, SiC and III-V developments

Oxford Instruments Plasma Technology has just completed its series of Asian seminars in Beijing, China and Hsinchu, Taiwan, attracting a record total attendance of over 250 people.



The seminar in Beijing was co-hosted by the Institute of Semiconductors, Chinese Academy of Sciences (IOS-CAS) one of the most important bases for the research and development of semiconductor science and technology in China. Its counterpart in Taiwan was co-hosted by ITRI, one of Taiwan's leading non-profit R&D organisations with over 5,800 employees.

Both seminars featured a range of International and national speakers including Yang Fuhua from IOS-CAS in China and Chyi, Jen-Inn, Executive Vice President, National Applied Research Laboratories in Taiwan.

The talks covered a number of key areas including GaN on silicon power device development, SiC wide bandgap semiconductors for power electronics applications and MEMS devices, processes and trends.

Shao-Chung Hsu, Executive Director of ITRI South Campus gave a welcome address at ITRI, and commented, "At ITRI we actively encourage our collaborations with leading industrial companies, and are delighted to join Oxford Instruments this week and hold such an informative conference. Oxford Instruments has an excellent cleanroom facility established here at ITRI so it is fitting for us to host an event covering the wide range of applications that the Oxford Instruments systems can offer including MEMS, HBLEED, ALD and III-V. "

He continued, "Talks about the recent progress in their research and development and future trends in the fabrication and applications in micro and nano structures, gave the audience from academia and industry much opportunity for discussion. We hope to hold more events like this with Oxford Instruments at ITRI."

Frazer Anderson, Business Group Director at Oxford Instruments Plasma Technology introduced the company at both seminars and summarises the company's pleasure at the events' success last week,

"These technical seminars in China and Taiwan gave us and our audiences a great opportunity to spend time being updated by a wide range of eminent speakers, in a relaxed atmosphere where we can share experiences and learn more from our peers. As a company our ethos is to use innovation to turn smart science into world class products, and by working closely with partners at the top of their field and learning about their evolving requirements, their research and technological developments, we hope to achieve this," he said.

## Infinera announces proposed \$100 million offering

The convertible senior notes will be due in 2018. Infinera expects to use the net proceeds of the offering for general corporate purposes, including working capital and potential strategic projects

InP PIC provider Infinera Corporation is intending to offer, subject to market conditions and other factors, \$100 million aggregate principal amount of convertible senior notes in a private placement to qualified institutional buyers.

Infinera also expects to grant the initial purchasers of the notes a 30-day option to purchase up to an additional \$15 million aggregate principal amount of the notes to cover over-allotments.

The notes will be unsecured, unsubordinated obligations of Infinera, and interest will be payable semi-annually. Prior to December 1st, 2017, the notes will be convertible at the option of the noteholders only upon the occurrence of specified events; thereafter until maturity the notes will be convertible at the option of the noteholders at any time.

Upon conversion, the notes will be settled in cash, shares of Infinera's common stock or any combination thereof at Infinera's option. Final terms of the notes, including the interest rate, initial conversion rate and other terms, will be determined by negotiations between Infinera and the initial purchasers of the notes.

The notes will be offered to qualified institutional buyers pursuant to Rule 144A under the act.

Neither the notes nor the shares of Infinera's common stock issuable upon conversion of the notes have been registered under the Act or the securities laws of any other jurisdiction and may not be offered or sold in the United States absent registration or an applicable exemption from such registration requirements.

## Nujira beats own world record for ET PA linearity

The firm's patented ISOGAIN gallium arsenide (GaAs) based technology achieves a linearisation of -53 dBc ACLR without the need for modem assistance or digital predistortion

Nujira, an expert in Envelope Tracking (ET) technology, will be presenting new performance results at the IEEE MTT International Microwave Symposium (IMS) this week.

The firm will demonstrate it has improved on its own world record linearity mark for an RF Power Amplifier (PA) operating under ET conditions.

Using its patented ISOGAIN technique to linearise the amplifier Nujira achieved an Adjacent Channel Leakage Ratio (ACLR) of -53dBc, without the use of modem assistance or Digital PreDistortion (DPD). The result beats Nujira's previous landmark of -50dBc, halving the signal distortion.

Gerard Wimpenny, CTO of Nujira says, "These headline linearity results demonstrate yet again how much of a disruptive shift ET is for the RF front end. The fact that we have been able to significantly improve our own previous linearity record shows the power that our patented ISOGAIN technique puts in the hands of designers. Our ISOGAIN approach allows for precise control of the AM characteristics of the PA in a simple lookup table, meaning that designers can now quickly and simply choose the optimum trade off between linearity and efficiency for any PA device."

The traditional approach to correct nonlinearities in RF PAs has been either to back off the output power, which increases cost and degrades energy efficiency, or to apply computationally intensive Adaptive Digital PreDistortion (DPD) techniques.

DPD pre-distorts the I/Q signals which drive the RF input to the PA, in order to precisely 'cancel out' the nonlinear response of the PA. This can require complex software algorithms to adapt the correction coefficients as the PA's RF performance varies with power levels, frequency bands, and temperature. DPD also represents a significant learning curve and software development effort for OEMs and chipset vendors.

Nujira's ISOGAIN ET approach instead uses the power supply pin of the PA to directly linearise the PA, and works by adapting the supply voltage at high speed to keep the gain constant as the RF amplitude is modulated. The mapping between instantaneous RF drive level and instantaneous supply voltage is static,

and is stored in a lookup table in the modem chipset. The mapping is applied on a sample-by-sample basis to a magnitude signal calculated from I&Q, and fed to a high speed D/A converter controlling the ET power supply. Achieving these linearity results requires an Envelope Tracking modulator which can simultaneously deliver high bandwidth, a wide voltage swing range, low noise, and high efficiency.

The linearity results were obtained from a commercially available multi mode, multi band GaAs)handset PA operating in the 850 MHz band, with 0.9v-4.6v supply modulation provided by Nujira's Coolteq.L Envelope Tracking IC for smartphones.

Using the latest Nujira Coolteq.L IC together with ET optimised PAs it is possible to save approximately 400 mW at 27 dBm output power, representing a 30 percent reduction in energy consumption.

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## Infinera top in global long-haul 100G market

Dell'Oro says that indium phosphide (InP) PIC specialist Infinera accounts for 29 percent of all long-haul 100G ports sold since the long-haul 100G market emerged in 2010

The Dell'Oro Group has ranked Infinera number one for the first quarter of 2013 in the global long-haul 100G wavelength division multiplexing (WDM) market as measured by the number of long-haul 100G ports sold.

As a result, Infinera retains the number one market share position in long-haul 100G since the DTN-X entered the market in third quarter of 2012. The Dell'Oro Group tracks the telecommunications market.

The May 20th, 2013, edition of the Dell'Oro Group Optical Transport Report shows that in the first quarter of 2013 Infinera remains number one in the worldwide long-haul 100G WDM market.

The Dell'Oro Group reports the market leaders in the long-haul 100G WDM market by the number of long-haul 100G ports recognised for revenue in the quarter. The report shows Infinera accounts for 34 percent of the long-haul 100G WDM ports sold in the first quarter of 2013.

It also says that Infinera accounts for 29 percent of all long-haul 100G ports sold since the long-haul 100G market emerged in 2010. The Dell'Oro Group forecast projects 100G revenue to grow at a 47 percent CAGR between 2012 and 2017, reaching \$5.6 billion and contributing 60 percent of WDM capacity shipments by

2017.

Infinera reports strong traction for the DTN-X around the world with purchase commitments from 27 customers through the first quarter 2013 in North America, Europe and Asia Pacific, including BICS, CenturyLink, Cable&Wireless Worldwide, KDDI, Telefonica International Wholesale Services, TeliaSonera International Carrier and DANTE for the GÉANT pan-European Research Network.

The Infinera DTN-X platform is designed for global network operators facing increasing bandwidth demands driven by video, high speed data and cloud-based services. For these operators the DTN-X provides a simple, scalable, and efficient solution that integrates optical transport network (OTN) switching capacity with market-leading multi-Terabit transport capacity.

The DTN-X enables network operators to efficiently deploy the world's first and only commercially available 500G long-haul super-channels. Long-haul super-channels enable operators to scale transport capacity without scaling operational complexity thereby lowering total cost of ownership for multi-Terabit transport networks.

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## Freescall launches GaAs LNA for optimal receiver performance

The low noise broadband gallium arsenide based amplifier is suited for small cell and macrocell transceivers and applications requiring high linearity and high RF output power

Freescall Semiconductor has introduced a new enhancement-mode pHEMT low noise amplifier (LNA) based on GaAs process technology.

It is designed to optimise receiver performance for a broad array of wireless systems operating between 700 and 1400 MHz. Typical applications include small cell and macrocell transceivers, as well as a range of applications requiring extremely low noise figures, high linearity, and high RF output power.

The noise figure of the MML09231H is 0.36 dB at 900 MHz, making it a top-performing LNA in its frequency range, while maintaining one of the lowest noise figures of any small signal device in the industry.

This performance level is ideal for receiver designers, because it can boost product sensitivity to very low-level signals.

What's more, the MML09231H has an output third order intercept point (OIP3) of 37.4 dBm at 900 MHz delivering the high linearity required by today's wireless systems.

The new Freescall LNA can tolerate a maximum input signal of +20 dBm, has an RF output peak power of +24.5 dBm (280 mW), high reverse isolation of -21 dB, small-signal gain of 17.2 dB (externally adjustable), and current consumption of only 55 mA from a single 5 Vdc supply.

Its features include an integrated power-down pin, active bias control for maintaining constant current, unconditional stability over temperature, and low external component count.

The MML09231H is now in full production. A reference test fixture is available for quick evaluation. For sampling and pricing information, please contact Freescall Semiconductor, a local Freescall sales office, or an authorised distributor.

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## u²t unveils 1550nm photodetector

The III-V based detector supports systems for next generation networks using 400 Gbit/s or 1 Tbit/s coherent detection-based optical transmission

u²t Photonics AG, a provider of optoelectronic components, says it has developed the world's fastest balanced photodetector offering a 3dB bandwidth of 70 GHz.

The BPDV3120R complements u²t's product portfolio of ultra high speed photodetectors and receivers.

The optical frontend consisting of a monolithic balanced photodetector chip with on-chip biasing has been successfully tested in a system environment and will be used in Test & Measurement (T&M) equipment, such as optical modulation analysers, for the test of next generation coherent network components and modules.



BPDV3120R

The coaxial single-ended output can detect up to 64

GBaud polarisation diversity x-QAM signals featuring highly reliable results for common mode rejection ratio, linearity and optical input power.

This means the device can be used in next generation long haul transmission systems at data rates of 400 Gbit/s and beyond. At the same time, the BPDV3120R is well suited for T&M applications as well as ongoing R&D activities at high Baud rates.

“While 100G coherent systems are being widely deployed today, we can already see that 400 Gbit/s or even 1 Tbit/s systems will be required in a few years to support the continued exponential growth of data traffic in mobile and fixed networks,” says u²t Photonics CEO Andreas Umbach. “Our 70 GHz balanced photodetector provides one of the key building blocks that will enable systems providers to build and deploy systems operating at 400G per wavelength or higher.”

u²t started sampling the BPDV3120R in March 2013 and will start its production in June.

u²t Photonics AG is a privately-held company headquartered in Berlin, Germany. It offers a comprehensive and fully TELCORDIA qualified portfolio.

## MEMS Vision combines silicon technology with SiC for sensors

The MVH3000D product line of tiny chips is designed to fulfil the needs of a wide range of applications and markets. These include consumer electronics, health & fitness, industrial, building automation, appliances, and wireless sensing (the internet of things)

MEMS Vision, a supplier of MEMS-based solutions to the global sensing market has launched its most advanced MVH3000D series of digital relative humidity (RH) and temperature (T) sensing chips.

The company maintains that a unique combination of features, programmability, and high performance specs, ensures the most competitive value in the industry.

The high accuracy MVH3001D chips have a  $\pm 1.5$  percent RH accuracy.

MEMS Vision also says unmatched robustness, reliability, and durability is achieved through the proprietary use of SiC to build and protect the miniature sensors.

These sensors also have high electromagnetic

interference protection and are claimed to be the only chips in this class to feature grounded metallic shields.

Apart from the wide range of allowable supply voltages (1.8V - 5.5V), the resolutions of the RH & T readings can be set independently from 8 to 14 bits, for a total of 16 different combinations.

The RH response time is typically 6 seconds for humidity measurements and have a low power consumption of 2 $\mu$ W average power for one RH+T measurement per second in the lowest power mode (1.8V, 8-bit resolution).

Very high temperature accuracy – a temperature accuracy of  $\pm 0.20$ C is guaranteed, over the wide range from -100C to 800C (models MVH3001D and MVH3002D).



The compact devices, shown above, measure 2.4 x 3 x 0.8 mm.

The MVH3000D series features four products, offering a comprehensive choice of RH accuracies, from  $\pm 1.5$  percent RH to  $\pm 3.8$  percent RH, and of temperature accuracies, from  $\pm 0.20$ C to  $\pm 0.30$ C.

International customers are currently sampling these new products, and an evaluation kit is now available to experience and assess the full capabilities of these sensors, along with a set of reference designs.

## NeoPhotonics opens sales and R&D office in Moscow

The firm's expansion targets high-speed indium phosphide “Core” network applications across Russia and Eastern Europe

NeoPhotonics Corporation, a designer and manufacturer of InP photonic integrated circuit (PIC), based optoelectronic modules and subsystems for bandwidth-intensive, high speed communications has opened sales and R&D office in Moscow.

“We are pleased to make this commitment to our customers and technology partners in the region, and to build on the growing demand in the region for advanced

telecommunications and enterprise data solutions,” says Tim Jenks, Chairman and CEO of NeoPhotonics.

“Together with our expanded sales force serving the region, this is the next step in our local business development activities including a greater research presence and the potential for production of advanced PIC-based solutions.”

As announced last year, NeoPhotonics completed a private placement investment with the Russian sovereign fund investor RUSNANO.

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## M/A-COM unveils HV CMOS driver for PIN diodes

M/A-COM Technology Solutions has introduced a high voltage CMOS driver for PIN diodes for use in military and commercial radio applications

MA/COM Tech’s MADR-010574 is designed to work with the firm’s high power and high voltage PIN diodes.

This driver supports series-shunt and all-series diode designs by biasing four diodes simultaneously. The back bias voltage is configurable from 20 V to 250 V, while the forward biasing current is configurable up to 200 mA. High voltage level shifters are integrated so that it can be easily controlled by 3 V or 5 V CMOS logic.

While consuming low quiescent current, the MADR-010574 has a typical delay of less than 8  $\mu$ s. If needed, the switching speed can be further improved by consuming more quiescent power. The driver is packaged in a lead free 7 mm 16-Lead QFN package and is available in tape and reel packaging for high volume applications.

“The MADR-010574 will set an industry standard in terms of versatility, functionality and size” says Scott Vasquez, Product Manager. “This device outperforms the competition and saves inches of board space on space challenged applications such as military and commercial radios. In addition, the applications for this driver are numerous and can be used in any environment that requires high voltage and current bias for PIN diodes.”

Production quantities and samples of MADR-010574 are available from stock.

## Infinera wins BICS pan-European network contract

The firm’s indium phosphide (InP) DTN-X 500G platform will enable BICS to deploy networks in days and services in minutes and lower operational costs. Infinera’s DTN-X platform has been selected to upgrade BICS’ Pan-European network.

The Infinera DTN-X delivers 500 Gigabit per second (Gb/s) long haul super-channels, enabling BICS to deliver flexible and cost effective 100 Gigabit Ethernet (GbE) services.

BICS offers international wholesale solutions to any communication service provider through a network of 100 points of presence in 55 cities and 33 countries across the globe.

The Infinera DTN-X InP based platform was selected to upgrade BICS’ Pan-European network, stretching across 9,000 kilometres of fibre in Europe and linking through a cable landing station in Marseille into the EIG & SEA-ME-WE 4 submarine cable systems.

BICS selected the Infinera DTN-X for the scalability, efficiency and simplicity the solution delivers.

“The Infinera DTN-X allows BICS to provide flexible solutions and ensures a faster service implementation, translating into a shorter time to market for our customers,” says Johan Wouters, SVP Capacity Business Management at BICS.

“This new platform will enable the aggregation of multiple high speed services on a single OTN interface. The advanced control plane offers the possibility of self-provisioning for high capacity services making BICS the perfect network outsourcing partner,” adds Wouters.

Infinera claims to be the first company to deliver 500Gb/s long-haul super-channels based on Photonic Integrated Circuits (PICs) and the FlexCoherent Processor, scaling transport capacity without scaling operational complexity.

The Infinera DTN-X increases network efficiency with five Terabits of non-blocking OTN switching per bay, scalable to 240 Tb/s in a multi-bay configuration and resulting in much more efficient utilisation when compared to conventional WDM architectures.

The Infinera solution includes an intelligent control plane that simplifies service deployment, enabling BICS to deploy networks in days and services in minutes thereby lowering operational costs while providing faster service delivery than the competition.

“We are delighted to be working with leading carriers like BICS to upgrade their networks with the DTN-X for 500G up to multi-Terabit capacities,” said Chris Champion, Infinera VP, EMEA Sales. “We’re seeing increasing traction for the DTN-X, evidenced by the purchase commitments we have received from 27 customers around the world for this new platform, out of our 115 total customers.”

## Xenics InGaAs detectors go into orbit

The firm’s indium gallium arsenide SWIR detectors were launched aboard the ESA satellite Proba-V to map crop and vegetation patterns across the face of the earth

European manufacturer Xenics has released a high-resolution line-scan detectors for demanding scientific and industrial applications.

On May 7th three of Xenics’ new Xlin-1.7-3000 SWIR InGaAs detectors were launched aboard the ESA satellite Proba-V.

Besides delivering a high resolution, the new line-scan detector offers high line rates and low noise.

The Xlin-1.7-3000, a line-scan detector in InGaAs technology offers over 3,000 pixels of resolution. Xenics says this is the best specification of any such device on the market.

With its high sensitivity in the SWIR range (0.9 to 1.7  $\mu\text{m}$ ) the Xlin-1.7-3000 is suited for the Proba-V (vegetation) satellite mission orbiting at an altitude of 880 km.

It reveals detailed long-term information on the changing crop and vegetation patterns of the planet and other vital parameters for preserving the biosphere.

### Perfectly Suited for Space

The Xlin-1.7-3000 line-scan detector is qualified for space missions with 10 krad of ionising radiation while maintaining its specified performance. A full qualification campaign as prescribed by ESA was carried out, covering harsh environmental, radiation and life test conditions.

Three of the new detectors are currently mounted on the Proba-V satellite, ready for launch with the new ESA VEGA launcher from Kourou, French Guyana. Right after the launch, the detectors will start delivering valuable earth environmental information in the SWIR range over a swath of 2,200 km with a centre resolution of just 100

m.

The Xlin-1.7-3000 consists of three individual InGaAs sub-arrays of 1,024 square pixels (25 x 25  $\mu\text{m}$ ) each. They are mechanically butted on a gold-coated boat and mounted on an alumina substrate, together with three individual readout-ICs (ROIC).

The overlap of 20 pixels enables perfect stitching of three individual images to a continuous line of 3,020 pixels over a length of 75.5 mm. The detector is assembled in a custom hermetically sealed 72-pin package with anti-reflective coated window. It is optionally also available in an open package.

## SEMI highlights the need for InP and GaAs

The organisation says that the restriction of the use of indium phosphide and gallium arsenide would have a negative impact on the semiconductor industry and Europe as a whole. SEMI has also described a new directive which will bring down patent application costs

According to Heinz Kundert, president of SEMI Europe, being able to quickly identify and seize the potential offered by new technologies and new markets is critical in the semiconductor industry. Keeping track of public policy developments is equally important.

Decisions made in a national Ministry or an EU institution can have a direct impact on the industry.

A new EU patent procedure, to be introduced by mid-2014, will significantly reduce the cost and time for a company to obtain a patent valid across 25 European states. The outcomes of the current review of substances under European EHS rules, for example, may have an impact on industry’s research priorities or its access to the EU market.

This article covers these topics: 7th SEMI Brussels Forum; EU Patent Protection; GaAs and InP under Review (REACH); RoHS Exemptions Expiring; Banned Substances under RoHS; EU Conflict Minerals Debate.

The SEMI Brussels Forum is one of Europe’s leading policy events for semiconductor equipment and materials, providing a unique platform for top-level executives and EU representatives to exchange views and debate how to reinforce Europe’s competitiveness in the global market.

The 7th SEMI Brussels Forum will discuss how Europe’s industry and policy-makers can increase their impact -

both individually and jointly to reinforce Europe's position.

How can industry build on its leading positions and expertise and optimise synergies? How can Europe balance its values and rules on free competition on one hand, with the need to provide for a global level playing field on the other?

SEMI says this is the only event that brings together top-level management and EU representatives to exchange views on how to reinforce Europe's competitiveness. More information can be accessed via the link [www.semi.org/eu/brusselsforum](http://www.semi.org/eu/brusselsforum).

#### New EU Patent Procedure Offers Automatic Protection in 25 Countries and Brings Down Costs

The new 'EU Unitary Patent', to be made available by April 2014, is expected to reduce the administrative and financial burden of patent protection across the EU. Companies will be able to fill out a single application to the European Patent Office. Once granted, the patent is automatically valid across 25 countries (all EU member states except for Italy and Spain). A single court will be created (Unified Patent Court) with jurisdiction over infringement proceedings in any of these countries.

Companies will no longer need to apply before each national body for their patent to have effect in that territory, nor satisfy local language and administrative requirements or pay local fees. Nor will they need to defend their patents in different jurisdictions and receive different, sometimes conflicting, rulings.

This new system is also expected to significantly bring down the costs of obtaining a patent. The European Commission estimates that today, a 'classic' European patent (that needs to be validated individually in 27 Member States) costs EUR (€)36 000. The new unitary patent system will bring the costs down dramatically to around €5 000, or one-seventh of today's cost.

#### GaAs and InP under Review for a Possible Restriction under REACH

A recent EU study collected information on the production, import and use of 44 substances, including GaAs and InP, in articles, as a first step towards assessing the need for a possible restriction on their use in the EU. Such a restriction (under Art. 68 REACH) could have an impact not only on European manufacturing but also on imports.

In a joint response with other industry associations, SEMI listed the applications where these compounds are used and the lack of risk to consumers when they are completely encapsulated. SEMI further highlighted the strategic importance of these compounds for micro- and

nano-electronics.

Their restriction would have a negative impact not only on industry, but on Europe as a whole. It would curb the global competitiveness of the European semiconductor manufacturing supply chain and it would deprive the EU of the industry base and products Europe needs to achieve its strategic goals for the global digital market.

GaAs and InP are the first III-V compounds being examined under the REACH microscope and SEMI is actively monitoring developments. In its upcoming advocacy activities, SEMI will collect information on risk management measures the industry has in place to avoid exposure to workers and the environment – if your company can contribute, please contact [gourania@semi.org](mailto:gourania@semi.org).

#### EU RoHS Update: Exemptions are Expiring; More Substances to be Banned under RoHS

The EU RoHS directive currently bans six substances from being used in electric and electronic equipment. Certain products of SEMI members are not covered by the Directive, such as PV panels going into fixed installations, large-scale stationary industrial tools (LSIT) and large-scale fixed installations. SEMI members also benefit from exemptions to the Directive, which allow for specific uses of the banned substances in specified quantities and for a limited period of time.

- A number of exemptions for specific applications will expire in July 2016. These exemptions can be renewed but applications for renewal need to be submitted by end of 2014. Now is therefore the time for industry to review the list of exempted applications, determine which ones are still needed and start pooling resources to draft the renewal application.

- Additional substances will be banned under RoHS by 22nd July 2014. An EU-funded study is currently underway to develop a methodology for evaluating the risk posed by hazardous substances and to determine whether they should be banned. By the end of 2013, this study will also propose additional substances that should be restricted. The European Commission will then decide on banning these substances under RoHS, the transition periods allowed for the manufacturing supply chain to adjust and start considering necessary exemptions.

The SEMI RoHS working is actively contributing to the drafting of the review methodology. For further information and to contribute to this work, please contact Sanjay Baliga at [sbaliga@semi.org](mailto:sbaliga@semi.org)

EU Conflict Minerals Debate is Launched – Potential Impact on Industry's Sourcing of Raw Materials from

## Conflict Zones

The EU is now also considering whether it needs to adopt EU measures to support responsible sourcing from conflict-affected or high-risk areas. It is not yet clear what minerals or what countries a possible EU initiative would focus on, nor whether its nature would be voluntary or binding. The question is also raised whether EU measures should address specific end-products or downstream industry sectors.

A number of initiatives on conflict minerals already exist, including the OECD guidelines on due diligence and the EU is looking to build on these and reinforce transparency through the supply chain. In the U.S., the Dodd-Frank act requires companies to report annually whether they or their suppliers are using conflict minerals (tin, tungsten, tantalum and gold originating from the Democratic Republic of Congo or an adjoining country) and the EU is seeking feedback on how these provisions are working in practice.

The adoption of an EU legislative measure would have significant implications for SEMI members, creating a traceability requirement across the entire manufacturing supply chain. The consultation is available online here – deadline for submissions is 26 June 2013. For further information, please contact [gourania@semi.org](mailto:gourania@semi.org)

Further information on SEMI advocacy activities in Europe and on the SEMI Europe Advocacy Partners program can be obtained from Rania Georgoutsakou ([gourania@semi.org](mailto:gourania@semi.org); +32 2 609 5334) or Heinz Kundert ([hkundert@semi.org](mailto:hkundert@semi.org)).

## Excelitas expands InGaAs based APD family

New product innovations in Avalanche Photodiodes offer an enhanced optical damage threshold and increased reliability

Excelitas Technologies has introduced two new products to its line of high-speed, low-light analogue APD LLAM receiver modules, the LLAM-1550E-R2AH and the LLAM-1550E-R08BH.

The modules feature enhanced optical damage thresholds and an increased 1550nm peak response.

Excelitas says the LLAM-1550E modules offer greater resilience when exposed to higher optical power densities and increased reliability for a broad range of mission-critical applications.



*Excelitas' LLAM-1550E InGaAs APD preamplifier modules*

The LLAM-1550E modules were developed specifically for situations requiring a wide dynamic operating range, high frequency response, extremely low-light detection scenarios such as laser imaging detection, combat, range finding and free-space communication.

The hermetically sealed components within a TO housing, are capable of detecting extremely low-light signals with a bandwidth up to 200MHz and have an excellent spectral response between 900 - 1700nm.

Excelitas' LLAM series is offered as a standard, RoHS-compliant, commercial off-the-shelf product. It can also be customised for bandwidth and gain optimisation, with the use of different APDs and packages.

"We are proud of our legacy in providing mission-critical solutions to our defence and aerospace industries," says Michael Ersoni, senior vice president and general manager, Excelitas Technologies' global detection business.

"By extending our line of APD offerings with the new LLAM-1550E modules, we continue to deliver innovative, customisable products that meet the specific needs of our customers," he continues.

## Wireless chip producer orders more Plasma-Therm tools

The VERSALINE processing tools will support backside GaAs RF power amplifier and switch chip production

A leading US wireless compound semiconductor device manufacturer has placed capacity driven, follow-on orders with Plasma-Therm LLC for VERSALINE wafer processing, etch modules.

The process systems will support RF power amplifier and switch chip production with advanced backside GaAs via

formation. These chipsets are used primarily in handsets and other RF applications.

The process modules include Plasma-Therm's EndPointWorks technology and unique active feedback chamber temperature management to ensure maximum etch yield, reproducibility and uptime productivity.

These orders compliment an installed base of Plasma-Therm VERSALINE and Versalock systems at this site for multiple plasma-processing steps that includes both deposition and etch.

David Lishan, Director-Technical Marketing explains, "Based on a history of repeat orders, Plasma-Therm has been a key supplier to wireless compound semiconductor manufactures for many years.

Follow-on orders are especially encouraging as they confirm we are continuously providing solutions that meet the expectations of our customers. On time solutions, whether for capacity or technology needs, are a result of close collaboration with our customers."

## Skyworks Q2 FY13 revenues up 16.6 percent Y-o-Y

The firm's revenues went up from \$364.7 million in Q2 FY2013 up to \$425.2 million in Q2 FY2012 and incomes also went up year over year

Skyworks Solutions, Inc., an innovator of analogue semiconductors, has reported second fiscal quarter 2013 results for the period ending March 29th, 2013.

Revenue for the quarter was \$425.2 million, up 17 percent when compared to \$364.7 million in the second fiscal quarter of 2012 and exceeding the company's guidance of \$420 million.

On a GAAP basis, operating income for the second fiscal quarter of 2013 was \$68.7 million and diluted earnings per share was \$0.32.

GAAP financial results Q2 FY 2013 & 2012



"As our better than seasonal results and growth outlook demonstrate, Skyworks is gaining margin-rich content and share across mobile applications while capitalising on adjacent home automation, networking, medical, smart grid and machine-to-machine vertical markets," said David J. Aldrich, president and chief executive officer of Skyworks.

"Leveraging our product innovation, scale and strong customer relationships, we are solidifying our position as a highly diversified analogue semiconductor market leader. Further to that end, we are increasingly migrating our product portfolio to differentiated, system-level solutions that provide greater value to our customers and command higher margins," he continued.

GAAP financial results for 6 months ended March 29th 2013 & 30th March 2012



### Third Fiscal Quarter 2013 Outlook

"We expect solid top and bottom line growth in the current quarter driven by specific program ramps and a more diversified, margin-accretive product mix," said Donald W. Palette, vice president and chief financial officer of Skyworks.

"Specifically, for the third fiscal quarter of 2013, we anticipate revenue of approximately \$435 million with gross margin expansion to the 43.5 to 44.0 percent range, a 130 to 180 basis point sequential improvement, operating margin in excess of 25 percent and diluted earnings per share of \$0.53, each on a non-GAAP basis."

## Osram's IR LED sensor simplifies smartphone design

The digital SFH 7776 sensor contains a GaAs (gallium arsenide) based infrared LED and two detectors. It registers the ambient brightness in order to control the display backlighting and also deactivates the touch function on the display as soon as you hold a phone up to your ear

Osram Opto Semiconductors has expanded its portfolio of proximity and ambient light sensors with an extremely powerful version with low power consumption.

The compact SFH 7776 sensor registers the ambient brightness even behind dark smartphone covers and prevents unintentional responses from the touch screen during telephone calls. This makes it even easier for smartphone designers to control the backlighting and touch functions of displays.



*The SFH 7776 combined proximity and ambient light sensor*

The digital SFH 7776 sensor contains a GaAs based infrared LED (IRED) and two detectors and performs two different functions. It registers the ambient brightness in order to control the display backlighting so that it can always be easily read but consumes as little power as possible.

It also deactivates the touch function on the display as soon as you hold the phone up to your ear during a phone call. To do this the sensor emits infrared light that is reflected by approaching objects, such as your ear.

With a working range of up to 16 centimetres and its small size, the SFH 7776 has been designed specifically for use in smartphones and other mobile devices. Thanks to the excellent sensitivity of the detector the component does not need lenses to bundle the emitted infrared light. As a result, it has an impressively small height of only 1.35 millimetres. With its black casing the sensor is virtually invisible even behind transparent phone covers. Its low power consumption is also an important factor in terms of its suitability for mobile devices – in standby mode it only needs 0.8 mA.

### Behind dark covers

The SFH 7776 is extremely sensitive to ambient light. With a detection limit of 0.002 lux (lx) it can even be used behind dark casing panels. Designers can place the sensor anywhere and do not need a special translucent window.

“The SFH 777x series gives our customers a complete family of multifunctional sensors for an extremely wide range of phone covers,” says Dirk Sossenheimer, responsible for intelligent sensor applications at Osram Opto Semiconductors.

What's more, the SFH 7776 is designed so that the ambient light sensor doesn't react to short-term fluctuations in the brightness of various lamp types, caused for example by changes in the power supply frequency. This ensures that the display backlighting remains constant.

### No crosstalk with the proximity sensor

Crosstalk – an effect in which the emitted infrared light is reflected by the smartphone casing directly onto the receiver – is eliminated by the SFH 7776 in the component itself. Designers no longer need to provide separate optical barriers between the IRED and the detector, which makes it much easier to create robust, uncomplicated solutions for different setups.

Since the SFH 7776 covers the complete working range from 0 to 16 mm it would even react to direct contact (“zero distance detection”). The touch function of the display is therefore reliably deactivated even in marginal situations.

“Overall, the SFH 7776 overcomes various challenges in terms of proximity and ambient light detection in the component itself, so designers can integrate the product in smartphones relatively easily”, adds Dirk Sossenheimer.

Technical data SFH 7776: Dimensions 4 x 2.1 x 1.35 mm

Current draw in standby mode 0.8  $\mu$ A

Sensitivity of the ambient light signal 0.002 to 68,000 lx

Working distance of proximity sensor max. 16 cm

## Sofradir to highlight InGaAs and MCT infrared detection developments

The French headquartered firm will talk about InGaAs, InSb, HgCdTe and MCT at SPIE DSS 2013

Sofradir will present its infrared (IR) advances across all wavelengths.

These will include designs that improve reconnaissance and target identification of military weapons, and enhance IR detectors used in space and industrial applications.

The developer and manufacturer of advanced infrared detectors will make four presentations on advances in next-generation IR in different wavelengths from the visible to far infrared (VLWIR) at the SPIE Defence and Security Symposium.

SPIE DSS 2013 is one of the defence industry's meetings for top scientists and engineers from the military, industry and research institutions from around the world.

"Sofradir has been actively participating in SPIE DSS for the last 20 years and sharing our latest innovations in infrared detection with participants at this highly attended conference," says David Billon-Lanfrey, VP of research & development at Sofradir.

"Increasing pixel density and resolution, producing larger format arrays, and meeting reduce Size, Weight and Power (SWaP) requirements remain key drivers in our research. We continue to push the boundaries of what can be done in infrared detection at various wavelengths using different IR technologies to bring further benefits to customers."

IR detectors are advanced technology components used in multiple military, space, commercial and scientific applications from heat seeking missiles to building inspection.

Sofradir offers a choice of four compound semiconductor materials which can be used to make IR detectors that offer capabilities at different wavelengths. These are InGaAs, InSb, HgCdTe or MCT (Mercury Cadmium Telluride) and QWIPs (Quantum Well infrared Photodetectors).

In recent developments, Sofradir acquired the full set of IR technologies by adding three to the MCT technology it already owned. At SPIE, the company will focus on InGaAs and MCT technologies.

One of the presentations addressing developments in high performance, long-range cooled IR technologies will be made in collaboration with researchers at DEFIR. DEFIR is a laboratory jointly owned by Sofradir and CEA-Leti, a leading micro- and nanotechnology research centre.

Higher resolution, smaller pixel-pitch InGaAs sensors are among the newest developments in IR imaging. Eric Costard, product line manager at Sofradir, will discuss "SWIR InGaAs focal plane arrays in France". He will focus on the next-generation of SWIR InGaAs products, such as VGA formats 15 micron pitch, targeting a large spectrum of applications from night vision and automotive safety to industrial non-destructive process control.

Yann Reibel, systems engineer, will present: "High Performance and Long-Range Cooled IR Technologies in France". To improve reconnaissance and target identification in long-range surveillance equipment, commander or gunner sights, ground-to-ground missile launchers and other applications, Sofradir is developing the future MWIR high resolution 10-micron pitch IR detector. The talk will also focus on the VGA format HOT (High Operating Temperature) IR detector that operates at 150K and is dedicated to SWaP applications.

Nicolas Jamin, space projects manager, will present "A Review of the Latest Developments of MCT Infrared Technology from Visible to VLWIR for Space Applications at Sofradir". As a result of Sofradir's increasing involvement in major space programs over the last ten years, such as the Meteosat third-generation (MTG) network, Jamin will share insights of Sofradir's space activities and experiences.

Particular emphasis will be placed on new generation visible – SWIR (Shortwave Infrared) large format detectors with low pixel pitch (1024x1024 / 15µm pitch), the latest results of MCT VLWIR technology for sounding applications and new MCT infrared detectors for earth observation.

Gerard Destefanis, research director at CEA-Leti, will take a close look at the exceptional physical properties of MCT in his presentation on "Recent Progress in MCT detectors in France". Large Focal Plane Arrays (FPA) with small pitches can be achieved in a large variety of cut-off wavelengths, such as SWIR, MWIR, LWIR, and VLWIR, including the visible.

Reducing the pixel pitch is important for increasing resolution and lowering the power consumption. The talk will cover new advanced functions enabled through more complex pixel design. These include multicolor detection with MCT hetero-structures grown by MBE (Molecular Beam Epitaxy), fast and noiseless amplification in the

pixel using avalanche photodiodes (APD), or signal processing with smart readout circuit made with advanced foundries.

#### Sofradir's Presentation Schedule

- Monday, April 29th at 8.10am, convention centre 343

"SWIR InGaAs focal plane arrays in France", by Eric Costard, product line manager at Sofradir

- Monday, April 29th at 11am, convention centre 343

"High Performance and Long-Range Cooled IR Technologies in France", by Yann Reibel, systems engineer at Sofradir.

- Monday, April 29th at 4.15pm, convention centre 343

"A Review of the Latest Developments of MCT Infrared Technology from Visible to VLWIR for Space Applications at Sofradir", Nicolas Jamin, space projects manager at Sofradir.

- Tuesday, April 30 at 10.50am, convention centre 343

"Recent Progress in MCT detectors in France", by Gerard Destefanis, research director at CEA-Leti

Sofradir develops and manufactures IR detectors for multiple military, space, commercial and scientific applications. These include thermal imagers, missile seekers, surveillance systems, machine vision, targeting systems or observation satellites.

## SiC device could mitigate blackouts & prevent equipment damage

New research indicates that silicon carbide could prevent surges in the power grid

A local power failure in Ohio ten years ago caused a series of cascading power failures that resulted in a massive blackout.

This event affected 50 million people and caused billions of dollars in damage and lost revenue.

Such blackouts could be prevented in the future, according to a new piece of equipment developed by engineering researchers at the University of Arkansas.

The device regulates or limits the amount of excess current that moves through

the power grid when a surge occurs.



"We didn't invent the fault current limiter," says Alan Mantooth, Distinguished Professor and executive director of the National Centre for Reliable Electric Power Transmission, based at the university.

"But we have developed the first one using a silicon-carbide semiconductor device and technology, which we have developed over the past five years. The significance of this material cannot be overestimated. It is much more durable and responds so much faster than materials currently used in systems on the U.S. power grid."

A fault current, also known as a surge, occurs when too much current flows through the electrical power grid in an uncontrolled manner. A fault current is typically caused by an accident or unintended event, such as lightning or contact between power lines and trees.

These events cause short-circuits, which result in a rapid increase in the electricity drawn from power sources within the grid.

When these sources do not have extra power to give, cascading or rolling blackouts can occur. This is what happened in Ohio, much of the northeast United States and parts of Canada in 2003.

A fault current limiter can be thought of as a giant surge protector. When excess current travels through a power line, the limiter absorbs it and then sends only what is necessary farther down the line, Mantooth adds. The system thus ensures uninterrupted service when the fault is intermittent. Most consumers would not even detect a problem.

What's more, if the fault is more permanent and will require repair to power lines, Mantooth points out that

the device then opens much like a normal circuit breaker, which would thus prevent further damage due to excess current.

Proper coordination and device placement will prevent cascading outages, says Mantooth.

“This device really can mean the difference between 25,000 customers or 5 million customers being affected,” Mantooth continues.

The U of A researchers worked with SiC that is stronger and faster than conventional materials used in the power grid. High-speed switching devices within the limiter rapidly insert energy-absorbing impedance into the circuit or use advanced control techniques to limit the fault current, Mantooth comments.

Silicon carbide has other benefits as well. Its properties allow for extremely high voltage, and it is a good thermal conductor, which means that it can operate at high temperatures without requiring extra equipment to remove heat. Overall, use of the material will reduce the mass and volume of equipment needed on a power grid.

Mantooth envisions the device working in concert with circuit breakers on individual buildings, especially critical facilities such as hospitals. It could also serve neighbourhoods, where one limiter could regulate current and thus preserve power for many houses. Depending on the size of the building or neighbourhood, devices would vary in terms of amperage and voltage.

Mantooth said the U of A's system, and fault current limiters in general, are examples of devices that will make and serve a “smart” grid, meaning they will play an integral role in the U.S. Department of Energy's vision for a more efficient and more reliable power grid.

The National Centre for Reliable Electric Power Transmission is funded as part of the federal government's focus on research and development on smart grid and renewable technologies. The centre is one of only a few university-based research centres chosen by the Energy Department to investigate electronic systems to make the nation's power grid more reliable and efficient.

The Energy Department has funded the centre since 2005 because of the university's research expertise in advanced power electronics and long-term investigation of silicon-carbide.

Mantooth is holder of the Twenty-First Century Chair in Mixed-Signal Integrated Circuit Design and Computer-Aided Design in the College of Engineering.

# RF Electronics

## Europe to boost micro- and nanoelectronic industries

A new initiative is supporting research, development and innovation and improvement in the entire semiconductor ecosystem

The European Semiconductor Industry Association (ESIA) welcomes the European Commission's Communication “A European strategy for micro- and nanoelectronic components and systems”.

The actions outlined in the Communication will strengthen the competitiveness and growth potential of the micro- and nanoelectronics industry in Europe, and build upon the European initiative on Key Enabling Technologies (KETs) and HORIZON 2020.

ESIA believes that this Communication takes a decisive approach to reinforce the European semiconductor industry, and to increase its contribution to the wider European economy.

ESIA commends the acknowledgment that semiconductors play a crucial role in driving business transformation and responding to growing societal needs. This communication recognises the electronics industry as a key force to address the challenges the economy in the EU is facing.

ESIA fully supports the Commission's multi-level strategy including financial support for research, development and innovation (R&D&I), as well as the improvement and better use of relevant legislation. Given the very high diversity of the European market, ESIA is pleased to see the entire semiconductor ecosystem being addressed.

With a clear focus on R&D&I, market pull for new application areas, education and production, the strategy builds on the four pillars ESIA has been promoting as a basis for a dedicated European industrial policy for the micro- and nanoelectronics sector.

Rick Clemmer, ESIA President and CEO of NXP Semiconductors, states, “Pilot lines and prototyping are a welcome addition to the European R&D stimulation programme. But this concept should not be limited to semiconductor manufacturing as such. Joint semiconductor downstream application pilots will provide significant additional leverage in economic growth and employment in areas such as the Internet of Things and Smart Cities, including Intelligent Traffic Systems, Smart Buildings and Smart Grids.”

Executing on this Communication has the potential to reverse the current trend in the European semiconductor market, which has seen production in Europe drop to less than 10% percent of world production in 2011.

“Leadership in innovation is key to developing a sustainable advantage for European industry and we need to build on the scientific excellence in Europe to turn great ideas into globally competitive technologies and related manufacturing,” comments Carlo Bozotti, President and Chief Executive Officer of STMicroelectronics.

“With traditional strengths in analogue and power as well as more recent innovations in technologies, companies in Europe have the capability to continue to lead the development of the next wave of electronic products. The actions outlined in the Commission’s Communication demonstrate a clear commitment to Europe’s future,” adds Bozotti.

Hendrik Abma, Director-General of ESIA, says, “ESIA welcomes the ambition and vision of the European Commission’s strategy. ESIA has consistently underlined the importance of the European semiconductor industry to the competitiveness and vitality of the European economy, as well as to tackling the grand societal challenges, such as energy efficiency and aging populations.”

ESIA looks forward to the full implementation of the European Commission’s strategy for micro- and nanoelectronic components and systems. ESIA is fully aware that the strategy’s successful execution requires significant alignments among all stakeholders.

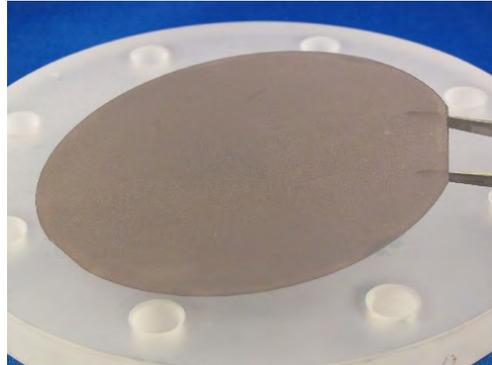
## Element Six acquires Group4 Labs` GaN-on-diamond IP and assets

Synthetic diamond enables higher performance gallium nitride devices. This results in smaller, faster and higher power electronic devices for defence and commercial applications

Element Six has acquired the assets and intellectual property of Group4 Labs, Inc. (Group4), a specialist in GaN-on-diamond semiconductor technology for RF and high-power devices.

The acquisition will expand Element Six’s semiconductor portfolio for defence and commercial applications. The assets were acquired through an assignment for the benefit of creditors from Group4 (Assignment for the Benefit of Creditors), LLC.

Group4 claims to have developed the first commercially available composite semiconductor wafer that includes GaN and diamond. Designed for manufacturers of transistor-based circuits with high power, temperature and frequency characteristics, the GaN-on-diamond system enables rapid, efficient and cost-effective heat extraction.



*GaN-on-diamond wafer*

This process reduces the operating temperatures of packaged devices, addressing heat issues that account for more than 50 percent of all electronic failures. Synthetic diamond dissipates heat up to five times better than existing materials, such as copper and SiC, enabling device manufacturers to produce smaller, faster and higher power electronic devices, with longer life spans and improved reliability.

When implemented within power amplifiers, microwave and millimetre wave circuits, GaN-on-diamond systems pose numerous benefits and applications within the defence and commercial sectors. This includes deployment in cellular base stations, radar sensing equipment, weather and communications satellite equipment, and inverters and converters typically used in hybrid and electronic vehicles.

The Group4 GaN-on-diamond technology was a critical element of TriQuint Semiconductor’s device, which won the Compound Semiconductor Industry Award in March. TriQuint demonstrated its new GaN-on-diamond, high electron mobility transistors (HEMT) in conjunction with partners at the University of Bristol, Group4 and Lockheed Martin under the Defence Advanced Research Projects Agency’s (DARPA) Near Junction Thermal Transport (NJTT) program.

TriQuint has designed devices using this technology to achieve up to a three-fold improvement in heat dissipation, the primary NJTT goal, while preserving RF functionality. This would translate into a potential reduction of the power amplifier size or increasing output power by a factor of three.

“GaN-on-diamond wafers are poised to take a centre

seat in many of our customers technology roadmaps, as new developments demonstrate its ability to dramatically reduce device temperatures, while maintaining output performance,” says Adrian Wilson, head of technologies for Element Six.

He continues, “With the acquisition of the GaN-on-diamond process developed by Group4, we plan to continue to support the market’s growth trajectory, ramping up manufacturing capabilities to deliver innovative synthetic diamond solutions to meet emerging market demands.”

Founded as a startup in 2003, Group4 has partnered with Element Six since 2008. “The scaling up of GaN-on-diamond wafer manufacturing volumes will need the unique heft, skill, and synergy of Element Six to make it possible,” says Felix Ejeckam, Chairman and CEO of Group4. “We believe that our customers will benefit enormously from this GaN-on-diamond process acquisition.”

Element Six’s Technologies division continues to experience strong market success, growing 20 percent per annum.

Element Six is a member of the De Beers group of companies. The firm designs, develops and produces synthetic diamond supermaterials. It operates worldwide with its head office registered in Luxembourg, and primary manufacturing facilities in the U.S. China, Germany, Ireland, Sweden, South Africa and the U.K.

The firm’s supermaterial solutions are used in applications such as cutting, grinding, drilling, shearing and polishing, while the extreme properties of synthetic diamond beyond hardness are already opening up new applications in a wide array of industries such as optics, water treatment, semiconductors and sensors.

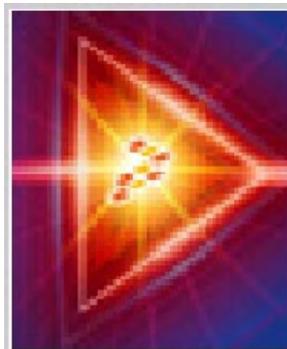
The 100 mm GaN-on-diamond wafer uses Element Six’s synthetic diamond to enable high performance semiconductor technology, allowing manufacturers to produce smaller, faster and higher power electronic devices.

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## Freescall reveals GaAs RF controller for Airfast Doherty amplifiers

The gallium arsenide MMIC based on E-pHEMT and InGaP HBT technology enables real-time digital adjustment of phase and amplitude to boost efficiency and linearity

Freescall Semiconductor has introduced an advanced GaAs monolithic microwave integrated circuit (MMIC) control circuit specifically designed to optimise the performance of Freescall Airfast Doherty amplifiers.



The MMDS20254H advanced Doherty alignment module (ADAM) enables more accurate alignment of phase and amplitude on the carrier and peaking paths of high-power Doherty amplifiers.

It therefore improves overall base station performance. The sophisticated technology also helps enhance power efficiency while boosting performance across the entire cellular frequency band.

“The process of optimising Doherty amplifiers can be challenging, time consuming and labour intensive,” says Ritu Favre, senior vice president and general manager of Freescall’s RF business.

“The highly sophisticated capabilities of our newest ADAM product demonstrate our deep understanding of the design challenges and issues facing RF engineers today. The MMDS20254H solution delivers the advanced technology and comprehensive support required to help RF engineers optimize the performance of Freescall’s industry-leading Airfast RF power portfolio,” adds Favre.

Fueled by the widespread adoption of TD-LTE and W-CDMA, Doherty amplifiers have regained prominence as an industry standard, providing high power-added efficiency when amplifying the types of signals associated with these popular protocols.

Freescall’s MMDS20254H ADAM device offers exceptional linearity/efficiency tradeoffs, while improving output power. The solution includes a coupler, digitally selectable phase shifters and step attenuators, while operating from a single voltage supply. The MMDS20254H is suitable for transmit protocols such as W-CDMA and LTE, using frequencies from 1800 to 2200 MHz, and is controlled using a SPI interface.

Product information

Freescall’s MMDS20254H ADAM is a GaAs MMIC

based on E-pHEMT and InGaP HBT technology. Housed in a RoHS-compliant industry-standard 6 mm QFN package, the device allows phase and peaking adjustments from 1800 to 2200 MHz.

The MMDS20254H ADAM has a constant 90 degree phase offset between port 2 and port 3 versus frequency (500 MHz bandwidth). Digital adjustment is possible to optimize power amplifier performance under different conditions, including power level, supply voltage and temperature.

Pricing and availability

The MMDS20254H is available now. A comprehensive evaluation kit including the ADAM evaluation board, SPI connector board, control software and quick start guide is available upon request to qualified customers.

## Oxford Instruments hosts Asian seminars in the Far East

The talks included GaN-on-silicon, HB-LED, SiC and III-V developments

Oxford Instruments Plasma Technology has just completed its series of Asian seminars in Beijing, China and Hsinchu, Taiwan, attracting a record total attendance of over 250 people.



The seminar in Beijing was co-hosted by the Institute of Semiconductors, Chinese Academy of Sciences (IOS-CAS) one of the most important bases for the research and development of semiconductor science and technology in China. Its counterpart in Taiwan was co-hosted by ITRI, one of Taiwan's leading non-profit R&D organisations with over 5,800 employees.

Both seminars featured a range of International and national speakers including Yang Fuhua from IOS-CAS in China and Chyi, Jen-Inn, Executive Vice President, National Applied Research Laboratories in Taiwan.

The talks covered a number of key areas including GaN on silicon power device development, SiC wide bandgap semiconductors for power electronics applications and MEMS devices, processes and trends.

Shao-Chung Hsu, Executive Director of ITRI South Campus gave a welcome address at ITRI, and commented, "At ITRI we actively encourage our collaborations with leading industrial companies, and are delighted to join Oxford Instruments this week and hold such an informative conference. Oxford Instruments has an excellent cleanroom facility established here at ITRI so it is fitting for us to host an event covering the wide range of applications that the Oxford Instruments systems can offer including MEMS, HBLED, ALD and III-V."

He continued, "Talks about the recent progress in their research and development and future trends in the fabrication and applications in micro and nano structures, gave the audience from academia and industry much opportunity for discussion. We hope to hold more events like this with Oxford Instruments at ITRI."

Frazer Anderson, Business Group Director at Oxford Instruments Plasma Technology introduced the company at both seminars and summarises the company's pleasure at the events' success last week,

"These technical seminars in China and Taiwan gave us and our audiences a great opportunity to spend time being updated by a wide range of eminent speakers, in a relaxed atmosphere where we can share experiences and learn more from our peers. As a company our ethos is to use innovation to turn smart science into world class products, and by working closely with partners at the top of their field and learning about their evolving requirements, their research and technological developments, we hope to achieve this," he said.

## TriQuint expands gallium nitride offerings

The firm has released significant new GaN products and foundry services

TriQuint Semiconductor has announced 15 new GaN amplifiers and transistors along with two new GaN processes.

These products offer performance, size and durability advantages for communications, radar and defence RF systems.

James L. Klein, Vice President and General Manager for Infrastructure and Defence Products, remarked that GaN's performance advantages are now more accessible to RF manufacturers thanks to TriQuint's expansion of process and product solutions.

He adds, "This announcement shows the accelerated pace of TriQuint innovation. Customers have access to more world-class products in addition to three GaN processes supported by packaging, assembly and test services. TriQuint is comprehensively addressing the most demanding RF requirements with the flexibility to engage customers of all sizes."

Strategy Analytics foresees significant GaN growth. "While defence remains the largest GaN revenue source, infrastructure is growing fast. Sat-Com, power and CATV are ramping to higher revenues. Strategy Analytics forecasts that the market for GaN microelectronic devices will grow with a CAAGR of over 34 percent to approximately \$186 million by 2015," says Eric Higham, Director of Semiconductor Practice.

TriQuint's original quarter-micron process is now complemented by a high voltage variant, TQGaN25HV. The new process extends the drain operating voltage of 0.25µm GaN to 48V while delivering higher breakdown voltage, greater power density and high gain for DC-10 GHz applications.

These advantages enable more rugged devices that can withstand VSWR mismatches that might destroy other circuits while delivering more RF output power.

A new TriQuint product designed with this process is T1G4012036-FS/FL, a 120W packaged transistor for radar and infrastructure. It is nearly two-thirds smaller than similar LDMOS devices. Additional products built with TQGaN25HV are now available.

TriQuint has taken GaN technology to new limits with its third process, TQGaN15. It pushes the frequency range of GaN to 40 GHz while delivering high power density and low-noise performance.

This 0.15µm GaN-on SiC-process was used to create TriQuint's new TGA2594 (5W) and TGA2595 (10W) Ka-band VSAT ground terminal amplifiers. They have up to 35 percent PAE and are three times smaller than comparable GaAs solutions. Additional products built using TQGaN15 are now available.

TriQuint's product portfolio of new GaN solutions also includes the ground-breaking TAT9988 direct-to-

board MMIC amplifier for CATV and fibre to the home (FTTH) optic networks. It was created with the second-generation of TriQuint's original TQGaN25 process. The TAT9988 leads the industry in gain, composite distortion performance and surface mount convenience.

TriQuint's expanded range of GaN innovation is complimented by its integrated assembly services that include die-level device packaging, X-ray and testing. TriQuint is also a DoD-accredited 'Trusted Source'

Product Solutions Technical Details:

Discrete RF Power Transistors

Description	Frequency Range (GHz)	P1dB (Psat) (dBm)	Gain (dB)	DE (%)	Voltage / Current (V / mA)	Package Style	Part Number
GaN 120W EA299	10-33	150	19	52	48 / 500	Ceramic	T124012036-FS-FL
GaN 10W EAR99	DC-6	40	16	53	32 / 50	5x5 QFN	T1G6001032-SM

Amplifiers

Description	Frequency Range (GHz)	Saturated Power (W)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) (%)	Voltage / Current (V / mA)	Package Style	Part Number
GaN S-Band PA	3-3.5	80	(49) / -	22	- / 55	28 / 125	Die	TGA2814
GaN S-Band PA	3-3.5	100	(50) / -	22	- / 55	28 / 150	Die	TGA2819
GaN X-Band HPA	6-12	30	(45) / -	30	- / 30	25 / 1100	Die	TGA2590
GaN X-Band PA	9-10	20	(43) / -	25	- / 50	25 / 150	Die	TGA2824
GaN X-Band PA	9-10	30	(45) / -	25	- / 45	25 / 250	Die	TGA2822
GaN X-Band PA	9-10	60	(48) / -	10	- / 35	24 / 2400	Die	TGA2312-FL
GaN X-Band PA	10-11	30	(45) / -	25	- / 45	25 / 250	Die	TGA2825
GaN X-Band PA	10-11	16	(42) / -	25	- / 45	25 / 150	Die	TGA2825
GaN Ka-Band PA	27-31	5	(37) / -	19	- / 30	20 / 280	Die	TGA2594
GaN Ka-Band PA	27-31	10	(40) / -	17	- / 25	20 / 580	Die	TGA2595

Driver Amplifier

Description	Frequency Range (GHz)	Saturated Power (W)	P1dB (Psat) / OIP3 (dBm)	Gain (dB)	NF / PAE (dB) (%)	Voltage / Current (V / mA)	Package Style	Part Number
GaN 2W Driver PA	2-6	2	33 / -	23	- / 30	25 / 170	Die	TGA2597

Low Noise Amplifiers

Description	Frequency Range (GHz)	P1dB (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
GaN LNA	2-6	25	25	1	10 / 100	Die	TGA2611
GaN LNA	6-12	25	25	1.5	10 / 100	Die	TGA2612

## SEMI highlights the need for InP and GaAs

The organisation says that the restriction of the use of indium phosphide and gallium arsenide would have a negative impact on the semiconductor industry and Europe as a whole. SEMI has also described a new directive which will bring down patent application costs

According to Heinz Kundert, president of SEMI Europe, being able to quickly identify and seize the potential offered by new technologies and new markets is critical in the semiconductor industry. Keeping track of public policy developments is equally important.

Decisions made in a national Ministry or an EU institution can have a direct impact on the industry.

A new EU patent procedure, to be introduced by mid-2014, will significantly reduce the cost and time for a company to obtain a patent valid across 25 European states. The outcomes of the current review of substances under European EHS rules, for example, may have an impact on industry's research priorities or its access to the EU market.

This article covers these topics: 7th SEMI Brussels Forum; EU Patent Protection; GaAs and InP under Review (REACH); RoHS Exemptions Expiring; Banned Substances under RoHS; EU Conflict Minerals Debate.

The SEMI Brussels Forum is one of Europe's leading policy events for semiconductor equipment and materials, providing a unique platform for top-level executives and EU representatives to exchange views and debate how to reinforce Europe's competitiveness in the global market.

The 7th SEMI Brussels Forum will discuss how Europe's industry and policy-makers can increase their impact - both individually and jointly to reinforce Europe's position.

How can industry build on its leading positions and expertise and optimise synergies? How can Europe balance its values and rules on free competition on one hand, with the need to provide for a global level playing field on the other?

SEMI says this is the only event that brings together top-level management and EU representatives to exchange views on how to reinforce Europe's competitiveness. More information can be accessed via the link [www.semi.org/eu/brusselsforum](http://www.semi.org/eu/brusselsforum).

**New EU Patent Procedure Offers Automatic Protection in 25 Countries and Brings Down Costs**

The new 'EU Unitary Patent', to be made available by April 2014, is expected to reduce the administrative and financial burden of patent protection across the EU. Companies will be able to fill out a single application to the European Patent Office. Once granted, the patent is automatically valid across 25 countries (all EU member states except for Italy and Spain). A single court will be created (Unified Patent Court) with jurisdiction over infringement proceedings in any of these countries.

Companies will no longer need to apply before each national body for their patent to have effect in that territory, nor satisfy local language and administrative requirements or pay local fees. Nor will they need to defend their patents in different jurisdictions and receive different, sometimes conflicting, rulings.

This new system is also expected to significantly bring down the costs of obtaining a patent. The European Commission estimates that today, a 'classic' European patent (that needs to be validated individually in 27 Member States) costs EUR (€)36 000. The new unitary patent system will bring the costs down dramatically to around €5 000, or one-seventh of today's cost.

**GaAs and InP under Review for a Possible Restriction under REACH**

A recent EU study collected information on the production, import and use of 44 substances, including GaAs and InP, in articles, as a first step towards assessing the need for a possible restriction on their use in the EU. Such a restriction (under Art. 68 REACH) could have an impact not only on European manufacturing but also on imports.

In a joint response with other industry associations, SEMI listed the applications where these compounds are used and the lack of risk to consumers when they are completely encapsulated. SEMI further highlighted the strategic importance of these compounds for micro- and nano-electronics.

Their restriction would have a negative impact not only on industry, but on Europe as a whole. It would curb the global competitiveness of the European semiconductor manufacturing supply chain and it would deprive the EU of the industry base and products Europe needs to achieve its strategic goals for the global digital market.

GaAs and InP are the first III-V compounds being examined under the REACH microscope and SEMI is actively monitoring developments. In its upcoming advocacy activities, SEMI will collect information on risk management measures the industry has in place to avoid exposure to workers and the environment – if your company can contribute, please contact [gourania@semi.org](mailto:gourania@semi.org).

**EU RoHS Update: Exemptions are Expiring; More Substances to be Banned under RoHS**

The EU RoHS directive currently bans six substances from being used in electric and electronic equipment. Certain products of SEMI members are not covered by the Directive, such as PV panels going into fixed installations, large-scale stationary industrial tools (LSIT) and large-scale fixed installations. SEMI members also benefit from exemptions to the Directive, which allow for specific uses of the banned substances in specified quantities and for a limited period of time.

- A number of exemptions for specific applications will expire in July 2016. These exemptions can be renewed but applications for renewal need to be submitted by end of 2014. Now is therefore the time for industry to review the list of exempted applications, determine which ones are still needed and start pooling resources to draft the renewal application.

- Additional substances will be banned under RoHS by 22nd July 2014. An EU-funded study is currently underway to develop a methodology for evaluating the risk posed by hazardous substances and to determine whether they should be banned. By the end of 2013, this study will also propose additional substances that should

be restricted. The European Commission will then decide on banning these substances under RoHS, the transition periods allowed for the manufacturing supply chain to adjust and start considering necessary exemptions.

The SEMI RoHS working is actively contributing to the drafting of the review methodology. For further information and to contribute to this work, please contact Sanjay Baliga at [sbaliga@semi.org](mailto:sbaliga@semi.org)

EU Conflict Minerals Debate is Launched – Potential Impact on Industry’s Sourcing of Raw Materials from Conflict Zones

The EU is now also considering whether it needs to adopt EU measures to support responsible sourcing from conflict-affected or high-risk areas. It is not yet clear what minerals or what countries a possible EU initiative would focus on, nor whether its nature would be voluntary or binding. The question is also raised whether EU measures should address specific end-products or downstream industry sectors.

A number of initiatives on conflict minerals already exist, including the OECD guidelines on due diligence and the EU is looking to build on these and reinforce transparency through the supply chain. In the U.S., the Dodd-Frank act requires companies to report annually whether they or their suppliers are using conflict minerals (tin, tungsten, tantalum and gold originating from the Democratic Republic of Congo or an adjoining country) and the EU is seeking feedback on how these provisions are working in practice.

The adoption of an EU legislative measure would have significant implications for SEMI members, creating a traceability requirement across the entire manufacturing supply chain. The consultation is available online here – deadline for submissions is 26 June 2013. For further information, please contact [gourania@semi.org](mailto:gourania@semi.org)

Further information on SEMI advocacy activities in Europe and on the SEMI Europe Advocacy Partners program can be obtained from Rania Georgoutsakou ([gourania@semi.org](mailto:gourania@semi.org); +32 2 609 5334) or Heinz Kundert ([hkundert@semi.org](mailto:hkundert@semi.org)).

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## Peregrine Introduces RF Switch for Wireless Infrastructure Market

SPDT switch promises increased network capacity and higher data rates

Peregrine Semiconductor Corporation, a fabless provider

of high-performance radio frequency integrated circuits (RFICs), has announced availability of what the company says is the industry’s highest-isolation SPDT RF switch for the wireless infrastructure market.

The UltraCMOS based PE42420 RF switch has high isolation of 64 dB @ 4 GHz—an approximately 20% increase over competing devices on the market. Additionally, the switch features HaRP technology enhancements to deliver high linearity, with an IIP3 of 65 dBm. By providing high linearity and isolation in a single, small package, the PE42420 switch simplifies Digital Pre-Distortion (DPD) loop design, which reduces cost and shortens time to market. This high-performance switch enables increased network capacity and higher data rates in infrastructure applications such as Base Station Transceiver Systems (BTSSs), Remote Radio Heads (RRHs), and wireless backhaul; as well as Industrial, Scientific and Medical (ISM) band devices that operate in the 2.4 GHz and 5.8 GHz frequencies.

“As we enter a period of major mobile broadband capacity upgrades, network equipment vendors are challenged to provide mobile operators with flexible, backward-compatible solutions to replace 2G and 3G network products with LTE-ready systems that are capable of supporting multiple standards,” said Mark Schrepferman, director of the communications and industrial product line for Peregrine’s High-Performance Solutions business unit. “At the same time, the demand for higher data rates is requiring improved network performance, which we believe is driving market needs for high-isolation and high-linearity RF components. The PE42420 switch enables equipment vendors to meet these network modernization challenges.”

In order to maximize network performance in next-generation wireless communication systems, high port-to-port isolation is required, to prevent the output signal from spilling into adjacent radio channels or bands. Additionally, because the DPD receiver is shared by multiple Power Amplifiers (PAs) in these systems, high isolation between the multiple paths ensures that the PA that is being sampled is not contaminated by other signals. The 0.1 to 6 GHz PE42420 switch supports 1.8V control logic, enabling the use of lower-voltage, and lower-power, microcontrollers. ESD tolerance of 2kV HBM on all pins eases manufacturing and results in higher reliability of the end product.

## Xenics InGaAs SWIR Detector Is Part of Proba-V Space Mission

Three detectors aboard the ESA satellite Proba-V to map crop and vegetation patterns across the face of the earth.

At SPIE DSS 2013 Xenics introduced the Xlin-1.7-3000, a line-scan detector in InGaAs technology that offers over 3,000 pixels of resolution. With high sensitivity in the SWIR range (0.9 to 1.7  $\mu\text{m}$ ) Xlin-1.7-3000 is suited for the Proba-V (vegetation) satellite mission orbiting at an altitude of 880 km to reveal detailed long-term information on the changing crop and vegetation patterns of the planet and other vital parameters for preserving the biosphere.

Xenics' new Xlin-1.7-3000 line-scan detector is qualified for space missions with 10 krad of ionizing radiation while maintaining its specified performance. A full qualification campaign as prescribed by ESA was carried out, covering harsh environmental, radiation and life test conditions. Three of the new detectors are currently mounted on the Proba-V satellite, ready for launch with the new ESA VEGA launcher from Kourou, French Guyana. Right after the launch, the detectors will start delivering valuable earth environmental information in the SWIR range over a swath of 2,200 km with a center resolution of just 100 m.

The Xlin-1.7-3000 consists of three individual InGaAs sub-arrays of 1,024 square pixels (25 x 25  $\mu\text{m}$ ) each. They are mechanically butted on a gold-coated boat and mounted on an alumina substrate, together with three individual readout-ICs (ROIC). The overlap of 20 pixels enables perfect stitching of three individual images to a continuous line of 3,020 pixels over a length of 75.5 mm. The detector is assembled in a custom hermetically sealed 72-pin package with anti-reflective coated window.

With a fill factor of 100 percent, high quantum efficiency of 75 percent and adjustable sensitivity the uncooled InGaAs detector operates at very low illumination levels. The three individual readout-ICs are manufactured in a 0.35- $\mu\text{m}$  CMOS technology and CTIA topology, which results in a high radiation tolerance for space applications. They allow a maximum pixel rate of 12.5 MHz, which yields a minimum line time of 100  $\mu\text{s}$ , or an output frequency of up to 10 kHz.

The ROICs are designed for flexibility. Once on board the Proba-V mission many of their operational parameters can be controlled in real time to adapt the detectors' characteristics to specific observation conditions and get the best value in terms of line period and integration

times (1  $\mu\text{s}$  to 1 sec). Variable gain setting enables the operator to set pixel well depth, which results in a wide span of sensitivity values beginning at just 60 ke- (dynamic range 60:1), to a very high dynamic range of 3,200:1 (pixel well depth 10 Me-). With these features the Proba-V mission can be adapted to various conditions in terms of illumination (night/day), objects of interest (ice/desert/vegetation/water) and global or detailed imaging.

## CrystAl-N launches 2-inch bulk AlN

Highly transparent, 2-inch AlN promises to enhance the performance of RF devices and deep UV lasers and LEDs.

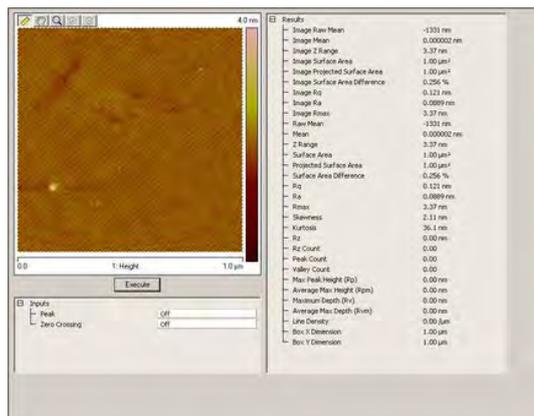
German AlN crystal maker CrystAl-N is shifting its production from 1-inch to 2-inch AlN and accepting pre-orders of the new material.

According to the company, which was founded in 2010 as spin-off of Friedrich-Alexander-University Erlangen-Nuremberg, AlN will boost the efficiency of deep UV LEDs, lasers and high-power, high-frequency devices as soon as its cost-performance ratio is competitive. Shifting production to larger substrates will help to realize this.

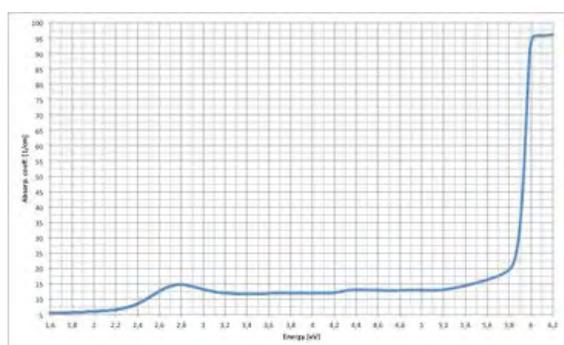


"After many years of R&D we finally managed to combine high uv transparency with suitable wafer size enabling a real commercial product," remarked company CTO Boris Epelbaum. "Further diameter increase in our patented tungsten based furnaces is not limited as we are using SiC as initial seed. "

Besides diameter enlargement wafer polishing drastically improved as well. "The corresponding wafers feature surface roughness of less than 0.3 nm and are highly UV transparent", says Octavian Filip, Director of Wafering.



AFM image (1 x 1 μm<sup>2</sup>) of a polished c-plane wafer. Ra surface roughness < 0.3 nm



low absorption coefficient values up to the band edge (peak at 2.8 eV - reason for yellowish coloration of bulk AlN grown by PVT)

## Wireless chip producer orders more Plasma-Therm tools

The VERSALINE processing tools will support backside GaAs RF power amplifier and switch chip production

A leading US wireless compound semiconductor device manufacturer has placed capacity driven, follow-on orders with Plasma-Therm LLC for VERSALINE wafer processing, etch modules.

The process systems will support RF power amplifier and switch chip production with advanced backside GaAs via formation. These chipsets are used primarily in handsets and other RF applications.

The process modules include Plasma-Therm's EndPointWorks technology and unique active

feedback chamber temperature management to ensure maximum etch yield, reproducibility and uptime productivity.

These orders compliment an installed base of Plasma-Therm VERSALINE and Versalock systems at this site for multiple plasma-processing steps that includes both deposition and etch.

David Lishan, Director-Technical Marketing explains, "Based on a history of repeat orders, Plasma-Therm has been a key supplier to wireless compound semiconductor manufactures for many years.

Follow-on orders are especially encouraging as they confirm we are continuously providing solutions that meet the expectations of our customers. On time solutions, whether for capacity or technology needs, are a result of close collaboration with our customers."

## Skyworks Q2 FY13 revenues up 16.6 percent Y-o-Y

The firm's revenues went up from \$364.7 million in Q2 FY2013 up to \$425.2 million in Q2 FY2012 and incomes also went up year over year

Skyworks Solutions, Inc., an innovator of analogue semiconductors, has reported second fiscal quarter 2013 results for the period ending March 29th, 2013.

Revenue for the quarter was \$425.2 million, up 17 percent when compared to \$364.7 million in the second fiscal quarter of 2012 and exceeding the company's guidance of \$420 million.

On a GAAP basis, operating income for the second fiscal quarter of 2013 was \$68.7 million and diluted earnings per share was \$0.32.

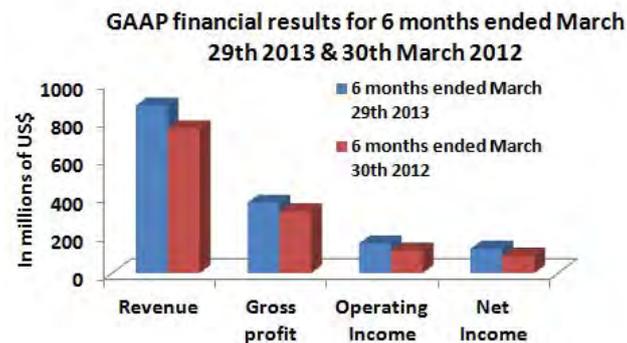
GAAP financial results Q2 FY 2013 & 2012



"As our better than seasonal results and growth outlook demonstrate, Skyworks is gaining margin-rich content and share across mobile applications while capitalising on adjacent home automation, networking, medical, smart grid and machine-to-machine vertical markets,"

said David J. Aldrich, president and chief executive officer of Skyworks.

“Leveraging our product innovation, scale and strong customer relationships, we are solidifying our position as a highly diversified analogue semiconductor market leader. Further to that end, we are increasingly migrating our product portfolio to differentiated, system-level solutions that provide greater value to our customers and command higher margins,” he continued.



### Third Fiscal Quarter 2013 Outlook

“We expect solid top and bottom line growth in the current quarter driven by specific program ramps and a more diversified, margin-accretive product mix,” said Donald W. Palette, vice president and chief financial officer of Skyworks.

“Specifically, for the third fiscal quarter of 2013, we anticipate revenue of approximately \$435 million with gross margin expansion to the 43.5 to 44.0 percent range, a 130 to 180 basis point sequential improvement, operating margin in excess of 25 percent and diluted earnings per share of \$0.53, each on a non-GAAP basis.” **Lasers**

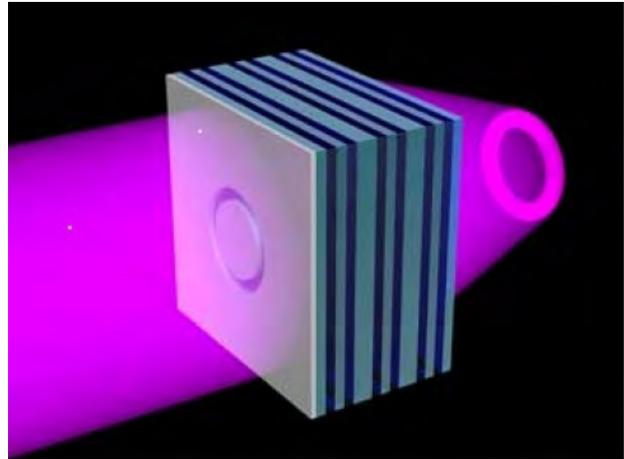
## Flat lens makes it all the better to see you with

A novel new lens could lead to improved photolithography, nanoscale manipulation and manufacturing and high-resolution 3D imaging

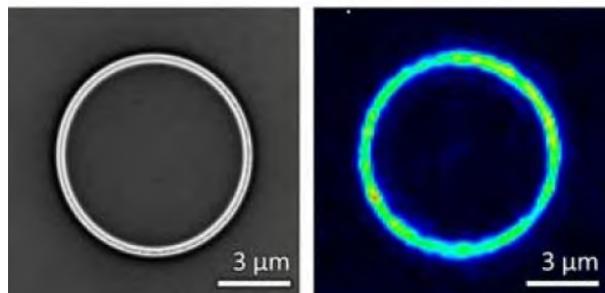
For the first time, scientists working at the National Institute of Standards and Technology (NIST) say they have demonstrated a new type of lens.

It bends and focuses ultraviolet (UV) light in such an unusual way that it can create ghostly, 3D images of objects that float in free space.

The easy-to-build lens could lead to improved photolithography, nanoscale manipulation and manufacturing, and even high-resolution three-dimensional imaging, as well as a number of as-yet-unimagined applications in a diverse range of fields.



The ultraviolet (UV) metamaterial formed of alternating nanolayers of silver (green) and titanium dioxide (blue). The metamaterial has an angle-independent negative refractive index, enabling it to act as a flat lens. When illuminated with UV light (purple) a sample object of any shape placed on the flat slab of metamaterial is projected as a three-dimensional image in free space on the other side of the slab.



Right image: Here a ring-shaped opening in an opaque sheet on the left of the slab is replicated in light on the right.

Left image: SEM micrograph of a ring-shaped opening in a chromium sheet located on the surface of a flat slab of metamaterial. Bottom right: Optical micrograph of the image projected beyond the slab under UV illumination, demonstrating that the metamaterial slab acts as a flat lens. (Credit: Lezec/NIST)

“Conventional lenses only capture two dimensions of a three-dimensional object,” says one of the paper’s co-authors, NIST’s Ting Xu. “Our flat lens is able to project three-dimensional images of three-dimensional objects that correspond one-to-one with the imaged object.”

An article published in the journal *Nature* explains that

the new lens is formed from a flat slab of metamaterial with special characteristics that cause light to flow backward - a counterintuitive situation in which waves and energy travel in opposite directions, creating a negative refractive index.

Naturally occurring materials such as air or water have a positive refractive index. You can see this when you put a straw into a glass of water and look at it from the side. The straw appears bent and broken as a result of the change in index of refraction between air, which has an index of 1, and water, which has an index of about 1.33. Because the refractive indices are both positive, the portion of the straw immersed in the water appears bent forward with respect to the portion in air.

The negative refractive index of metamaterials causes light entering or exiting the material to bend in a direction opposite to what would occur in almost all other materials. For instance, if we looked at our straw placed in a glass filled with a negative-index material, the immersed portion would appear to bend backwards, completely unlike the way we're used to light behaving.

In 1967, Russian physicist Victor Veselago described how a material with both negative electric permittivity and negative magnetic permeability would have a negative index of refraction.

Permittivity is a measure of a material's response to an applied electric field, while permeability is a measure of the material's response to an applied magnetic field.

Veselago reasoned that a material with a refractive index of -1 could be used to make a lens that is flat, as opposed to traditional refractive lenses, which are curved. A flat lens with a refractive index of -1 could be used to directly image three-dimensional objects, projecting a three-dimensional replica into free space.

A negative-index flat lens like this has also been predicted to enable the transfer of image details substantially smaller than the wavelength of light and create higher-resolution images than are possible with lenses made of positive-index materials such as glass.

It took over 30 years from Veselago's prediction for scientists to create a negative-index material in the form of metamaterials, which are engineered on a subwavelength scale. For the past decade, scientists have made metamaterials that work at microwave, infrared and visible wavelengths by fabricating repeating metallic patterns on flat substrates.

However, the smaller the wavelength of light scientists want to manipulate, the smaller these features need to be, which makes fabricating the structures an increasingly difficult task. Until now, making

metamaterials that work in the UV has been impossible because it required making structures with features as small as 10 nanometers, or 10 billionths of a metre.

What's more, because of limitations inherent in their design, metamaterials of this type designed for infrared and visible wavelengths have, so far, been shown to impart a negative index of refraction to light that is traveling only in a certain direction. This makes them hard to use for imaging and other applications that rely on refracted light.

To overcome these problems, researchers working at NIST took inspiration from a theoretical metamaterial design recently proposed by a group at the FOM Institute for Atomic and Molecular Physics in Holland. They adapted the design to work in the UV- a frequency range of particular technological interest.

According to co-authors Xu, Amit Agrawal and Henri Lezec, aside from achieving record-short wavelengths, their metamaterial lens is inherently easy to fabricate. It doesn't rely on nanoscale patterns, but instead is a simple sandwich of alternating nanometre-thick layers of silver and titanium dioxide, the construction of which is routine.

And because its unique design consists of a stack of strongly coupled waveguides sustaining backward waves, the metamaterial exhibits a negative index of refraction to incoming light regardless of its angle of travel.

The researchers say this realisation of a Veselago flat lens operating in the UV is the first such demonstration of a flat lens at any frequency beyond the microwave. By using other combinations of materials, it may be possible to make similarly layered metamaterials for use in other parts of the spectrum, including the visible and the infrared.

The metamaterial flat lens achieves its refractive action over a distance of about two wavelengths of UV light, about half a millionth of a metre - a focal length challenging to achieve with conventional refractive optics such as glass lenses.

What's more, transmission through the metamaterial can be turned on and off using higher frequency light as a switch, allowing the flat lens to also act as a shutter with no moving parts.

"Our lens will offer other researchers greater flexibility for manipulating UV light at small length scales," says Lezec. "With its high photon energies, UV light has a myriad of applications, including photochemistry, fluorescence microscopy and semiconductor manufacturing. That, and the fact that our lens is so easy

to make, should encourage other researchers to explore its possibilities.”

The new work was performed in collaboration with researchers from the Maryland NanoCentre at the University of Maryland, College Park; Syracuse University; and the University of British Columbia, Kelowna, Canada.

## Panasonic UV lasers and phosphors energise white lights

The company's newly developed technology will enable wider variation in design and a higher brightness and smaller form factor in data projectors and vehicle headlights

Panasonic Corporation has developed a semiconductor white light source capable of outputting luminous flux in the 10,000-lumen class.

An increased light output was achieved due to the high-efficiency, low-loss design and modularisation of the near-ultraviolet semiconductor laser used in the light source.

A high luminous flux of white light was realised through the development of a phosphor material that is not subject to luminance saturation even when irradiated with high-intensity laser light.

Luminance saturation is when the optical power may decline as the intensity of incident radiation increases.

The use of a laser with a smaller light-emitting area and superior light emission directionality to LEDs has made a compact optical configuration that boasts higher brightness and a smaller form factor possible. Panasonic says this technology opens the way to the greater use of semiconductor light sources in the projection and lighting market.

The new technology has the following features:

- By increasing the output of the near-ultraviolet laser in the light source to ten times that of a conventional Panasonic laser, the industry's highest light output of 60 watts (W) has been achieved. The miniaturised laser module, a component where two or more semiconductor lasers are mounted functioning as a light source, can be incorporated into a wider range of equipment.

- The use of a newly developed phosphor material has

increased blue light emissions by 40 percent when irradiated with 60W near-ultraviolet semiconductor laser light. This contributes to the realisation of a 10,000-lumen class high-luminous flux white light source through the red, green and blue phosphors.

- The generation of red, green and blue lights from only one type of laser light using a rotating phosphor wheel simplifies the optical system and ensures that the laser is projected directly onto the screen. The phosphor wheel is a component where light is shined onto the surface of a disc, onto which phosphor has been applied, which is then rotated by a motor on the central shaft, continuously creating phosphor light.

This development is based on the following new technologies:

- High-output, low-loss laser design technique with wider near-ultraviolet laser optical waveguide and optimised light loss control.

- Phosphor material technology that utilises the high-density crystalline structure of SMS (Sr<sub>3</sub>MgSi<sub>2</sub>O<sub>8</sub>) phosphor to control the density of the luminescent centre and thus prevent luminous saturation.

- Wavelength conversion technology that uses a rotating phosphor wheel that absorbs near-ultraviolet laser light and converts it to red, green and blue luminescent light.

Conventional laser white light sources require multiple visible light semiconductor lasers that emit blue and other colours, which creates a trade off between small form factor and high brightness. Some laser wavelengths are even projected directly, without passing through the phosphor material.

Conventional phosphors are not suitable for use as high-intensity light sources, as they are subject to significant luminance saturation when laser light is focused on them.

Panasonic holds 39 patents in Japan and 22 overseas patents, including pending applications, for this development.

This newly developed technology received the Distinguished Paper Award from the Society for Information Display (SID), an international conference for displays and related products held last week.

## Europe to boost micro- and nanoelectronic industries

A new initiative is supporting research, development and innovation and improvement in the entire semiconductor ecosystem

The European Semiconductor Industry Association (ESIA) welcomes the European Commission's Communication "A European strategy for micro- and nanoelectronic components and systems".

The actions outlined in the Communication will strengthen the competitiveness and growth potential of the micro- and nanoelectronics industry in Europe, and build upon the European initiative on Key Enabling Technologies (KETs) and HORIZON 2020.

ESIA believes that this Communication takes a decisive approach to reinforce the European semiconductor industry, and to increase its contribution to the wider European economy.

ESIA commends the acknowledgment that semiconductors play a crucial role in driving business transformation and responding to growing societal needs. This communication recognises the electronics industry as a key force to address the challenges the economy in the EU is facing.

ESIA fully supports the Commission's multi-level strategy including financial support for research, development and innovation (R&D&I), as well as the improvement and better use of relevant legislation. Given the very high diversity of the European market, ESIA is pleased to see the entire semiconductor ecosystem being addressed.

With a clear focus on R&D&I, market pull for new application areas, education and production, the strategy builds on the four pillars ESIA has been promoting as a basis for a dedicated European industrial policy for the micro- and nanoelectronics sector.

Rick Clemmer, ESIA President and CEO of NXP Semiconductors, states, "Pilot lines and prototyping are a welcome addition to the European R&D stimulation programme. But this concept should not be limited to semiconductor manufacturing as such. Joint semiconductor downstream application pilots will provide significant additional leverage in economic growth and employment in areas such as the Internet of Things and Smart Cities, including Intelligent Traffic Systems, Smart Buildings and Smart Grids."

Executing on this Communication has the potential to reverse the current trend in the European semiconductor market, which has seen production in Europe drop to

less than 10% percent of world production in 2011.

"Leadership in innovation is key to developing a sustainable advantage for European industry and we need to build on the scientific excellence in Europe to turn great ideas into globally competitive technologies and related manufacturing," comments Carlo Bozotti, President and Chief Executive Officer of STMicroelectronics.

"With traditional strengths in analogue and power as well as more recent innovations in technologies, companies in Europe have the capability to continue to lead the development of the next wave of electronic products. The actions outlined in the Commission's Communication demonstrate a clear commitment to Europe's future," adds Bozotti.

Hendrik Abma, Director-General of ESIA, says, "ESIA welcomes the ambition and vision of the European Commission's strategy. ESIA has consistently underlined the importance of the European semiconductor industry to the competitiveness and vitality of the European economy, as well as to tackling the grand societal challenges, such as energy efficiency and aging populations."

ESIA looks forward to the full implementation of the European Commission's strategy for micro- and nanoelectronic components and systems. ESIA is fully aware that the strategy's successful execution requires significant alignments among all stakeholders.

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## OSA receives \$250,000 from IPG for laser school

The program will enable students to present their research, learn from international speakers, and network with other students in the field of optics

The OSA Foundation has received a \$250,000 donation from IPG Photonics (IPG) for the Siegman International School on Lasers Endowment.

The gift provided by IPG will help permanently establish the program, modelled after the summer school program that first took place in 2011 at the Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP).

The donation will go toward providing world-class lecturers, important student travel grants and achievement awards as well as other general programming costs. In recognition of this significant contribution, IPG has been named co-founder of the school.

The program provides an opportunity for graduate students to present their own research to their peers, learn from an international group of accomplished speakers, and network with other students in the field of optics.

Each year, the school will take place in a different region of the world, bringing world-class education to students who may not have had access to such resources otherwise. Students interested in attending will have their applications reviewed by a program committee for approval.

“The Siegman International School on Lasers will provide students from across the globe with an opportunity to advance their education, foster future collaboration, and promote research and engineering for the optical community,” says Michael Morris, OSA Foundation board chair. “IPG’s generosity has made this important initiative a reality and we look forward to our continuing partnership in this endeavour.”

The fundraising campaign for the Siegman International School on Lasers, launched in January of 2012, is named in honour of Anthony E. Siegman, past president of the Optical Society (OSA) and founding member of the OSA Foundation Board. Siegman passed away in October 2011 at the age of 79.

“IPG is honoured to support the Siegman International School on Lasers,” comments Valentin P. Gapontsev, chairman and chief executive officer of IPG. “The future of the laser industry depends on tomorrow’s scientists and innovators; IPG is happy to provide some of the building blocks for their success.”

The first Siegman International Summer School on Lasers will take place in summer 2014. More information is available on the OSA Foundation website.

## Oxford Instruments hosts Asian seminars in the Far East

The talks included GaN-on-silicon, HB-LED, SiC and III-V developments

Oxford Instruments Plasma Technology has just completed its series of Asian seminars in Beijing, China and Hsinchu, Taiwan, attracting a record total attendance of over 250 people.



The seminar in Beijing was co-hosted by the Institute of Semiconductors, Chinese Academy of Sciences (IOS-CAS) one of the most important bases for the research and development of semiconductor science and technology in China. Its counterpart in Taiwan was co-hosted by ITRI, one of Taiwan’s leading non-profit R&D organisations with over 5,800 employees.

Both seminars featured a range of International and national speakers including Yang Fuhua from IOS-CAS in China and Chyi, Jen-Inn, Executive Vice President, National Applied Research Laboratories in Taiwan.

The talks covered a number of key areas including GaN on silicon power device development, SiC wide bandgap semiconductors for power electronics applications and MEMS devices, processes and trends.

Shao-Chung Hsu, Executive Director of ITRI South Campus gave a welcome address at ITRI, and commented, “At ITRI we actively encourage our collaborations with leading industrial companies, and are delighted to join Oxford Instruments this week and hold such an informative conference. Oxford Instruments has an excellent cleanroom facility established here at ITRI so it is fitting for us to host an event covering the wide range of applications that the Oxford Instruments systems can offer including MEMS, HBLED, ALD and III-V. “

He continued, “Talks about the recent progress in their research and development and future trends in the fabrication and applications in micro and nano structures, gave the audience from academia and industry much opportunity for discussion. We hope to hold more events like this with Oxford Instruments at ITRI.”

Frazer Anderson, Business Group Director at Oxford Instruments Plasma Technology introduced the company at both seminars and summarises the company’s pleasure at the events’ success last week,

“These technical seminars in China and Taiwan gave us and our audiences a great opportunity to spend time being updated by a wide range of eminent speakers, in a relaxed atmosphere where we can share experiences and learn more from our peers. As a company our ethos is to use innovation to turn smart science into world class products, and by working closely with partners at the top of their field and learning about their evolving requirements, their research and technological developments, we hope to achieve this,” he said.

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## **IQE’s 850nm VCSELs achieve key milestones**

The firm’s gallium arsenide (GaAs) based laser products have broken barriers in high volume photonic communications applications

IQE has announced that its vertical cavity surface emitting laser (VCSEL) devices using wafers produced at its Cardiff, UK facility have broken the 40 Gbit/s barrier at high temperatures.

This is a key milestone in the adoption of photonic technologies for a wide range of data communications applications.

Optical communications provide the only reliable means of transferring the large volumes of data at ultra-high speeds needed in today’s data centres. The computing environments in which the data is transferred generally operate at elevated temperatures which make reliable operation at high temperature an essential element for the deployment of optical components.

VCSELs provide the primary light source for short-reach optical communication and currently provide the enabling technology for high capacity optical interconnect cables in storage area networks such as data centres and server farms.

VCSEL enabled, multimode fibre optic interconnects optimised for transmission speed at a wavelength of 850 nm are also used in high performance computing systems such as computer clusters and supercomputers.

Current high speed optical interconnects use VCSEL technology to operate at serial data rates of between 10-14 Gbit/s, with devices expected to perform at 25-28 Gbit/s under development. Next generation optical interconnect standards are expected to require data rates in excess of 40 Gbit/s. Such devices will be required to operate at the high ambient temperatures expected inside datacomms equipment.

The results were achieved at a modulation bandwidth of 27GHz at 250C and 21GHz at 850C, which is the highest for any VCSEL and the data rate is the highest of any VCSEL-based optical link without equalisation. This is also the first 40 Gbit/s VCSEL operating at elevated temperatures, which is of utmost importance for practical applications.

The results also generated significant commercial interest when they were presented at the Optical Fibre Communication Conference (OFC) in Anaheim, California, last month.

Drew Nelson, CEO of IQE plc, says, “Photonics applications are emerging as a key enabling technology and the deployment of devices such as VCSELs is expected to rapidly increase over the coming years as global data usage grows exponentially.”

He continues, “IQE has a powerful reputation as a world leader in the development of a range of photonic devices and is pleased to work with notable experts in the field such as Chalmers University of Technology in the development of next generation products.”

More details of this work has been published by Chalmers University of Technology and IQE in a paper in *IEEE Photonics Technology Letters* (Vol. 25, No. 8, pp. 768-771, 2013). It reports on the successful development of VCSEL devices operating at data rates of up to 47 Gbit/s at 250C and 40 Gbit/s at 850C.

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## **A new era of atomic-scale semiconductor devices**

Scientists have demonstrated the semiconductor molybdenum sulphide can be grown in layers only one atom thick without compromising its properties

Researchers at North Carolina State University have developed a new technique for creating high-quality semiconductor thin films on the atomic scale where the films are only one atom thick.

The technique can be used to create these thin films on a large scale, sufficient to coat wafers that are two inches wide, or larger.

“This could be used to scale current semiconductor technologies down to the atomic scale, lasers, LEDs, computer chips, anything,” says Linyou Cao, an assistant professor of materials science and engineering at NC State and senior author of a paper on the work. “People have been talking about this concept for a long time, but it wasn’t possible. With this discovery, I think it’s

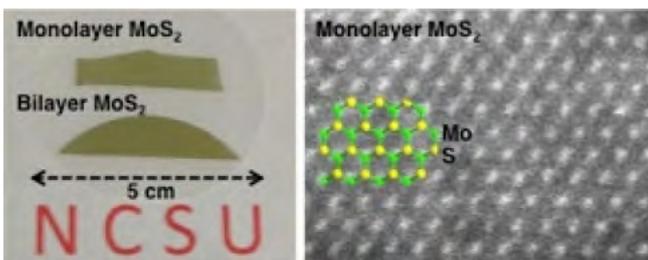
possible.”

The researchers worked with molybdenum sulphide (MoS<sub>2</sub>), an inexpensive semiconductor material with electronic and optical properties similar to materials already used in the semiconductor industry.

However, MoS<sub>2</sub> is different from other semiconductor materials because it can be grown in layers only one atom thick without compromising its properties.

In the new technique, researchers place sulphur and molybdenum chloride powders in a furnace and gradually raise the temperature to 8500C, which vaporises the powder. The two substances react at high temperatures to form MoS<sub>2</sub>. While still under high temperatures, the vapour is then deposited in a thin layer onto the substrate.

“The key to our success is the development of a new growth mechanism, a self-limiting growth,” Cao says.



MoS<sub>2</sub> structure

The researchers can precisely control the thickness of the MoS<sub>2</sub> layer by controlling the partial pressure and vapour pressure in the furnace. Partial pressure is the tendency of atoms or molecules suspended in the air to condense into a solid and settle onto the substrate. Vapour pressure is the tendency of solid atoms or molecules on the substrate to vaporise and rise into the air.

To create a single layer of MoS<sub>2</sub> on the substrate, the partial pressure must be higher than the vapour pressure. The higher the partial pressure, the more layers of MoS<sub>2</sub> will settle to the bottom.

If the partial pressure is higher than the vapour pressure of a single layer of atoms on the substrate, but not higher than the vapour pressure of two layers, the balance between the partial pressure and the vapour pressure can ensure that thin-film growth automatically stops once the monolayer is formed. Cao calls this “self-limiting” growth.

Partial pressure is controlled by adjusting the amount of molybdenum chloride in the furnace - the more molybdenum is in the furnace, the higher the partial pressure.

“Using this technique, we can create wafer-scale MoS<sub>2</sub> monolayer thin films, one atom thick, every time,” Cao explains. “We can also produce layers that are two, three or four atoms thick.”

Cao’s team is now trying to find ways to create similar thin films in which each atomic layer is made of a different material. Cao is also working to create field-effect transistors and LEDs using the technique. Cao has filed a patent on the new technique.

## Oclaro to showcase expanded laser diode portfolio

The lineup includes an 80 W fibre laser pump, an 150ps DFB seed laser, high performance diode bars at 10xx and 14xx nm and higher power 63x red diode lasers in a smaller package

Oclaro showcased several new, innovative laser diode products for fibre laser, direct diode, medical and consumer applications at the LASER World of PHOTONICS conference in Munich.

Leveraging the newest generation 9xx chip design, the BMU80 fibre-coupled, single-emitter module delivers 80 W power in a 105 µm fibre, enabling fibre laser manufacturers to reduce system complexity and achieve higher power with fewer modules.

The 1060 nm DFB seed laser, capable of 800mW peak power at 150 ps pulses and 150 kHz line-width in CW mode, enables short pulse lasers for materials processing applications with improved precision and reduced thermal effects.

Oclaro is also expanding their high power laser diode portfolio to include 10xx and 14xx nm wavelengths. Highly reliable 10xx bars enable multi-Kw direct diode systems through wavelength multiplexing with the 9xx wavelengths. The new family of 14xx nm bar and single emitter products can be used for medical, cosmetics and industrial applications.

The new additions to the visible laser diode family are 100 mW, 633 nm and 150 mW, 638 nm laser diodes.

The 633 nm laser diode offers a compact, high efficiency alternative to the existing bulky He-Ne gas lasers and enables system designers to achieve measurement accuracy, stability and speed which are essential for biomedical and inspection applications.

The 638 nm laser diode delivers 25 percent more output

power from its predecessor in a more compact 3.8mm package, ideal for the growing mobile display market.

Additional products on display at the LASER World Munich show will include Oclaro fiber-coupled bar products for DPSS pumping, stacks for medical and materials processing applications, visible diodes for medical, measurement and display, and high power VCSEL arrays for sensing and thermal applications. Oclaro will also showcase the integration capability of VCSEL arrays on a microchannel cooler.

“With a comprehensive portfolio of solutions for direct diode applications that deliver industry-leading innovation, quality and brightness, Oclaro customers can address their most challenging product performance needs,” says Yves LeMaitre, Chief Commercial Officer for Oclaro, Inc.

Mike Wale, an Oclaro Director of Active Products Research from the company’s Towchester UK site presented at the CLEO/Europe 2013 Forum.

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## Firecomms awarded ISO certifications

The laser manufacturer’s Chinese manufacturing facility has gained certification for its quality management and environmental management systems

A global innovator in the provision of fibre optic solutions and optical transceivers, Firecomms has announced that its manufacturing facility in China has been awarded ISO 9001:2008 and ISO 14001:2004 certification.



The award of ISO 9001:2008 certification indicates that Firecomms has implemented a quality management system that enables the firm to consistently provide product that meets customer and applicable statutory and regulatory requirements, and to enhance customer satisfaction through the effective application of the system. These include processes for continual

improvement of the system and the assurance of conformity to customer and applicable statutory and regulatory requirements.

“The ISO 9001:2008 certification demonstrates our on-going commitment to both the quality and reliability of our optical transceivers,” says Hsin Chia, CEO of Firecomms. “Having our own in-house ISO-certified production system enables us to easily adjust our product offering to meet the needs of our global customers, for maximum flexibility with short lead times.”

The ISO 14001:2004 certification was awarded to Firecomms for the company’s willingness and commitment to improve its environmental impact within day-to-day operations, and to constantly improve environmental performance.

Firecomms’ manufacturing facility comprises a 4,000 square metre building with a 1,000 square metre clean room facility that can be expanded to accommodate future growth. Dedicated to the manufacture of the company’s, RedLink, LC and OptoLock fibre optic transceiver products, Firecomms’ manufacturing facility has a production capacity of two million devices per month.

Located in China where the market for POF transceivers is growing significantly, the manufacturing facility is situated in Tongxiang, Zhejiang, in close proximity to major sea ports and airports.

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## Oclaro expands laser diode range : 800 to 1070nm

The innovator of optical communications and laser solutions has developed a range of laser diodes with high performance and brightness over an expanded wavelength range

Oclaro has claimed it has the industry’s broadest wavelength range of high-power, high-brightness laser diodes enabling multi-kilowatt direct diode systems.

The company’s high power laser diodes are available over a wavelength range from 800 nm to 1070 nm and are shipping in volume today.

Typical customers are laser system manufacturers targeting the industrial, semiconductor, automotive, and materials processing markets.

In addition to output power and brightness, another critical factor for scaling the power of kilowatt direct diode systems is the consistency of performance and reliability

across the entire available wavelength range that is used.

Within the wavelength range of 910 nm to 1070 nm, Oclaro offers seven standard wavelength windows with up to 200 W on a microchannel cooler and up to 120 W on the industry's standard passive mini-cooler, the Oclaro BLM.

This Oclaro family of mounted bar products enables the scaling of system power up to 15 kW. With on-going innovation efforts, Oclaro recently demonstrated output powers of up to 350 W on a microchannel cooler and 250 W on a passive mini-cooler which illustrates the technology reach.

"Today's announcement underscores our ability to deliver a comprehensive portfolio of solutions for direct diode applications and highlights the extensive technology and design capabilities we have assembled in-house to achieve industry-leading performance," says Gunnar Stolze, VP of Sales for the Global Industrial and Consumer business at Oclaro, Inc.

"By offering the industry's broadest wavelength range while consistently delivering product performance and reliability, our customers have the flexibility to scale system power as needed to better respond to their customer's needs," adds Stolze.

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## Imra on the war path with Coherent

The firm is alleging that Coherent has infringed patents essential for the precise micromachining of most materials used for microelectronics application lasers

Imra America, Inc., has filed a patent infringement lawsuit at the District Court of Duesseldorf in Germany.

The allegation has been made against the German subsidiaries of Coherent Inc., namely Coherent Kaiserslautern GmbH (formerly Lumera Laser GmbH) and Coherent (Deutschland) GmbH.

The lawsuit asserts that certain laser products marketed by Coherent in Germany infringe the German part of the European Patent 0 754 103 B1 "Method for controlling configuration of laser-induced breakdown and ablation".

The suit involves a patent considered essential for the precise micromachining of most materials used for microelectronics applications with picosecond and femtosecond lasers. Material examples given in the patent are gold and glass.

The European Patent 0 754 103 B1 was invented by Professor Gerard Mourou (Presently Professor of the Ecole Polytechnique Haut Collège) and his colleagues while he was at the University of Michigan. Imra is the exclusive licensee of this patent for all non biological applications.

"We have multiple license agreements with many laser manufacturers," Takashi Omitsu, President of Imra America remarks, "We truly try to avoid filing lawsuits. However, we could not come to a reasonable solution with them for both our existing licensees and ourselves. We filed this suit as a last resort."

Imra's technology portfolio includes over 450 US and international patents and patent applications. The company's pioneering technologies, rigorous quality control and high volume manufacturing operation make its products for scientific, OEM and industrial use. Imra also to research areas in new functional nano-materials for bio-medical and energy applications.

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## SEMI highlights the need for InP and GaAs

The organisation says that the restriction of the use of indium phosphide and gallium arsenide would have a negative impact on the semiconductor industry and Europe as a whole. SEMI has also described a new directive which will bring down patent application costs

According to Heinz Kundert, president of SEMI Europe, being able to quickly identify and seize the potential offered by new technologies and new markets is critical in the semiconductor industry. Keeping track of public policy developments is equally important.

Decisions made in a national Ministry or an EU institution can have a direct impact on the industry.

A new EU patent procedure, to be introduced by mid-2014, will significantly reduce the cost and time for a company to obtain a patent valid across 25 European states. The outcomes of the current review of substances under European EHS rules, for example, may have an impact on industry's research priorities or its access to the EU market.

This article covers these topics: 7th SEMI Brussels Forum; EU Patent Protection; GaAs and InP under Review (REACH); RoHS Exemptions Expiring; Banned Substances under RoHS; EU Conflict Minerals Debate.

The SEMI Brussels Forum is one of Europe's leading policy events for semiconductor equipment and

materials, providing a unique platform for top-level executives and EU representatives to exchange views and debate how to reinforce Europe's competitiveness in the global market.

The 7th SEMI Brussels Forum will discuss how Europe's industry and policy-makers can increase their impact - both individually and jointly to reinforce Europe's position.

How can industry build on its leading positions and expertise and optimise synergies? How can Europe balance its values and rules on free competition on one hand, with the need to provide for a global level playing field on the other?

SEMI says this is the only event that brings together top-level management and EU representatives to exchange views on how to reinforce Europe's competitiveness. More information can be accessed via the link [www.semi.org/eu/brusselsforum](http://www.semi.org/eu/brusselsforum).

**New EU Patent Procedure Offers Automatic Protection in 25 Countries and Brings Down Costs**

The new 'EU Unitary Patent', to be made available by April 2014, is expected to reduce the administrative and financial burden of patent protection across the EU. Companies will be able to fill out a single application to the European Patent Office. Once granted, the patent is automatically valid across 25 countries (all EU member states except for Italy and Spain). A single court will be created (Unified Patent Court) with jurisdiction over infringement proceedings in any of these countries.

Companies will no longer need to apply before each national body for their patent to have effect in that territory, nor satisfy local language and administrative requirements or pay local fees. Nor will they need to defend their patents in different jurisdictions and receive different, sometimes conflicting, rulings.

This new system is also expected to significantly bring down the costs of obtaining a patent. The European Commission estimates that today, a 'classic' European patent (that needs to be validated individually in 27 Member States) costs EUR (€)36 000. The new unitary patent system will bring the costs down dramatically to around €5 000, or one-seventh of today's cost.

**GaAs and InP under Review for a Possible Restriction under REACH**

A recent EU study collected information on the production, import and use of 44 substances, including GaAs and InP, in articles, as a first step towards assessing the need for a possible restriction on their use in the EU. Such a restriction (under Art. 68 REACH) could have an impact not only on European

manufacturing but also on imports.

In a joint response with other industry associations, SEMI listed the applications where these compounds are used and the lack of risk to consumers when they are completely encapsulated. SEMI further highlighted the strategic importance of these compounds for micro- and nano-electronics.

Their restriction would have a negative impact not only on industry, but on Europe as a whole. It would curb the global competitiveness of the European semiconductor manufacturing supply chain and it would deprive the EU of the industry base and products Europe needs to achieve its strategic goals for the global digital market.

GaAs and InP are the first III-V compounds being examined under the REACH microscope and SEMI is actively monitoring developments. In its upcoming advocacy activities, SEMI will collect information on risk management measures the industry has in place to avoid exposure to workers and the environment – if your company can contribute, please contact [gourania@semi.org](mailto:gourania@semi.org).

**EU RoHS Update: Exemptions are Expiring; More Substances to be Banned under RoHS**

The EU RoHS directive currently bans six substances from being used in electric and electronic equipment. Certain products of SEMI members are not covered by the Directive, such as PV panels going into fixed installations, large-scale stationary industrial tools (LSIT) and large-scale fixed installations. SEMI members also benefit from exemptions to the Directive, which allow for specific uses of the banned substances in specified quantities and for a limited period of time.

- A number of exemptions for specific applications will expire in July 2016. These exemptions can be renewed but applications for renewal need to be submitted by end of 2014. Now is therefore the time for industry to review the list of exempted applications, determine which ones are still needed and start pooling resources to draft the renewal application.

- Additional substances will be banned under RoHS by 22nd July 2014. An EU-funded study is currently underway to develop a methodology for evaluating the risk posed by hazardous substances and to determine whether they should be banned. By the end of 2013, this study will also propose additional substances that should be restricted. The European Commission will then decide on banning these substances under RoHS, the transition periods allowed for the manufacturing supply chain to adjust and start considering necessary exemptions.

The SEMI RoHS working is actively contributing to the drafting of the review methodology. For further information and to contribute to this work, please contact Sanjay Baliga at [sbaliga@semi.org](mailto:sbaliga@semi.org)

EU Conflict Minerals Debate is Launched – Potential Impact on Industry’s Sourcing of Raw Materials from Conflict Zones

The EU is now also considering whether it needs to adopt EU measures to support responsible sourcing from conflict-affected or high-risk areas. It is not yet clear what minerals or what countries a possible EU initiative would focus on, nor whether its nature would be voluntary or binding. The question is also raised whether EU measures should address specific end-products or downstream industry sectors.

A number of initiatives on conflict minerals already exist, including the OECD guidelines on due diligence and the EU is looking to build on these and reinforce transparency through the supply chain. In the U.S., the Dodd-Frank act requires companies to report annually whether they or their suppliers are using conflict minerals (tin, tungsten, tantalum and gold originating from the Democratic Republic of Congo or an adjoining country) and the EU is seeking feedback on how these provisions are working in practice.

The adoption of an EU legislative measure would have significant implications for SEMI members, creating a traceability requirement across the entire manufacturing supply chain. The consultation is available online here – deadline for submissions is 26 June 2013. For further information, please contact [gourania@semi.org](mailto:gourania@semi.org)

Further information on SEMI advocacy activities in Europe and on the SEMI Europe Advocacy Partners program can be obtained from Rania Georgoutsakou ([gourania@semi.org](mailto:gourania@semi.org); +32 2 609 5334) or Heinz Kundert ([hkundert@semi.org](mailto:hkundert@semi.org)).

## Oclaro’s shorter wavelength diode delivers higher power

Technology breakthrough was accomplished by developing new processes

Oclaro, Inc, a provider and of optical communications and laser solutions, has announced the introduction of the HL63153AT product, a red laser diode which delivers a 150 mW single-transverse-mode optical output power at a wavelength of 638 nm.

The Oclaro HL63153AT laser diode, the company says,

offers a more brilliant image display over previous versions, enabling high-lumen pico projector or miniature displays for personal computers, and other mobile devices such as smartphones, gaming, and digital cameras, making it possible to project a bright image of multimedia and information content anytime, anywhere.

The company says that the HL63153AT laser diode offers the highest single-transverse-mode optical output power at a red wavelength available on the market, with 25% more power than its predecessor. This technology breakthrough was accomplished by developing new processes including an optimized waveguide structure and fine-tuning the laser device structural parameters.

The HL63153AT laser diode has a low power consumption of 0.6 W at 150 mW optical output power, operates in the 638 nm wavelength range, and comes in a very small, 3.8 mm-diameter TO industry-standard package facilitating very compact integration.

“This newest red laser diode product has been designed as a direct result of customer requests for a shorter wavelength diode that delivers higher power in a thin package,” said Takayuki Kanno, President, Oclaro Japan and GM of the Modules and Devices Business Unit. “We are able to deliver this light source with high brightness, high operating temperature range and small-form-factor package, so that system designers can develop compact RGB modules for the mobile display market which is experiencing rapid growth leading into 2014.”

## Monitoring UV exposure with the help of AlGaN

Aluminium gallium nitride technology and can withstand continuous exposure to UV light without damage

UV lamps are used to cure coatings and adhesives in many industrial manufacturing processes. And special sensors are used to measure the intensity of the UV light applied to these surfaces.

But because these sensors age too quickly, they can only be used to record intermittent measurements.

Now, Fraunhofer researchers have developed a new generation of sensors capable of continuously monitoring UV intensity.

“UV exposure” is a term that tends to ring alarm bells, as most people associate it with sunburn and the risk of skin cancer. But ultraviolet (UV) light can also be beneficial, or indeed essential; the human body needs it to produce vitamin D.

Industry, too, makes use of UV light, for example to cure adhesives or the coatings applied to food packaging, and also to disinfect water.

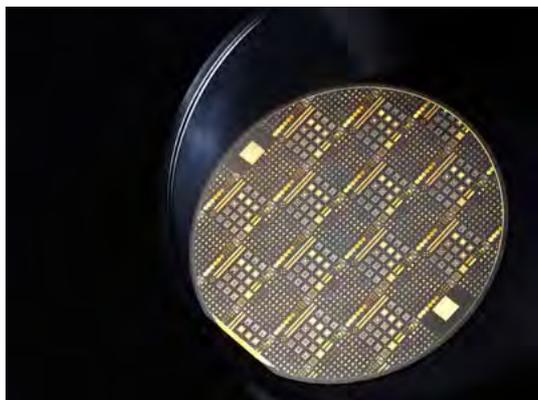
On the other hand, surfaces can be damaged if they are exposed to too much UV light, and poorly regulated UV lamps also waste energy and generate excessive amounts of ozone. UV sensors are therefore used to optimise light intensity.

Usually these sensors are made of silicon or SiC. The problem with silicon sensors is that they only deliver useful results if visible light is excluded from the measurement by external filters. Unfortunately, the filters used are very expensive and not particularly resistant to ultraviolet light. So to reduce ageing, measurements can only be taken intermittently, as snapshots.

SiC sensors have the advantage of being able to withstand longer exposure to UV light, but they only operate in a narrow spectral band. In the majority of industrial curing processes, it is the longer wavelengths that are of interest – precisely the area in which these sensors are least accurate.

Researchers at the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg have now developed a new UV sensor in collaboration with colleagues at the Fraunhofer Institutes for Manufacturing Technology and Advanced Materials IFAM, for Optronics, System Technologies and Image Exploitation IOSB, for Silicon Technology ISIT and for Physical Measurement Techniques IPM.

“Our sensor is based on aluminium gallium nitride technology and can withstand continuous exposure to UV light without damage,” says IAF project manager Susanne Kopta. “This enables it to be used not only for intermittent snapshots but also for permanent inline monitoring.” A sapphire wafer serves as the substrate for the sensors. The researchers apply epitaxial growth to deposit layers of the active material onto the substrate, in other words the layers have a crystalline structure.



Processed AlGaIn-based UV sensors on a sapphire

*wafer* (© Fraunhofer IAF)

#### Sensor for high UV intensities

The particular strength of this novel sensor is its suitability for applications involving very high UV intensities – and for tasks that require the monitoring of specific spectral ranges. This is due to the fact that the detectors can be set to operate in two different ways.

The first option is to define a maximum wavelength threshold. In this case the sensor detects all UV light emitted at wavelengths below the set limit. The alternative is to define two wavelength thresholds, thus “cutting out” certain parts of the spectrum.

“The narrowest range we have been able to achieve is a separation of 20 nanometres,” reports Kopta. This makes it possible to manufacture one sensor for UV-A, another for UV-B, and a third for UV-C.

But how do the researchers set the wavelengths to be detected by the sensor?

Kopta replies, “We do this by varying the ratio of gallium to aluminium in one of the AlGaIn layers.”

Defining this ratio is one of the challenges that the researchers are working on at present. Another challenge is growing the AlGaIn crystal – the heart of the sensor – in such a way that it is free of structural defects and impurities.

Failure to do so would result in unreliable measurements because different areas of the sensor would absorb light at different wavelengths. “The hardest part is dealing with the wide range of parameters that affect the manufacture of thin crystal films, which demands a great deal of experience,” explains Kopta.

A few demonstration models have already been produced. In the next stage of the project, the researchers aim to optimise crystal growth and obtain more sharply defined wavelength limits. They are also investigating the component durability, with very encouraging results so far.

“Initial tests have confirmed that the sensors are capable of operating for 1000 hours under high UV exposure without suffering any damage,” reports Kopta.

#### UV sensors as team players

The UV sensors are not only excellent “solo artists”; they are also great team players. By placing more than 100 detectors side by side in a strip, you obtain a UV camera. This device can be used to monitor plasma deposition processes, such as those employed to coat solar cells

with an antireflective film.

The sensor strip can also serve as a spectrometer. In this case, the UV light is first passed through a diffraction grating which splits the light into its various spectral components, like the colours of a rainbow. Each individual sensor detects a specific wavelength and provides information on the intensity of light at that wavelength.

This would be a good way of conducting ageing tests on the mercury lamps commonly used for water disinfection or UV curing. Does the lamp still emit light of the desired intensity throughout the entire spectrum, or are certain wavelengths weaker than they ought to be?

## ZnO technology could revolutionise LEDs and UV lasers

To make lasers and LEDs both n-type and p-type materials are used. Researchers have claimed that shedding excess energy at the p-n junction is what produces light in both these types of devices

Scientists from North Carolina State University say they have solved a long-standing materials science problem.

They claim that it is possible to create new semiconductor devices using zinc oxide (ZnO).

The development could pave the way for efficient ultraviolet (UV) lasers and LED devices for use in sensors and drinking water treatment, as well as new ferromagnetic devices.

“The challenge of using ZnO to make these devices has stumped researchers for a long time, and we’ve developed a solution that uses some very common elements: nitrogen, hydrogen and oxygen,” says Lew Reynolds, co-author of a paper describing the research and a teaching associate professor of materials science and engineering at NC State.

“We’ve shown that it can be done, and how it can be done and that opens the door to a suite of new UV laser and LED technologies,” continues Judith Reynolds, a research scientist at NC State and lead author of the paper.

To make laser and LED technologies, you need both “n-type” materials and “p-type” materials. N-type materials contain an abundance of free electrons. P-type materials have “holes” that attract those free electrons.

But the holes in the p-type materials have a lower energy state, which means that electrons release their excess energy in the form of light as they travel from the n-type material to the p-type material.

The shedding of excess energy at the p-n junction is what produces light in lasers and LED devices.

Scientists have been interested in using ZnO to create these devices because ZnO produces UV light, and because it can be used to make devices with relatively fewer unwanted defects than other UV emitters. This means the resulting lasers or LEDs would be more energy efficient.

However, in the past, researchers have found it hard to consistently produce stable p-type materials out of ZnO.

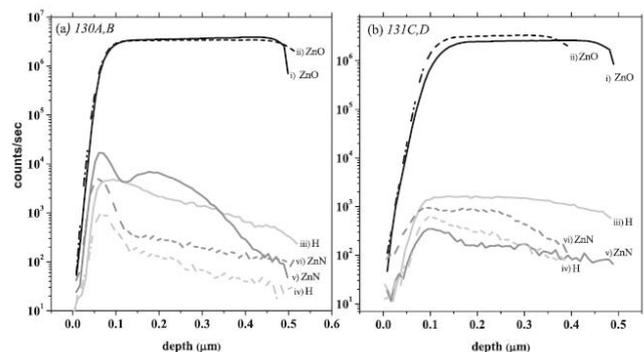
Now the scientists at NC State say they have solved that problem by introducing a specific “defect complex,” using a unique set of growth and annealing procedures in the ZnO.

The table below shows conditions used for the research.

TABLE I. Summary of process conditions for thin films of ZnO.

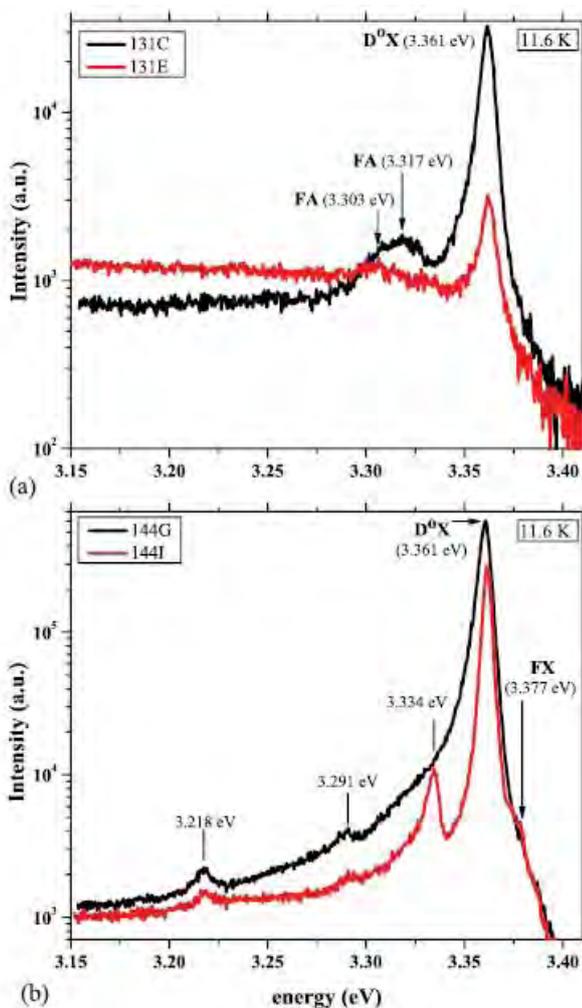
Sample I.D	450 °C <i>in situ</i> anneal		Post-growth cooldown		800 °C <i>ex situ</i> anneal	
	<i>t</i> (s)	N <sub>2</sub>	N <sub>2</sub> O	<i>t</i> (s)	Ambient	
130A	0	Y	Y	0		
130B	0	Y	Y	60	N <sub>2</sub>	
131C	300	N	Y	0		
131D	300	N	Y	30	N <sub>2</sub>	
131E	300	N	Y	30	O <sub>2</sub>	
131F	300	N	Y	300	O <sub>2</sub>	
144G	0	Y	N	0		
144H	0	Y	N	30	N <sub>2</sub>	
144I	0	Y	N	30	O <sub>2</sub>	

The defect complex looks different from a normal ZnO molecule. The zinc atom is missing and a nitrogen atom (attached to a hydrogen atom) substitutes for the oxygen atom. These defect complexes are dispersed throughout the ZnO material and serve as the “holes” that accept the electrons in p-type materials.



SIMS depth profiles of ZnO, H, and ZnN collected for

*N*-doped ZnO films of (a) *n* type sample 130A before (solid lines) and 130B after (dashed lines) an 800 C, 60s ex situ anneal in N<sub>2</sub> and (b) *p*-type sample 131C before (solid lines) and 131D after (dashed lines) a 30s ex situ anneal in N<sub>2</sub>



11.6K PL spectra of (a) 131C, 131E, and 144G, 144I before and (b) after the ex situ 8000C O<sub>2</sub> anneal

This research illustrates how to create *p*-type materials from ZnO, but the defect complex allows the ZnO *p*-*n* junction to function efficiently and produce UV light at room temperature.

More details of this work are published in the paper, "Shallow acceptor complexes in *p*-type ZnO," by Judith Reynolds *et al* in *Applied Physics Letters*, 102, 152114 published online on 19th April 2013. <http://dx.doi.org/10.1063/1.4802753>

This research was supported by the Defence Advanced Research Projects Agency.

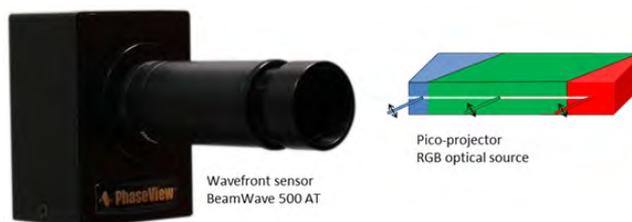
## RGB lasers for pico-projectors use a novel wavefront measurement

Pico-projectors are an emerging technology that integrates image projectors in a handheld device, offering numerous benefits for consumers. These include portability, space saving, flexible projection screen and setup time

Pico-projectors can be used as stand-alone or embedded projectors in mobile devices, for example in smartphones, tablets, digital cameras.

The market of pico-projectors is rising rapidly with already a million units a year sold as cost price decreases with volume, and is expected to continue growing as new applications appear every day.

The three major pico-projector technologies DLP (Digital Light processing), LCoS (Liquid Crystal on Silicon) and LBS (Laser-Beam-Steering), bring specific advantages and drawbacks for image quality, consumption, size or cost.



Among the main components integrated in these very small devices (battery, microcontroller, MEMS micro mirrors, projection lens), the optical RGB source block is a key component that determines the resulting image projection quality.

Each colour LD combined with collimation lens must be precisely adjusted in XYZ $\theta$  to provide same optical axis and focus conditions. Due to the low beam divergence and tight adjustment tolerances, the alignment of the light source is a complex and tedious task.

The beam waste position of the near collimated beam must be precisely adjusted within +/- 10mm range and tilt deviation may initially exceed 20 degrees.

Beyond the measurement performance, the manufacturing process dictates a limited space for the measurement device and a close position to the RGB source block.

What's more, the cost of the quality control system must be in accordance with the expected return on

investment for the mass production. Therefore the requested measurement performance and manufacturing environment constraints bring *new challenges* to manufacturing-quality-control systems.

Beam analysis in XYZ $\Theta$  dimensions can be achieved using wavefront sensing technique that provides beam propagation parameters or using standard beam profiling technique by translating a sensor on the beam propagation.

However, these latest scanning based systems with multiple image planes acquisition along the Z axis for measuring the beam waist position cannot meet the quality control needs in high volume manufacturing as exhibiting low measurement speed, large footprint and high cost.

Wavefront sensors can fulfill the adjustment requirements thanks to their real time wavefront analysis of low and high order aberrations (i.e. tilt, defocus, astigmatism).

But according to the wavefront acquisition principle, measurement capabilities can largely differ and may alter, in some cases, the measurement of critical features for the optical source alignment.

Standard wavefront sensors are based on a micro-lens array that divides the incoming light beam in smaller beams focused onto a CCD or CMOS camera.

This principle is relatively easy to implement, however it suffers from drastic limitations in terms of resolution (number of micro lenses) and tilt range acceptance (lenslet aperture).

Also, as the intensity image is sampled, these sensor types are restricted to sole wavefront analysis purpose and cannot be used as laser beam profiler for intensity distribution analysis.

The alternative wavefront sensing technology proposed by Phaseview overcomes the above limitations; instead of using a mask of microlenses, the technique relies on direct phase extraction from intensity images.

The acquisition device is a standard CCD or CMOS camera that allows real time acquisition of two image planes separated by a short distance along the propagation axis. A smart algorithm based on transport intensity equation extracts the phase information from the set of intensity images.

As a result the spatial wavefront resolution is identical to camera resolution, providing an ultra-detailed wavefront map that allows fine tuning of laser beams. The sensor aperture provides large tilt measurement range as not being limited by individual micro lens

The device also delivers simultaneous wavefront and intensity data, thus both high resolution wavefront analysis and laser beam profiling can be achieved with a single sensor.

Based on its popular wavefront sensor model BeamWave 500, PhaseView has developed a new version to match the quality control requirements for the alignment of a Pico-projector RGB light source.

The BeamWave 500 AT (AT for Alignment Tool) delivers high spatial wavefront resolution (500 x 500) with a tilt range of over of 20° and ensures defocus measurement repeatability of 0.3nm to determine the optimum beam waist position.

This compact sensor can be placed very close to the laser source and is well adapted to quality control on production line even in harsh production environment. The sensor offers the optimal performance for this application while keeping affordable cost for the mass production.

The software displays in real time the XYZ $\Theta$  adjustment parameters and beam intensity properties; it also allows data exchange to external devices for the automated quality control. In addition low and high order aberrations using Zernike analysis as well as intensity distribution analysis are provided as complementary diagnostic tools.

This measurement technique overcomes inherent limitations of conventional wavefront sensing methods to serve a challenging QC application in industrial environment, providing a fast, accurate and reliable optical source alignment tool for the Pico-projectors industry.

# Solar

## Ascent Solar debuts EnerPlex CIGS technology in China

The EnerPlex product line has changed the solar-integrated consumer electronics market. It provides consumers with lightweight and powerful charging solutions for all their portable electronics

Ascent Solar Technologies has officially entered its EnerPlex brand into the Chinese consumer market through Ascent's strategic partner, Shenzhen Radiant Enterprise.



Some of Ascent Solar's Enerplex products

Radiant Enterprise has signed a distribution agreement with D.Phone (DiXinTong Inc.), one of China's largest retailers of mobile phones and accessories.

Founded in 1993, D.Phone is a specialist in the mobile phones and accessories market. With over 1,300 stores across 25 provinces and municipalities in China, D.Phone has achieved excellent market penetration throughout China, enabling EnerPlex products to quickly reach the hands of consumers throughout the country.

Victor Lee, Ascent Solar's President & CEO, says, "D. Phone's proven history of bringing new and novel products to the Chinese market makes it the perfect company to introduce the revolutionary EnerPlex series of solar integrated products to a consumer base which has shown an endless appetite for innovative solutions."

After receiving overwhelming interest in EnerPlex products at selected D.Phone pilot stores, the EnerPlex line will be available at D.Phone stores in four of the largest regions in China. This marks for another major milestone taking EnerPlex a step closer to a well recognised consumer brand globally. The EnerPlex product line has quickly changed the paradigm of solar-integrated consumer electronics, providing consumers with lightweight, powerful and extremely durable charging solutions for all their portable electronics.

Lee continues, "The expansion of our distribution network throughout China is an extremely exciting step in the continuing development of Ascent's consumer presence throughout the world. This partnership immediately brings EnerPlex products to storefronts across China, enabling several hundred millions of consumers to interact with our products for the first time."

## Europe to boost micro- and nanoelectronic industries

A new initiative is supporting research, development and innovation and improvement in the entire semiconductor ecosystem

The European Semiconductor Industry Association (ESIA) welcomes the European Commission's Communication "A European strategy for micro- and nanoelectronic components and systems".

The actions outlined in the Communication will strengthen the competitiveness and growth potential of the micro- and nanoelectronics industry in Europe, and build upon the European initiative on Key Enabling Technologies (KETs) and HORIZON 2020.

ESIA believes that this Communication takes a decisive approach to reinforce the European semiconductor industry, and to increase its contribution to the wider European economy.

ESIA commends the acknowledgment that semiconductors play a crucial role in driving business transformation and responding to growing societal needs. This communication recognises the electronics industry as a key force to address the challenges the economy in the EU is facing.

ESIA fully supports the Commission's multi-level strategy including financial support for research, development and innovation (R&D&I), as well as the improvement and better use of relevant legislation. Given the very high diversity of the European market, ESIA is pleased to see the entire semiconductor ecosystem being addressed.

With a clear focus on R&D&I, market pull for new application areas, education and production, the strategy builds on the four pillars ESIA has been promoting as a basis for a dedicated European industrial policy for the micro- and nanoelectronics sector.

Rick Clemmer, ESIA President and CEO of NXP Semiconductors, states, "Pilot lines and prototyping are a welcome addition to the European R&D stimulation programme. But this concept should not be limited

to semiconductor manufacturing as such. Joint semiconductor downstream application pilots will provide significant additional leverage in economic growth and employment in areas such as the Internet of Things and Smart Cities, including Intelligent Traffic Systems, Smart Buildings and Smart Grids.”

Executing on this Communication has the potential to reverse the current trend in the European semiconductor market, which has seen production in Europe drop to less than 10% percent of world production in 2011.

“Leadership in innovation is key to developing a sustainable advantage for European industry and we need to build on the scientific excellence in Europe to turn great ideas into globally competitive technologies and related manufacturing,” comments Carlo Bozotti, President and Chief Executive Officer of STMicroelectronics.

“With traditional strengths in analogue and power as well as more recent innovations in technologies, companies in Europe have the capability to continue to lead the development of the next wave of electronic products. The actions outlined in the Commission’s Communication demonstrate a clear commitment to Europe’s future,” adds Bozotti.

Hendrik Abma, Director-General of ESIA, says, “ESIA welcomes the ambition and vision of the European Commission’s strategy. ESIA has consistently underlined the importance of the European semiconductor industry to the competitiveness and vitality of the European economy, as well as to tackling the grand societal challenges, such as energy efficiency and aging populations.”

ESIA looks forward to the full implementation of the European Commission’s strategy for micro- and nanoelectronic components and systems. ESIA is fully aware that the strategy’s successful execution requires significant alignments among all stakeholders.

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## Oxford Instruments hosts Asian seminars in the Far East

The talks included GaN-on-silicon, HB-LED, SiC and III-V developments

Oxford Instruments Plasma Technology has just completed its series of Asian seminars in Beijing, China and Hsinchu, Taiwan, attracting a record total attendance of over 250 people.



The seminar in Beijing was co-hosted by the Institute of Semiconductors, Chinese Academy of Sciences (IOS-CAS) one of the most important bases for the research and development of semiconductor science and technology in China. Its counterpart in Taiwan was co-hosted by ITRI, one of Taiwan’s leading non-profit R&D organisations with over 5,800 employees.

Both seminars featured a range of International and national speakers including Yang Fuhua from IOS-CAS in China and Chyi, Jen-Inn, Executive Vice President, National Applied Research Laboratories in Taiwan.

The talks covered a number of key areas including GaN on silicon power device development, SiC wide bandgap semiconductors for power electronics applications and MEMS devices, processes and trends.

Shao-Chung Hsu, Executive Director of ITRI South Campus gave a welcome address at ITRI, and commented, “At ITRI we actively encourage our collaborations with leading industrial companies, and are delighted to join Oxford Instruments this week and hold such an informative conference. Oxford Instruments has an excellent cleanroom facility established here at ITRI so it is fitting for us to host an event covering the wide range of applications that the Oxford Instruments systems can offer including MEMS, HBLED, ALD and III-V. “

He continued, “Talks about the recent progress in their research and development and future trends in the fabrication and applications in micro and nano structures, gave the audience from academia and industry much opportunity for discussion. We hope to hold more events like this with Oxford Instruments at ITRI.”

Frazer Anderson, Business Group Director at Oxford Instruments Plasma Technology introduced the company at both seminars and summarises the company’s pleasure at the events’ success last week,

“These technical seminars in China and Taiwan gave us and our audiences a great opportunity to spend time being updated by a wide range of eminent speakers, in a relaxed atmosphere where we can share experiences

and learn more from our peers. As a company our ethos is to use innovation to turn smart science into world class products, and by working closely with partners at the top of their field and learning about their evolving requirements, their research and technological developments, we hope to achieve this," he said.

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## Soitec III-V cell raises the bar with 43.6 percent efficiency

The firm's four-junction technology innovation opens the path to competitiveness in the PV industry

Soitec has revealed what it says is the industry's first four-junction solar cell device, which works under concentrated sunlight.

This breakthrough puts the company on the solar-energy industry's technology roadmap at an outstanding 43.6 percent efficiency.

The development is thanks to a strong collaboration between solar cell device and epitaxial growth centres of expertise combined with Soitec's experience in substrate-bonding and layer-transfer technologies.

Soitec believes this validates the unique roadmap enabling the target of a 50 percent efficiency level.

Soitec's four-junction solar cell was measured by the Fraunhofer ISE Calibration Laboratory.

This measurement was achieved at a concentration level of 319 suns. The new cell has demonstrated more than 43 percent energy-generating efficiency over a concentration range between 250 and 500.

Today's triple-junction solar cells used in commercial concentrator photovoltaic (CPV) modules in real-world applications are approaching their physical limits in converting sunlight into renewable energy.

Soitec's four-junction cell is designed to increase the conversion efficiency of commercial CPV systems to the highest level ever achieved by any photovoltaic technology.

The innovative four-junction cell uses two new, highly sophisticated dual-junction sub cells grown on different III-V compound materials. It allows optimal band-gap combinations tailored to capture a broader range of the solar spectrum. This maximises energy-generating efficiency.

Soitec is leveraging its Smart Stacking bonding and Smart Cut layer-transfer technologies to successfully

stack non-lattice-matched materials while also raising the possibility of re-using expensive materials.

The new cell was developed in collaboration with the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany, and the Helmholtz-Zentrum für Materialien und Energie in Berlin, which developed and deposited III-V epitaxial layers on new base materials as well as fabricating and characterising the device.

CEA-Leti, France's research institute for electronics and information technologies also participated in the project. It contributed its expertise in mechanically strong, electrically conductive and optically transparent bonding interfaces as well as layer-transfer engineering of III-V compound materials.

"Boosting efficiency levels is a key step in outperforming the economics of conventional PV. This great achievement brings strong value to our solar division and validates our strategy and business model in the solar market," says André-Jacques Auberton-Hervé, CEO of Soitec.

"Through our collaboration with the Fraunhofer and the Leti, two world-class R&D partners, our own leadership experience in materials and bonding technologies as well as our CPV commercial experience, we have been able to achieve this major advancement in a very short time. This represents a major proof-of-concept, on track to demonstrate a concentrated solar cell with 50 percent efficiency as soon as 2015," he adds.

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## Emcore wins contract for NASA green propellant infusion

Solar panels populated with Emcore's most advanced ZTJ III-V triple-junction solar cells will power a satellite that will carry the GPIM payload

Emcore Corporation, a provider of compound semiconductor-based components and subsystems for the fibre optic and solar power markets, has been awarded a contract by ATK.

The company will design and manufacture solar panels for NASA's Green Propellant Infusion Mission (GPIM) planned for launch in 2015.

ATK will integrate Emcore's solar panels into its heritage-designed solar arrays for final flight configuration for the GPIM satellite.

The GPIM project will demonstrate the practical

capabilities of AF-M315E, a high-performance green alternative to hydrazine that has traditionally been used to fuel many spacecrafts.

This innovative, low-toxicity propellant is expected to improve overall vehicle performance. It boasts a higher density than hydrazine, meaning that more can be stored in containers of the same volume, and it delivers a greater thrust per given quantity of fuel.

GPIM is supported by co-investigators. These include NASA's Glenn Research Centre and the U.S. Air Force Research Laboratory at Wright-Patterson Air Force Base in Ohio; Aerojet Corporation, a GenCorp company in Washington; NASA's Kennedy Space Centre in Florida; and the U.S. Air Force Space & Missile Systems Centre at Kirtland Air Force Base in New Mexico.

"ATK is pleased to be providing the solar arrays for the GPIM project to Ball Aerospace, and we look forward to another successful collaboration with Emcore in support of this innovative program," says Dave Messner, General Manager of ATK Space Systems in Goleta, California.

"Emcore is extremely pleased and honoured to receive this program award from ATK," adds Brad Clevenger, General Manager of Emcore's Photovoltaics Division. "Emcore has partnered with ATK on many successful missions, and we greatly value our long-standing business relationship. We look forward to supporting ATK on the Green Propellant Infusion Mission."

Emcore is a manufacturer of highly-efficient radiation-hard solar cells for space power applications. With a Beginning-Of-Life (BOL) conversion efficiency nearing 30 percent and the option for a patented, onboard monolithic bypass diode, Emcore's multi-junction solar cells provide amongst the highest available power to interplanetary spacecraft and earth orbiting satellites.

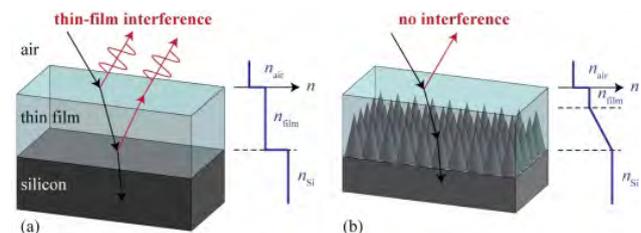
## Solar cell interference reduced by moth eye reflection

Mimicking nature can improve thin-film III-V solar cells and other optoelectronic devices



Inspired by the structure of moth eyes, researchers at North Carolina State University have developed nanostructures that limit reflection at the interfaces where two thin films meet.

This suppresses the "thin-film interference" phenomenon commonly observed in nature which could potentially improve the efficiency of thin-film solar cells and other optoelectronic devices.



Thin-film interference occurs when a thin film of one substance lies on top of a second substance.

The phenomenon of interference and no interference are depicted in the schematic above.

For example, thin-film interference is what causes the rainbow sheen we see when there is gasoline in a puddle of water.

Gasoline is transparent, but some light is still reflected off of its surface. Similarly, some of the light that passes through the gasoline is reflected off the underlying surface of the water where the two substances interface, or meet.

Because the light reflected off the water has to pass back through the gasoline, it takes a slightly different optical path than the light that was reflected off the surface of the gasoline.

The mismatch of these optical path "lengths" is what creates the rainbow sheen - and that phenomenon is thin-film interference.

Thin-film interference is a problem for devices that use multiple layers of thin films, like thin-film solar cells. because it means that some wavelengths of light are being reflected - or "lost," at every film interface.

The more thin films a device has, the more interfaces there are, and the more light is lost.

"We were inspired by the surface structure of a moth's eye, which has evolved so that it doesn't reflect light," says Chih-Hao Chang, an assistant professor of mechanical and aerospace engineering at NC State and co-author of a paper on the research.

"By mimicking that concept, we've developed a nanostructure that significantly minimises thin-film interference."

The nanostructures are built into thin films that will have a second thin film placed on top of them. The nanostructures are an extension of the thin film beneath them, and resemble a tightly-packed forest of thin cones. These nanostructures are "interfacial," penetrating into whatever thin film is layered on top of them and limiting the amount of light reflected at that interface.

Chang's team found that the an interface featuring the interfacial nanostructures reflects 100 times less light than an interface of thin films without the nanostructures.

"Our next steps are to design a solar device that takes advantage of this concept and to determine how we can scale it up for commercial applications," Chang says.

Further details of this work have been published in the article, "Antireflection Effects at Nanostructured Material Interfaces and the Suppression of Thin-Film Interference," by Qiaoyin Yanget al, *Nanotechnology* 2013, **24** 235202 [doi:10.1088/0957-4484/24/23/235202](https://doi.org/10.1088/0957-4484/24/23/235202)

The research was supported by a NASA Early Career Faculty Award and the National Science Foundation's ASSIST Engineering Research Centre at NC State.

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## Cleantech expert joins CIGS innovator XsunX

The new appointment will strengthen the firm's CIGS technological and business capabilities

XsunX, Inc. the developer of CIGSolar, a patent-pending technology for the mass production of CIGS solar cells has recruited John R. Tuttle to the the company's Advisory Board.

"John's extensive entrepreneurial background and comprehensive knowledge of the Cleantech industry is the perfect addition to XsunX at just the right time," says XsunX CEO, Tom Djokovich.

Over the last several years, the company has been developing its CIGSolar technology while navigating the solar industry-wide restructuring. Recently XsunX began its transition from focusing on its CIGSolar baseline system design and build-out to marketing of its CIGSolar® technology. The next logical step was the addition of a seasoned industry innovation and business development veteran to aid in this transition and further development of XsunX's business relationships with customers and investors.

"There's been a paradigm shift occurring at virtually every level of the solar industry including, and most significantly, how business, the capital markets, and project finance assess the value of the solar industry as a whole and, more specifically, the value of any particular technology," adds Djokovich.

"Our current requirement was to find someone with world-class CIGS experience and someone who could also "think outside of the box" - or in the CIGS business - outside of the vacuum chamber to commercialize technology. Dr. Tuttle's years of noteworthy experience at NREL elevating the science and capabilities of CIGS, and his experience transitioning innovation into operational results provides XsunX with the hands-on capabilities that we were looking for," concludes Djokovich.

Tuttle brings 30 years of experience in the semiconductor & photovoltaic industries to XsunX, and for the last several years has focused on assisting with operational and capital management of early-stage companies in the Cleantech sector. Previously, he was the co-founder, Chief Executive & Chairman of DayStar Technologies, Inc. where he took the company from 3 employees to an operational organization with world-class development and pilot production facilities, achieving an over 900% value creation for its IPO shareholders.

From 1986-1997, Tuttle held the position of Senior Scientist at NREL where his research guided the fabrication of thin-film CIGS PV devices with multiple world-record efficiencies. He has authored/co-authored over 70 publications, 14 Patent's / Patent applications, and conducted over 100 presentations about technology & business development.

He holds a Ph.D. in EE from the University of Colorado, an M.S. from the Colorado School of Mines and a B.S in Applied and Engineering Physics from Cornell University. Tuttle is joining as Senior Scientific and Business Advisor

to XsunX.

## First Solar financials shine year over year

The cadmium telluride (CdTe) solar cell manufacturer did however suffer due to the Topaz project

First Solar has announced financial results for the first quarter of 2013.

Net sales were \$755 million in the quarter, a decrease of \$320 million from the fourth quarter of 2012 and an increase of \$258 million from the first quarter of 2012.

The firm says decrease in net sales from the fourth quarter of 2012 was primarily due to less revenue recognition from its systems business projects primarily related to the Topaz project.

The increase over the first quarter of 2012 was mainly due to higher sales volumes for third-party module sales and an increase in revenue from systems projects.

The company reported first quarter net income per fully diluted share of \$0.66, compared to \$1.74 in the fourth quarter of 2012 and a loss of \$5.20 in the first quarter of 2012, which included \$444 million in pre-tax restructuring charges and costs in excess of normal warranty.

The first quarter of 2013 was impacted by pre-tax restructuring charges of \$2 million (reducing EPS by \$0.03), compared to \$25 million (reducing EPS by \$0.30) in the fourth quarter of 2012.

In both cases the pre-tax charges related to previously announced restructuring actions.

The sequential decrease in earnings was primarily due to higher revenue recognition for Topaz in the fourth quarter of 2012.

Also, temporary construction delays at the AVSR project, and pre-planned lower manufacturing utilisation as the company accelerated efforts to upgrade production lines to enable the firm to achieve near term targets on its module cost and efficiency improvement roadmaps made an impact.

Cash and Marketable Securities at the end of the first quarter were approximately \$1 billion, essentially unchanged compared to the end of the fourth quarter of 2012, and an increase of \$262 million over the first quarter of 2012. Cash flows from operations were \$66 million in the first quarter, compared to \$328 million for

the fourth quarter of 2012.

The firm also maintained its full year 2013 financial guidance as issued during the 2013 Analyst Day event held April 9, 2013. Copies of the presentation materials for both the Analyst Day event and the first quarter 2013 earnings call are posted in the Investor section of its website at [www.firstsolar.com](http://www.firstsolar.com).

“We demonstrated progress on several fronts during the first quarter, including continued strengthening of our balance sheet and additions to our pipeline,” said Jim Hughes, CEO of First Solar. “We remain on track for the year and reaffirm our full-year 2013 financial guidance and are focused on achieving our goal of new bookings to shipments ratio of one-to-one.”

## GaAs nanowires harvest solar power

A novel 3 dimensional geometry based on gallium arsenide enables trapping more light than planar structures, such as silicon solar devices, and with less material

How can we harvest the energy of the sun at a better quality and at a cheaper cost?

To find out, Anna Fontcuberta and her team in the STI Laboratory of Semiconductor Materials (LMSC) at EPFL are working on novel solutions to produce the solar cells of tomorrow.

The research of Fontcuberta, a professor in the STI LSMCL, focuses on new ways to engineer semiconducting structures, mainly with the use of nanotechnologies.

Semiconductors, thanks to their physical properties, have increased the functionality of many objects in our daily lives (microwave ovens, cars, DVD player or computers e.g.) and at the same time our quality of life.

The LSMC works on new geometries using nanowires. These are needle-like crystals of a diameter between 20 and 100 nm and several microns long.

The objective is to increase their functionality by understanding their properties and finding new ways to fabricate them. Among the many applications using nanowires is one of a higher interest to Fontcuberta and her team: solar cells.

Because of the world's urgent need to harvest greener energies, nanowire solar cells have a huge societal and

industrial potential for the future.

“We are working on nanowire solar cells using GaAs in their core, a high conducting material which absorbs light at the ideal range with respect to the solar spectrum”, explains Fontcuberta.

For example, in the 1990’s, GaAs solar cells took over from silicon devices in photovoltaic arrays for satellite applications, or power the robots that are exploring the surface of Mars.

In the LMSC, gallium and arsenide atoms are engineered (or “tricked”) in a way that they organise themselves to form wires rather than horizontal layer on layer structures (which they tend to do naturally).

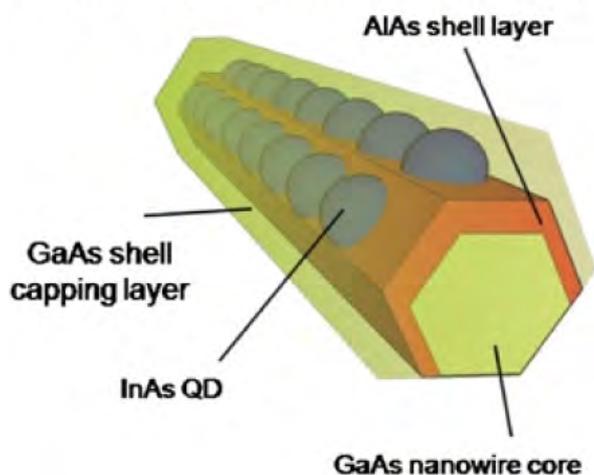
This 3 dimensional geometry is a novelty as it enables the trapping of more light than planar structures, such as silicon solar devices, and with less material.

Each vertical nanowire becomes a device that produces current. The combination of the nanowires’ small scale (one micron) and revolutionary 3D geometry (a little bit like hair standing up), enables a significant decrease of the solar cell’s cost per watt - compared to commonly used solar cells.

Apart from enhancing the light absorption, Fontcuberta and her team are working on ways to optimise it. For example, they combine the nanowire’s GaAs core with other nanoscale materials in both axial and radial directions. As an example, InAs quantum dots (or “islands”) on the nanowire play the role of stimulants for a better absorption of the light.

An illustration of an example structure is shown below.

### GaAs-core nanowire structure

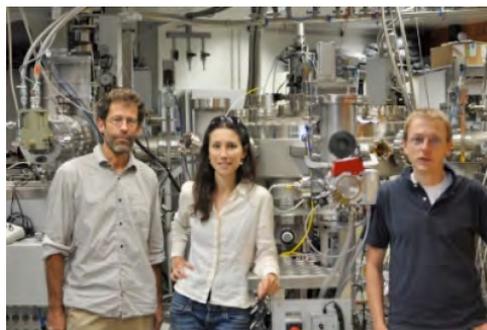


Nanowire solar cells represent the 3rd generation of solar cells because they are made on a very small scale

and can be combined in many different ways, enabling the extraction of more energy at a lower cost.

Despite encouraging applications, “It might take ten more years before nanowires can be found on the market”, explains Fontcuberta.

This is an objective, which the LMSC will pursue at EPFL.



*From left to right, Francois Morier Genoud (Laboratory of Quantum Optoelectronics), Anna Fontcuberta and Emanuele Uccelli (Laboratory of Semiconductor Materials) in front of the MBE machine which is used for nanowire research, and which both groups share*

## SEMI highlights the need for InP and GaAs

The organisation says that the restriction of the use of indium phosphide and gallium arsenide would have a negative impact on the semiconductor industry and Europe as a whole. SEMI has also described a new directive which will bring down patent application costs

According to Heinz Kundert, president of SEMI Europe, being able to quickly identify and seize the potential offered by new technologies and new markets is critical in the semiconductor industry. Keeping track of public policy developments is equally important.

Decisions made in a national Ministry or an EU institution can have a direct impact on the industry.

A new EU patent procedure, to be introduced by mid-2014, will significantly reduce the cost and time for a company to obtain a patent valid across 25 European states. The outcomes of the current review of substances under European EHS rules, for example, may have an impact on industry’s research priorities or its access to the EU market.

This article covers these topics: 7th SEMI Brussels Forum; EU Patent Protection; GaAs and InP under

Review (REACH); RoHS Exemptions Expiring; Banned Substances under RoHS; EU Conflict Minerals Debate.

The SEMI Brussels Forum is one of Europe's leading policy events for semiconductor equipment and materials, providing a unique platform for top-level executives and EU representatives to exchange views and debate how to reinforce Europe's competitiveness in the global market.

The 7th SEMI Brussels Forum will discuss how Europe's industry and policy-makers can increase their impact - both individually and jointly to reinforce Europe's position.

How can industry build on its leading positions and expertise and optimise synergies? How can Europe balance its values and rules on free competition on one hand, with the need to provide for a global level playing field on the other?

SEMI says this is the only event that brings together top-level management and EU representatives to exchange views on how to reinforce Europe's competitiveness. More information can be accessed via the link [www.semi.org/eu/brusselsforum](http://www.semi.org/eu/brusselsforum).

New EU Patent Procedure Offers Automatic Protection in 25 Countries and Brings Down Costs

The new 'EU Unitary Patent', to be made available by April 2014, is expected to reduce the administrative and financial burden of patent protection across the EU. Companies will be able to fill out a single application to the European Patent Office. Once granted, the patent is automatically valid across 25 countries (all EU member states except for Italy and Spain). A single court will be created (Unified Patent Court) with jurisdiction over infringement proceedings in any of these countries.

Companies will no longer need to apply before each national body for their patent to have effect in that territory, nor satisfy local language and administrative requirements or pay local fees. Nor will they need to defend their patents in different jurisdictions and receive different, sometimes conflicting, rulings.

This new system is also expected to significantly bring down the costs of obtaining a patent. The European Commission estimates that today, a 'classic' European patent (that needs to be validated individually in 27 Member States) costs EUR (€)36 000. The new unitary patent system will bring the costs down dramatically to around €5 000, or one-seventh of today's cost.

GaAs and InP under Review for a Possible Restriction under REACH

A recent EU study collected information on the

production, import and use of 44 substances, including GaAs and InP, in articles, as a first step towards assessing the need for a possible restriction on their use in the EU. Such a restriction (under Art. 68 REACH) could have an impact not only on European manufacturing but also on imports.

In a joint response with other industry associations, SEMI listed the applications where these compounds are used and the lack of risk to consumers when they are completely encapsulated. SEMI further highlighted the strategic importance of these compounds for micro- and nano-electronics.

Their restriction would have a negative impact not only on industry, but on Europe as a whole. It would curb the global competitiveness of the European semiconductor manufacturing supply chain and it would deprive the EU of the industry base and products Europe needs to achieve its strategic goals for the global digital market.

GaAs and InP are the first III-V compounds being examined under the REACH microscope and SEMI is actively monitoring developments. In its upcoming advocacy activities, SEMI will collect information on risk management measures the industry has in place to avoid exposure to workers and the environment – if your company can contribute, please contact [gourania@semi.org](mailto:gourania@semi.org).

EU RoHS Update: Exemptions are Expiring; More Substances to be Banned under RoHS

The EU RoHS directive currently bans six substances from being used in electric and electronic equipment. Certain products of SEMI members are not covered by the Directive, such as PV panels going into fixed installations, large-scale stationary industrial tools (LSIT) and large-scale fixed installations. SEMI members also benefit from exemptions to the Directive, which allow for specific uses of the banned substances in specified quantities and for a limited period of time.

- A number of exemptions for specific applications will expire in July 2016. These exemptions can be renewed but applications for renewal need to be submitted by end of 2014. Now is therefore the time for industry to review the list of exempted applications, determine which ones are still needed and start pooling resources to draft the renewal application.

- Additional substances will be banned under RoHS by 22nd July 2014. An EU-funded study is currently underway to develop a methodology for evaluating the risk posed by hazardous substances and to determine whether they should be banned. By the end of 2013, this study will also propose additional substances that should be restricted. The European

Commission will then decide on banning these substances under RoHS, the transition periods allowed for the manufacturing supply chain to adjust and start considering necessary exemptions.

The SEMI RoHS working is actively contributing to the drafting of the review methodology. For further information and to contribute to this work, please contact Sanjay Baliga at [sbaliga@semi.org](mailto:sbaliga@semi.org)

EU Conflict Minerals Debate is Launched – Potential Impact on Industry’s Sourcing of Raw Materials from Conflict Zones

The EU is now also considering whether it needs to adopt EU measures to support responsible sourcing from conflict-affected or high-risk areas. It is not yet clear what minerals or what countries a possible EU initiative would focus on, nor whether its nature would be voluntary or binding. The question is also raised whether EU measures should address specific end-products or downstream industry sectors.

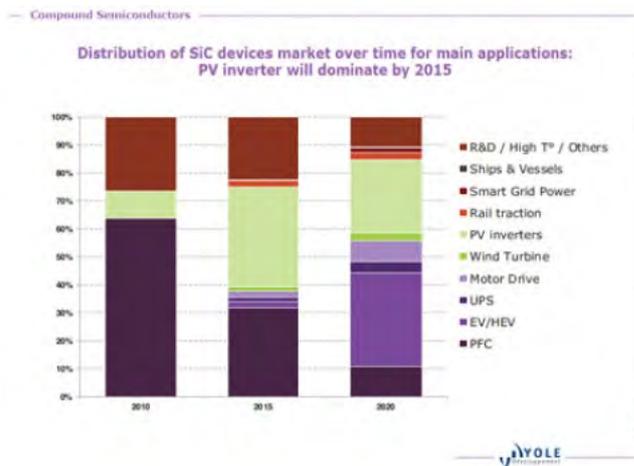
A number of initiatives on conflict minerals already exist, including the OECD guidelines on due diligence and the EU is looking to build on these and reinforce transparency through the supply chain. In the U.S., the Dodd-Frank act requires companies to report annually whether they or their suppliers are using conflict minerals (tin, tungsten, tantalum and gold originating from the Democratic Republic of Congo or an adjoining country) and the EU is seeking feedback on how these provisions are working in practice.

The adoption of an EU legislative measure would have significant implications for SEMI members, creating a traceability requirement across the entire manufacturing supply chain. The consultation is available online here – deadline for submissions is 26 June 2013. For further information, please contact [gourania@semi.org](mailto:gourania@semi.org)

Further information on SEMI advocacy activities in Europe and on the SEMI Europe Advocacy Partners program can be obtained from Rania Georgoutsakou ([gourania@semi.org](mailto:gourania@semi.org); +32 2 609 5334) or Heinz Kundert ([hkundert@semi.org](mailto:hkundert@semi.org)).

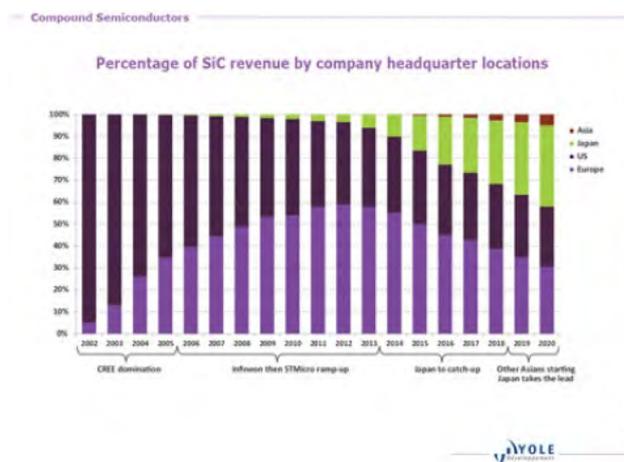
## Electric vehicle go-slow hits SiC power devices

Wide-bandgap transistor and diode growth potential is obscured by automotive qualification: PV inverter growth is a bright spot



Uncertainty hangs over the market for power devices made with wide-bandgap semiconductor SiC, due to a lack of clarity over whether and when electric vehicles will adopt them. “We have no firm estimate of when it will come,” said Philippe Roussel, business unit manager compound semiconductors, power electronics, LED & photovoltaics at market analysts Yole Développement in Lyon, France. “It’s still questionable.”

Automotive qualification can take up to five years, Roussel pointed out. So even if qualification for use in electric and hybrid electric vehicles (EV/HEV) is on-going it likely won’t be clear if SiC has been successful until 2015. And though qualification for EV/HEV charger inverters would be quicker, SiC faces a greater challenge there from silicon superjunction MOSFETs, IGBTs, and also wide-bandgap GaN devices.



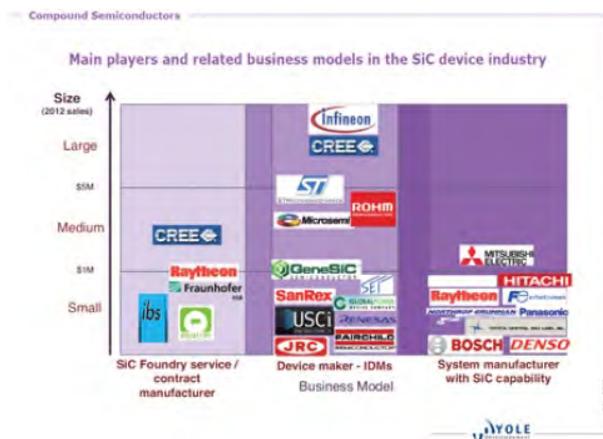
As a result, when Yole releases its latest analysis on the SiC industry on May 8, it will describe two scenarios for SiC industry evolution. Its more optimistic scenario will see SiC devices used commercially in EV/HEV from 2015 onwards, taking 11% of the market from silicon IGBT devices by 2020. In the pessimistic scenario EV/HEV implementation doesn’t start until 2017/2018, making PV inverters the number one SiC application in 2020.

Today there remains much room for increasing SiC device usage in PV inverter applications, Roussel underlined. “Each inverter manufacturer’s product line-up has just one or two models with SiC in them, among dozens,” he said. “But it’s a very positive starting point.” That helped SiC power device industry revenues to \$76 million in 2012, including R&D but excluding military use. PV inverter producers are the second industry to broadly adopt SiC devices, after manufacturers using SiC for power factor correction in high-end server power supplies.

Some PV inverter manufacturers use a SiC diode and silicon IGBT or MOSFET, and some offer full SiC inverters. “They’re just the first attempt, as inverter makers have limited their SiC development investment,” Roussel said. “They’re doing a simple replacement for silicon devices, taking the minimum extra work.” But that means that inverter producers are selling more expensive SiC products on their efficiency, without fully exploiting the material’s benefits. “The next step will definitely be a full redesign within the inverter that should fit with SiC’s high frequency and temperature capabilities, reducing the number of capacitors and inductors needed,” Roussel said.

Working with reverse costing specialist System Plus Consulting, Yole has modelled the benefits of increasing the standard PV inverter switching frequency from 12 to 32 kHz. That shortens the payback time on the SiC investment, and would make large 50 kW SiC inverters cheaper than their silicon equivalents by 2020. Such benefits will help increase annual revenues for SiC devices sold into PV inverters to \$200 million by 2020, Yole predicts.

Even though PV inverters are currently better established, EV/HEV inverter producers could still be more advanced in making full use of SiC. “Efficiency drives adoption, but putting SiC in any system could also make it smaller and lighter,” Roussel stressed. “For EV/HEV, that is just fantastic.”



## Soitec Completes \$100 Million Solar Financing Bond In South Africa

The bonds to finance the construction of a 44 MWp utility-scale CPV solar power plant

Soitec, a supplier of materials for the energy and electronics markets, has successfully finalised the ZAR 1,000,000,000 (more than \$100 millions) solar financing bond issued by CPV Power Plant No.1 Bond SPV (RF) Ltd, an affiliate of Soitec Solar GmbH.

The bonds will finance the construction of a 44 MWp utility-scale CPV solar power plant in Touwsrivier, South Africa.

This is the first publicly-listed project bond ever issued to finance a solar power plant based on CPV technology. In terms of financing solar energy projects, the bond is an inaugural transaction in South Africa and only the third such transaction worldwide.

A consortium comprised of Deloitte & Touche, The Standard Bank of South Africa, Trident Capital and Webber Wentzel Attorneys advised Soitec throughout the transaction, with the bank acting as lead manager, book runner and debt sponsor for the offering. Moody’s, the credit rating agency, confirmed the supportive investment grade rating of Baa2.za assigned to the Touwsrivier project.

“Soitec is the world’s leading developer and technology provider for utility-scale CPV projects, and the successful placement of these bonds is a significant endorsement of Soitec’s solar technology,” said Bo MacEwan, Associate Director Corporate Finance, Deloitte & Touche. “The bonds were placed with a diverse pool of South African institutional investors, pension funds and asset managers, all of whom welcomed the opportunity to participate in this inaugural offering,” said Kimon Boyiatjis, Chief Investment Officer, Trident Capital. “The bond provides developers with a new and attractive capital market instrument to finance solar power plants” said Rainer Nowak, Director at Webber Wentzel.

“We are very pleased that Soitec has succeeded with this inaugural transaction. It opens an entirely new field of project funding to the solar industry in South Africa,” said Ompi Aphane, Deputy Director General Energy Policy and Planning of the Department of Energy. “We hope that this will contribute to the creation of a new pool of financial resources that can support the South African government’s ambitious plans for renewable energy.”

“Together with the selected equity investors for this

project, we are well positioned to rapidly deploy the 44-MWp Touwsrivier project”, said Gaëtan Borgers Executive Vice President of Soitec Solar Division. “Group Five, our EPC partner, has already started construction and the first of more than 1500 high efficiency Soitec CPV systems will soon be erected on the project site. Scheduled for completion by June 2014, Touwsrivier will be the largest CPV plant in the western world.”

The success of this transaction demonstrates that Soitec can plan, finance and deliver utility scale power plants based on CPV technology “Our presence across the whole value chain is an important part of our business model” added Gaëtan Borgers.

André-Jacques Auberton-Hervé, CEO and founder of Soitec concluded “the strong support we received from bond investors demonstrates that Soitec’s utility-scale solar power plants can be financed like traditional infrastructure projects.” He added : “the market for utility-scale solar power plants is the fastest growing segment today. Leveraging our world-class manufacturing facilities, we will continue to execute our pipeline of over 440 MWp (\*) and to develop new opportunities in South Africa and other high irradiance countries.”

## EU funds program to speed up energy storage and solar energy production

The project will also focus on in-line high throughput manufacturing technologies for light weight construction for aerospace

LayTec is participating in the Seventh Framework Programme (FP7) funded by the European Union (cordis.europa.eu/fp7).

Together with several other companies, LayTec will work in a research project led by Germany’s largest research organisation – Fraunhofer-Gesellschaft.

The goal is the development of in-line high throughput manufacturing technologies for application in energy storage, solar energy production and light weight construction for aerospace.

LayTec will contribute to the development of process control concepts based on in-line monitoring methods allowing direct correlation of synthesis parameters with nanomaterial structure and composition.

## Laytec reveals non-destructive metrology tool for solar cell analysis

The firm says its new tool results in a perfect lamination process, which is the key to high-quality modules

One of the reasons why solar modules fail in the field is the insufficient cross-linking of ethylene vinyl acetate (EVA) caused by vacuum lamination process deviations or unstable EVA foil materials.

Laytec says the current standard tests are slow, destructive, manual, inaccurate and patchy.



*X-Link in action*

LayTec’s new off-line metrology system X Link provides fast, automated, non-destructive and accurate evaluation of EVA cross-linking degree immediately after lamination. It can be integrated in every solar module production line and offers 100 percent coverage for process and quality control.

The high precision measurements are performed through the backsheet without damaging the laminated surface.

They take only a few seconds, do not influence the performance of the tested module and have a precision of  $\pm 1.5$  percent.

With X Link’s direct feedback, the lamination process can be quickly optimised for better cross-linking quality by adjusting the heating zones and the duration of lamination. Laytec claims the result is a perfect lamination process, which is the key to high-quality modules.

## Quantum physics could boost III-V solar cell efficiency

InAs (indium arsenide), GaAs (gallium arsenide) and CdSe (cadmium selenide) will be some of the materials used to produce quantum dots in proposed solar cell research

The University of Salford is to conduct theoretical work on third generation solar cells.

Researchers aim to use semiconductor nanostructures in order to significantly increase the electricity produced by sunlight – from around 10 percent efficiency to 31 percent or more.



*Solar Panels*

Stanko Tomic, a professor from the University of Salford's School of Computing, Science & Engineering and his team will be designing the semiconductor quantum dots. They aim to substantially reduce the energy losses present in conventional silicon solar cells.

The conversion of extra energy, which would otherwise be lost in the form of panel heat, into electricity is a major key in increasing solar cell efficiency and reducing cost.

Conventional silicon solar cells turn between 10 and 20 percent of light into electricity – the new cells will increase this to up to 31 percent or even higher.

Tomic and his team will use methods of computational physics, which combine the laws of quantum mechanics and advanced numerical algorithms, together with supercomputer power, to describe the structure of the materials, in order to design new solar cell devices.

Tomic will design the quantum dots that will be fabricated

at the University of Manchester and the University of Tokyo, using, amongst other materials, CdSe, InAs and GaAs.

The impact of this research, which is funded, among others, by the Engineering and Physical Sciences Research Council, UK, and the Royal Society, London, is a significant development in the de-carbonising of energy supplies.

Currently, though prices are falling. Solar generation is more expensive than traditional fossil fuel generation.

Once this technology reaches efficiencies that can be mass-produced, the gap will diminish and possibly disappear, and more energy will be generated from fewer cells covering less space.

This, the researchers believe, makes them ideal for densely populated urban areas, which currently receive electricity through inefficient long distances power grids.

Tomic says, "Governments around the world are keen to pursue this technology, but in the UK we have one of the few teams able to create working cells. While the high efficiency solar cells possibly represent the energy source of the second half of the century, the work we're doing now is of utmost importance as we seek to limit carbon emissions."

## Amonix III-V cell achieves record PV module efficiency at 36 percent

The firm's multi-junction solar cell's result was verified by NREL and beats the firm's previous record of 34.2 percent

Amonix, a designer and manufacturer of concentrator photovoltaic (CPV) solar power systems, has successfully converted more than 36 percent of direct sunlight into electricity.

A module showcasing Amonix's latest-generation CPV technology has been in outdoor testing from late February to April of this year.

During this period, the Amonix module demonstrated a peak operating efficiency of 36.2 percent measured on March 14th, 2013 with a DNI of 876 W/m<sup>2</sup>, an ambient temperature of 16°C and instantaneous wind speed of 1 m/s. This breaks the previous 34.2 percent peak efficiency set by Amonix in May 2012.

Over the entire testing period, the Amonix module earned

a National Renewable Energy Laboratory (NREL). This result continues Amonix's history of leading solar module efficiency, having been the first to convert over 1/3rd of the sun's energy in May 2012, and the first to break 30 percent module efficiency in 2011.

"Amonix's proprietary technology platform allows us to continue driving rapid performance improvements in our CPV system," says Vahan Garboushian, Amonix Founder and CTO.

"The advances we have demonstrated over the last 2 years have all been with the same generation 40 percent cells, demonstrating an unprecedented cell to module conversion efficiency of greater than 90 percent."

"With improvements that are underway in cell efficiency and additional advances in our module technology, we will continue to drive efficiency higher over the coming years," he continues.

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## Ascent Solar partners with Power IT-2-Channel

The firms will work together to distribute Ascent's CIGS EnerPlex products in the UK

CIGS solar panel innovator Ascent Solar Technologies has forged a partnership with Power IT-2-Channel, a United Kingdom-based consultancy.

The two firms will work together to distribute Ascent's EnerPlex series of consumer products in the United Kingdom.

Mark Power, Managing Director of Power IT, comments, "We are delighted to have won the opportunity to take Ascent's new consumer range of solar power products to market in Europe. There is clearly significant interest in the potential of renewable energy for CE devices, especially Solar, but all too often in the past the practical reality has failed to live up to the hype. The arrival of EnerPlex's award-winning products changes the landscape entirely and offers consumers a real option when it comes to sourcing power on the move, given how much we now all rely on our mobile technology, the opportunities are huge and growing all the time."

Ascent says its EnerPlex series is changing the way consumers view solar; with the Surfr line of solar and battery integrated phone cases, as well as the Kickr line of portable solar chargers.



Ascent's Enerplex product series

EnerPlex products enable consumers to hold the power of solar in their hands. The addition of the JumpR line-up of portable batteries now enables consumers to have a complete, integrated, solar charging and storage solution for life on the go.

Rob Roche, Ascent's Vice-President of Sales and Marketing says, "This exciting partnership will immediately expand the reach of Ascent Solar's products and distribution channels in the United Kingdom, leveraging Power IT's deep connections in the British market to quickly help Ascent become a recognised player in consumer electronics and specialty outdoor gear markets."

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## Soitec to help boost solar energy in Saudi Arabia

Soitec will use its triple junction compound semiconductor cells to take advantage of the region's hot temperatures

Khaled Juffali Company (KJC), a Saudi Arabian investment company, and Soitec, a supplier of semiconductor materials for the electronics and energy industries, have signed a memorandum of understanding (MOU).

The two companies will cooperate in driving solar industry growth in Saudi Arabia and the Middle East.

Under the MOU, the two companies will create a joint venture to market and sell concentrator photovoltaic (CPV) systems in the Kingdom of Saudi Arabia.

Soitec will provide the technical and commercial solar expertise, while KJC will facilitate access to key local and regional stakeholders and share managing international joint ventures.

Soitec claims its CPV technology, which uses triple-junction cells mounted on a glass plate, achieves at least twice the performance of conventional photovoltaic technologies, making it the most cost efficient solution for high-volume power generation in regions with high direct

normal irradiation.

The KJC-Soitec MOU is in line with the on going thrust of Saudi Arabia to explore and tap into renewable energy sources, as shown by the white paper recently published by the King Abdullah City for Atomic and Renewable Energy (K.A.CARE) which outlines the competitive procurement process for solar, wind, geothermal and waste to energy projects in Saudi Arabia.

Sheik Khaled Juffali, founder and chairman of KJC, commenting on the deal, says, "Soitec holds a leading position in the CPV industry with a pipeline of projects totaling hundreds of megawatts in the USA and South Africa and operates in 14 countries around the world, including a demonstration system at the Medina College of Technology (MCT) in Saudi Arabia."

He adds, "Soitec has already demonstrated its ability to industrialise disruptive innovations with high-quality standards. Thanks to Soitec's leading CPV technology, our partnership will have a true competitive advantage and help to realise the Kingdom's high solar potential. CPV is indeed perfectly suited for countries which benefit, like Saudi Arabia, from intensive solar radiation."

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## IBM multijunction flower cell aims to hit 2000 suns

The firm's prototype HCPVT system uses a large parabolic dish, incorporating many mirror facets, which are attached to a sun tracking system. The tracking system positions the dish at the best angle to capture the sun's rays, which then reflect off the mirrors onto several microchannel-liquid cooled receivers with triple junction compound semiconductor chips

Scientists are collaborating to increase concentrating solar radiation by 2,000 times and converting 80 percent of the incoming radiation into useful energy.

The system could also provide desalinated water and cool air in sunny, remote locations where they are often in short supply.

A three-year, \$2.4 million (2.25 million CHF) grant from the Swiss Commission for Technology and Innovation has been awarded to scientists at IBM Research, Airlight Energy, a supplier of solar power technology, ETH Zurich (Professorship of Renewable Energy Carriers) and the Interstate University of Applied Sciences Buchs NTB (Institute for Micro- and Nanotechnology MNT).

Together, the institutes aim to develop an economical High Concentration PhotoVoltaic Thermal (HCPVT)

system.

Based on a study by the European Solar Thermal Electricity Association and Greenpeace International, technically, it would only take two percent of the solar energy from the Sahara Desert to supply the world's electricity needs.

According to this study, the researchers say that solar technologies on the market today are too expensive and slow to produce; they require rare Earth minerals and lack the efficiency to make such massive installations practical.

The prototype HCPVT system uses a large parabolic dish, made from a multitude of mirror facets, which are attached to a sun tracking system. The tracking system positions the dish at the best angle to capture the sun's rays, which then reflect off the mirrors onto several microchannel-liquid cooled receivers with triple junction photovoltaic chips. Each 1x1 centimetre chip can convert 200-250 watts, on average, over a typical eight hour day in a sunny region.

The entire receiver combines hundreds of chips and provides 25 kilowatts of electrical power. The photovoltaic chips are mounted on micro-structured layers that pipe liquid coolants within a few tens of micrometers off the chip to absorb the heat and draw it away 10 times more effective than with passive air cooling.

The coolant maintains the chips almost at the same temperature for a solar concentration of 2,000 times and can keep them at safe temperatures up to a solar concentration of 5,000 times.

The direct cooling solution with very small pumping power is inspired by the hierarchical branched blood supply system of the human body and has been already tested by IBM scientists in high performance computers, including Aquasar.

An initial demonstrator of the multi-chip receiver was developed in a previous collaboration between IBM and the Egypt Nanotechnology Research Centre.

"We plan to use triple-junction photovoltaic cells on a micro-channel cooled module which can directly convert more than 30 percent of collected solar radiation into electrical energy and allow for the efficient recovery of an additional 50 percent waste heat," says Bruno Michel, manager, advanced thermal packaging at IBM Research.

"We believe that we can achieve this with a very practical design that is made of lightweight and high strength concrete, which is used in bridges, and primary optics composed of inexpensive pneumatic mirrors -it's frugal innovation, but builds on decades of experience in

microtechnology.”

“The design of the system is elegantly simple,” adds Andrea Pedretti, chief technology officer at Airlight Energy. “We replace expensive steel and glass with low cost concrete and simple pressurised metalised foils. The small high-tech components, in particular the microchannel coolers and the moulds, can be manufactured in Switzerland with the remaining construction and assembly done in the region of the installation. This leads to a win-win situation where the system is cost competitive and jobs are created in both regions.”

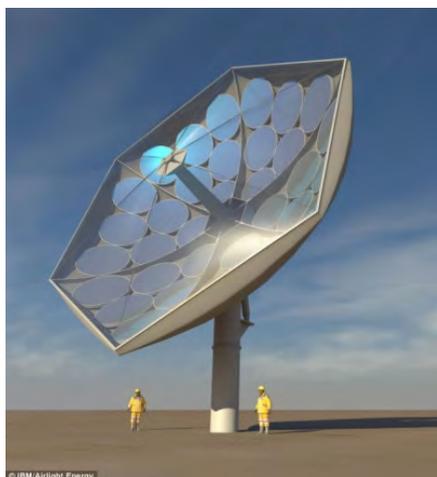
The solar concentrating optics will be developed by ETH Zurich. “Advanced ray-tracing numerical techniques will be applied to optimise the design of the optical configuration and reach uniform solar fluxes exceeding 2,000 suns at the surface of the photovoltaic cell,” explains Aldo Steinfeld, a professor at ETH Zurich.

With such a high concentration and a radically low cost design scientists believe they can achieve a cost per aperture area below \$250 per square meter, which is three times lower than comparable systems. The levelised cost of energy will be less than 10 cents per kilowatt hour (KWh).

For comparison, feed in tariffs for electrical energy in Germany are currently still larger than 25 cents per KWh and production cost at coal power stations are around 5-10 cents per KWh.

#### Water Desalination and Cool Air

Current concentration photovoltaic systems only collect electrical energy and dissipate the thermal energy to the atmosphere. With the HCPVT packaging approach scientists can both eliminate the overheating problems of solar chips while also repurposing the energy for thermal water desalination and adsorption cooling.



To capture the medium grade heat IBM scientists and engineers are utilising an advanced technology they developed for water-cooled high performance computers, including Aquasar and SuperMUC. With both computers water is used to absorb heat from the processor chips, which is then used to provide space heating for the facilities.

“Microtechnology as known from computer chip manufacturing is crucial to enable such an efficient thermal transfer from the photovoltaic chip over to the cooling liquid,” says Andre Bernard, head of the MNT Institute at NTB Buchs. “And by using innovative ways to fabricate these heat transfer devices we aim at a cost-efficient production.”

In the HCPVT system, instead of heating a building, the 90 degree Celsius water will be used to heat salty water that then passes through a porous membrane distillation system where it is vaporized and desalinated. Such a system could provide 30-40 litres of drinkable water per square metre of receiver area per day, while still generating electricity with a more than 25 percent yield or two kilowatt hours per day - a little less than half the amount of water the average person needs per day according to the United Nations, but a large installation could provide enough water for a town.

The HCPVT system can also provide air conditioning by means of a thermal driven adsorption chiller. An adsorption chiller is a device that converts heat into cooling via a thermal cycle applied to an absorber made from silica gel, for example.

Adsorption chillers, with water as working fluid, can replace compression chillers, which stress electrical grids in hot climates and contain working fluids that are harmful to the ozone layer.

Scientists envision the HCPVT system providing sustainable energy and potable water to locations around the world including southern Europe, Africa, Arabic peninsula, the southwestern part of the United States, South America, and Australia.

Remote tourism locations are also an interesting market, particularly resorts on small islands, such as the Maldives, Seychelles and Mauritius, since conventional systems require separate units, with consequent loss in efficiency and increased cost.

A prototype of the HCPVT system is currently being tested at IBM Research in Zurich. Additional prototypes will be built in Biasca and Rueschlikon, Switzerland as part of the collaboration.

## UK funds III-V-on-silicon cell development

EPSRC awards £600,000 for new research for solar cells

Huiyun Liu and Alwyn Seeds from University College of London have been awarded £601,519 from the EPSRC to develop low-cost and high-efficiency III-V quantum-dot (QD) solar cells on silicon substrates.

The research will be in collaboration with Bristol University who will do the modelling and characterisation. The grant in total is worth around £1 million over 42 months.

To help combat climate change, the UK has a target to reduce carbon emissions by 80 percent by 2050.

This is a huge task requiring changes to energy generation and supply. To limit the impact on scarce natural resources and the environment, these reductions need to be delivered by providing affordable green energy.

This research project will address this target by developing high-efficiency and low-cost solar cells by growing III-V compound semiconductor self-organised QD structures on cheap and plentiful silicon substrates.

The researchers aim to exploit the advantages of both QD technology and germanium-on-silicon substrates to develop both multi-junction solar cell and intermediate band solar cell design.

UCL will carry out the epitaxial material growth of III-V on germanium-on-silicon substrates by MBE at the department of Electronic and Electrical Engineering, and the device fabrication in the London Centre for Nanotechnology.

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## Cree works with Delta Energy with solar SiC

Cree's SiC MOSFET technology could significantly improve weight, cost and efficiency in PV inverters

Cree, and Delta Energy Systems say they have made a breakthrough in the photovoltaic (PV) inverter industry with the release of Delta's new generation of solar inverters.

They utilise Cree's SiC power MOSFETs.

The use of SiC MOSFETs in the next-generation PV

inverters can enable significant new milestones in power density, efficiency and weight.

"The next-generation PV inverters from Delta are designed to set a new milestone of power density by utilising SiC MOSFETs," comments Klaus Gremmelspacher, head of research and development for PV inverters at Delta Energy Systems. "The SiC MOSFETs from Cree were essential for us to realise our goals for new, high-power inverters that are lightweight and have industry-leading efficiency."

Cree released the first SiC MOSFETs in 2011 and dramatically improved second-generation SiC MOSFETs in 2013.

Now, as a milestone product announcement, Delta Energy Systems, a subsidiary of Delta Electronics Group, one of the world's largest providers of power management solutions, has incorporated Cree SiC MOSFETs into its next-generation solar power inverter.

Utilising 1200V SiC MOSFET's in an 11kW PV inverter, Delta has already been able to extend the DC input voltage range while maintaining and even increasing the maximum efficiency of its previous products.

The Delta 11kW booster, which employs Cree's SiC MOSFET and now has 1kV DC input instead of 900V, is targeted for release in Q2 2013.

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## Solar Junction & IQE to further develop satellite III-V cells

After surpassing its own world record in October 2012 of nitride based modules of 44 percent efficiency, Solar Junction is teaming up with IQE to supply the European Space Agency

Silicon Valley-based Solar Junction, a developer of high-efficiency multi-junction solar energy cells for the concentrated photovoltaic (CPV) market, is in contract negotiation with IQE.

IQE is a global supplier of semiconductor wafers for the development of next-generation satellite solar cells for the European Space Agency.

"Solar Junction and IQE have been working closely for the past year as strategic manufacturing partners of the world's most efficient multi-junction solar cells. Our dilute nitride technology and high-efficiency roadmap is a proven and sustainable pathway for present and future

space and terrestrial applications. Winning this contract proves that we're on-track. We're proud to be the best solution for the European Space Agency," states Jim Weldon, CEO of Solar Junction.

Solar Junction surpassed its own world record in October 2012, achieving 44 percent efficiency at a concentration of 942 suns. This record continues to demonstrate the value of its proprietary Adjustable Spectrum Lattice Matched (A-SLAM) architecture.

A-SLAM provides material bandgap tuneability to maximise the absorbed sunlight within CPV modules, thereby increasing the efficiency and energy harvested. Additionally, A-SLAM maintains the lattice-matched paradigm, which has been the foundation of semiconductor and multi-junction solar cell reliability for decades.

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## Power Electronics

### Anadigics announces GaN amp for 1.2 GHz CATV systems

The firm's gallium nitride power doublers provide excellent output power, linearity, and bit error rate performance for CATV system amplifier and deep fibre node applications

Anadigics has introduced the ACA2429 GaN power doubler surface mount IC supporting operation up to 1.2 GHz.



The company's GaN line amplifiers combine Anadigics' MESFET technology with a GaN output stage in a proven package to deliver exceptional performance and reliability in CATV infrastructure applications.

With a combination of high gain, output power, and linearity coupled with low current consumption and bit error rate (BER), Anadigics' GaN line amplifiers can be used as output power doublers for system amplifiers and deep fibre nodes.

This level of performance provides a power efficient "green" solution that saves energy and ensures distortion free video and audio in an advanced fully-loaded spectrum.

"New high speed HFC networks are demanding higher gain, output power and operating frequencies to provide additional video capabilities and increased data speeds," says Tim Laverick, vice president of Infrastructure Products at Anadigics.

"These systems continue to require exceptionally linear amplification at greater gain and output power levels than 1 GHz systems to ensure quality and reliability. Anadigics has responded to this challenge by developing GaN line amplifier solutions that combines our field-proven, highly linear GaAs technology with a high power GaN output stage in our reliable surface mount package platform."

Anadigics' ACA2429 GaN power doubler provides 25 dB gain with +60 dBmV output power and 1.2 GHz bandwidth.

The new ACA2429 delivers this performance with 10 W of power consumption in a standard surface mount package. The firm's GaN surface mount line amplifiers offer exceptional composite triple beat (CTB), composite second order (CSO), cross modulation, and carrier-to-intermodulation noise (CIN) characteristics for optimal performance in a fully-loaded spectrum.

The Anadigics GaN line amplifiers have a high gain, output power and isolation and operate at 24V with 420 mA current consumption. With a positive slope cable equivalent, the devices have a very low bit error rate. The GaN output stage increases power efficiency and minimises the operating (bias) current and have a reliable 16-lead SOIC surface mount package.

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### TriQuint's GaN & GaAs power doublers boost CATV performance

The firm has released GaAs (gallium arsenide) and gallium nitride products to speed up uninterrupted connectivity

TriQuint Semiconductor has released a new GaN

integrated power doubler with superior performance for fast-growing CATV infrastructure.

The firm's new GaN MMIC amplifier offers high gain (24dB) and excellent composite distortion performance (CTB/CSO), which is a critical characteristic in multi-carrier CATV environments.



TriQuint has also released its new GaAs power doubler that delivers the highest gain and output power among 'green' 12 Volt CATV amplifiers. The new amplifier provides RF output of +58dBmV/ch while consuming less than 8W, making it one of the highest output 12V GaAs solutions in the CATV industry. Thanks to its low power consumption and gain, it can replace the equivalent of two legacy devices.

"TriQuint continues to expand solutions for cable TV infrastructure. Early customer feedback has been very positive on high output amplifier products," comments James L. Klein, Vice President and General Manager for TriQuint's Infrastructure and Defense Products. "Today's homes, schools and businesses are looking to cable and fibre operators to provide high speed uninterrupted connectivity to ensure access for digital education and entertainment. TriQuint's GaN and GaAs product innovations are key enablers for the systems."

The growth of CATV technologies is important to delivering sought-after content, notes Directing Analyst for Broadband Access and Video, Jeff Heynen, of Infonetics Research.

"Cable operators are gaining significant traction with DOCSIS 3.0 in North America, Europe, Korea and Japan; they're in the early stages of rolling out video gateways that combine DOCSIS CPE with video transcoding capabilities to deliver whole-home, multi-screen service; we anticipate hearty growth for the devices over the next few years," says Heynen.

TriQuint says its innovative CATV / FTTH products deliver improved system-level performance. They are offered as surface-mount, 40-pin 5x7mm QFN packages which drive cost-effective direct-to-board assembly.

Samples and evaluation boards are now available; both devices are production-ready.

## NXP bags £2 million for GaN power research in the UK

The Stockport based firm has been awarded the cash by the UK government to develop gallium nitride electronics

The UK Chief Secretary to the Treasury, Danny Alexander, has announced a £2 million boost for research into the development of a breakthrough electronics material, GaN at one of the UK's leading electronics firms in Stockport.

The funding, which comes from the government's Regional Growth Fund (RGF), will support a private sector investment of over £7.5 million.

This investment safeguards over 400 existing jobs, creates up to 100 new positions in Stockport and firmly establishes the UK as a global research hub for the world-leading electronics firm NXP.

NXP Semiconductors UK successfully bid for funding to develop its next generation of power semiconductors using GaN.

GaN is more efficient than conventional silicon and as a result is likely to become a vital resource for the power industry, and future electronics market. Eventually this material could replace traditional silicon components in power electronic systems such as used in car systems, mobile phones and communications infrastructure as well as cloud computing.

The funding has been awarded as part of the third round of the Regional Growth Fund and will be used to recruit extra research and development staff, make prototype models, consult the UK's leading academics and provide equipment for the development phase. It will support NXP's investment to create a leading centre for power semiconductors in its Manchester facility, as well as local businesses and suppliers.

Danny Alexander, speaking in Manchester says, "I'm very pleased that money from the Regional Growth Fund is supporting the world-leading GaN research facility in Stockport which is a great boost for the local area, supporting a huge private sector investment and local jobs."

"The Regional Growth Fund gives us the opportunity to drive forward innovative projects like this and shows we are doing everything we can to boost growth and the position of the UK as a global leader in science and innovative technology."

The government's Regional Growth Fund (RGF) is a £2.6 billion fund operating across England from 2011 to

2016. It supports projects and programmes that lever private sector investment to create economic growth and sustainable employment.

The first three rounds will generate over £13 billion of private sector investment and create or safeguard over 500,000 jobs. The fourth round of RGF will make a further £350 million available in the pot and bidding has now closed. For more information please go to: [www.gov.uk/understanding-the-regional-growth-fund](http://www.gov.uk/understanding-the-regional-growth-fund)

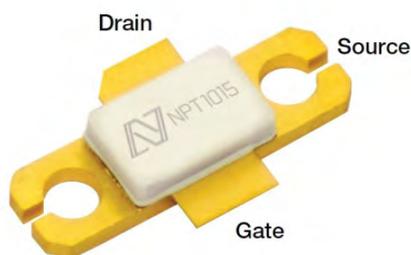
Round 4 closed on 20th March. Over 300 bids have been received in Round 4, competing for a share of £350 million. Bids are being appraised and results will be announced in the summer. A regional summary of bids received in this round was published on 5th April 2013.

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## Nitronex process creates industry's toughest GaN transistor

The firm has qualified its gallium nitride transistor for military and satellite communications, broadband, RADAR, wireless and point to point microwave applications

Nitronex, a designer and manufacturer of GaN based RF solutions for the defence, communications, cable TV, and industrial & scientific markets, has fully qualified the robust NPT1015 transistor.



The NPT1015 is a 28V, DC-2.5GHz, 50W power transistor with 15dB saturated gain and 65 percent peak drain efficiency at 2GHz.

The thermal resistance of the NPT1015 transistor is 1.9°C/W, which is among the lowest in the industry in this power class. This GaN technology is capable of surviving the industry's most severe robustness tests without significant device degradation.

Developed under an entirely new design process, the NPT1015 leverages Nitronex's existing 28V NRF1

process platform, which has been in volume production since 2009. One hundred NPT1015 devices from four wafers were subjected to a 15:1 VSWR at all phase angles with 90°C base plate temperature.

During VSWR testing, all devices operated in a saturated average power condition driven by a 4000 carrier 200MHz wideband signal with a 19.5dB peak-to-average ratio. The devices showed 100 percent survivability and only ~ 0.2dB average change in saturated output power.

"The NPT1015 is a robust next-generation product, as it incorporates significant thermal management improvements that increase breakdown and lowers thermal impedance. We are using these same techniques in our new 48V product line. Nitronex is very excited about the advancements in product robustness and reliability that put our GaN-on-Si devices on par or ahead of competitive products that primarily use GaN-on-SiC," says Greg Baker, president and CEO at Nitronex.

Nitronex says its patented SIGANTIC GaN-on-Silicon process is the only production qualified GaN process using an industry standard 4" silicon substrate. This results in a robust, scalable supply chain and positions Nitronex well for the growth expected from emerging GaN markets such as military communications, broadband, RADAR, commercial wireless, satellite communications and point to point microwave.

Fully qualified NPT1015 transistors are now available from stock to 12 weeks, and can be purchased through the Nitronex sales channel and distribution.

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## SPTS & QMF unite to grow SiC on 300mm silicon

The aim of the joint project is to provide a cost-effective buffer material to enable fabrication of gallium nitride (GaN) devices on silicon substrates

The Queensland Micro and Nanotechnology Facility (QMF) of Griffith University and industry partner SPTS Technologies have announced the epitaxial growth of 3C SiC films on 300mm silicon wafers.

This breakthrough is the result of over 10 years research at QMF on low temperature SiC deposition on silicon and the joint development by QMF and SPTS of a commercial reactor to extend the epitaxial growth process to commercial scale production of SiC coated silicon wafers.

The ultimate target of the joint project is to provide a cost-effective buffer material to enable fabrication of GaN

devices on silicon substrates.

Fabricating GaN LEDs and power devices on large diameter silicon wafers is viewed as a path to improve performance and reduce cost, thereby increasing commercial acceptance of these devices. However, existing buffer layers used to bridge the large thermal and lattice mismatch between silicon and GaN are costly and not completely effective for large scale production.

A 3C-SiC film provides an effective buffer layer lattice-matched for GaN growth on silicon, as well as an impervious barrier to prevent silicon from diffusing into GaN, of particular concern to power devices.

Initial estimates are that the new SiC on silicon coating process in volume production would add no more than \$25-35 to the cost of a silicon wafer, substantially increasing the appeal of silicon as a substrate for LEDs and GaN power devices.

“We believe we are the first in the world to grow 3C-SiC epitaxially on 300mm silicon wafers, which means following the same crystal structure as the silicon crystal substrate,” says Alan Iacopi, QMF Director of Operations.

“The reactor development project with SPTS has allowed the QMF R&D process to be extended from small wafers up to 300mm wafers with semiconductor industry specifications; in fact, we have already achieved SiC film thickness uniformities of around 1 percent on 300mm wafers using the new reactor,” he adds.

“SPTS is excited to be a partner in this project, as we see the QMF SiC technology as a potential breakthrough in reducing the cost of LEDs and improving the performance of GaN power devices,” according to William Johnson, President and CEO of SPTS.

He continues, “Based on our extensive background in vertical furnace technology, the new reactor has been designed for high temperature vacuum processing of batch loads of 150mm to 300mm wafers, with process automation suitable for commercial application. There are a number of buffer and template wafer suppliers offering alternative solutions; however, we see a strong business case for device manufacturers adopting the QMF/SPTS SiC solution to optimize process and control substrate costs.”

Iacopi adds, “The Griffith University and SPTS partnership has far reaching implications in terms of demonstrating how Australian research entities (like QMF) can collaborate with international industry to advance frontier technologies and bring industrial benefit to Queensland. We have all the ingredients to develop a high tech economy in Queensland, including technically leading Universities, the Australian National Fabrication

Facility infrastructure, entrepreneurial spirit, and start-up company investment support.”

## Europe to boost micro- and nanoelectronic industries

A new initiative is supporting research, development and innovation and improvement in the entire semiconductor ecosystem

The European Semiconductor Industry Association (ESIA) welcomes the European Commission’s Communication “A European strategy for micro- and nanoelectronic components and systems”.

The actions outlined in the Communication will strengthen the competitiveness and growth potential of the micro- and nanoelectronics industry in Europe, and build upon the European initiative on Key Enabling Technologies (KETs) and HORIZON 2020.

ESIA believes that this Communication takes a decisive approach to reinforce the European semiconductor industry, and to increase its contribution to the wider European economy.

ESIA commends the acknowledgment that semiconductors play a crucial role in driving business transformation and responding to growing societal needs. This communication recognises the electronics industry as a key force to address the challenges the economy in the EU is facing.

ESIA fully supports the Commission’s multi-level strategy including financial support for research, development and innovation (R&D&I), as well as the improvement and better use of relevant legislation. Given the very high diversity of the European market, ESIA is pleased to see the entire semiconductor ecosystem being addressed.

With a clear focus on R&D&I, market pull for new application areas, education and production, the strategy builds on the four pillars ESIA has been promoting as a basis for a dedicated European industrial policy for the micro- and nanoelectronics sector.

Rick Clemmer, ESIA President and CEO of NXP Semiconductors, states, “Pilot lines and prototyping are a welcome addition to the European R&D stimulation programme. But this concept should not be limited to semiconductor manufacturing as such. Joint semiconductor downstream application pilots will provide significant additional leverage in economic growth and employment in areas such as the Internet of Things and Smart Cities, including Intelligent Traffic Systems, Smart

Buildings and Smart Grids.”

Executing on this Communication has the potential to reverse the current trend in the European semiconductor market, which has seen production in Europe drop to less than 10% percent of world production in 2011.

“Leadership in innovation is key to developing a sustainable advantage for European industry and we need to build on the scientific excellence in Europe to turn great ideas into globally competitive technologies and related manufacturing,” comments Carlo Bozotti, President and Chief Executive Officer of STMicroelectronics.

“With traditional strengths in analogue and power as well as more recent innovations in technologies, companies in Europe have the capability to continue to lead the development of the next wave of electronic products. The actions outlined in the Commission’s Communication demonstrate a clear commitment to Europe’s future,” adds Bozotti.

Hendrik Abma, Director-General of ESIA, says, “ESIA welcomes the ambition and vision of the European Commission’s strategy. ESIA has consistently underlined the importance of the European semiconductor industry to the competitiveness and vitality of the European economy, as well as to tackling the grand societal challenges, such as energy efficiency and aging populations.”

ESIA looks forward to the full implementation of the European Commission’s strategy for micro- and nanoelectronic components and systems. ESIA is fully aware that the strategy’s successful execution requires significant alignments among all stakeholders.

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## Element Six acquires Group4 Labs` GaN-on-diamond IP and assets

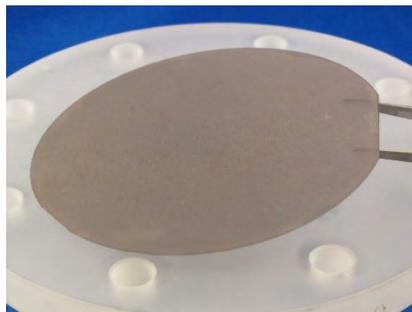
Synthetic diamond enables higher performance gallium nitride devices. This results in smaller, faster and higher power electronic devices for defence and commercial applications

Element Six has acquired the assets and intellectual property of Group4 Labs, Inc. (Group4), a specialist in GaN-on-diamond semiconductor technology for RF and high-power devices.

The acquisition will expand Element Six’s semiconductor portfolio for defence and commercial applications. The

assets were acquired through an assignment for the benefit of creditors from Group4 (Assignment for the Benefit of Creditors), LLC.

Group4 claims to have developed the first commercially available composite semiconductor wafer that includes GaN and diamond. Designed for manufacturers of transistor-based circuits with high power, temperature and frequency characteristics, the GaN-on-diamond system enables rapid, efficient and cost-effective heat extraction.



*GaN-on-diamond wafer*

This process reduces the operating temperatures of packaged devices, addressing heat issues that account for more than 50 percent of all electronic failures. Synthetic diamond dissipates heat up to five times better than existing materials, such as copper and SiC, enabling device manufacturers to produce smaller, faster and higher power electronic devices, with longer life spans and improved reliability.

When implemented within power amplifiers, microwave and millimetre wave circuits, GaN-on-diamond systems pose numerous benefits and applications within the defence and commercial sectors. This includes deployment in cellular base stations, radar sensing equipment, weather and communications satellite equipment, and inverters and converters typically used in hybrid and electronic vehicles.

The Group4 GaN-on-diamond technology was a critical element of TriQuint Semiconductor’s device, which won the Compound Semiconductor Industry Award in March. TriQuint demonstrated its new GaN-on-diamond, high electron mobility transistors (HEMT) in conjunction with partners at the University of Bristol, Group4 and Lockheed Martin under the Defence Advanced Research Projects Agency’s (DARPA) Near Junction Thermal Transport (NJTT) program.

TriQuint has designed devices using this technology to achieve up to a three-fold improvement in heat dissipation, the primary NJTT goal, while preserving RF functionality. This would translate into a potential reduction of the power amplifier size or increasing output

power by a factor of three.

“GaN-on-diamond wafers are poised to take a centre seat in many of our customers technology roadmaps, as new developments demonstrate its ability to dramatically reduce device temperatures, while maintaining output performance,” says Adrian Wilson, head of technologies for Element Six.

He continues, “With the acquisition of the GaN-on-diamond process developed by Group4, we plan to continue to support the market’s growth trajectory, ramping up manufacturing capabilities to deliver innovative synthetic diamond solutions to meet emerging market demands.”

Founded as a startup in 2003, Group4 has partnered with Element Six since 2008. “The scaling up of GaN-on-diamond wafer manufacturing volumes will need the unique heft, skill, and synergy of Element Six to make it possible,” says Felix Ejeckam, Chairman and CEO of Group4. “We believe that our customers will benefit enormously from this GaN-on-diamond process acquisition.”

Element Six’s Technologies division continues to experience strong market success, growing 20 percent per annum.

Element Six is a member of the De Beers group of companies. The firm designs, develops and produces synthetic diamond supermaterials. It operates worldwide with its head office registered in Luxembourg, and primary manufacturing facilities in the U.S. China, Germany, Ireland, Sweden, South Africa and the U.K.

The firm’s supermaterial solutions are used in applications such as cutting, grinding, drilling, shearing and polishing, while the extreme properties of synthetic diamond beyond hardness are already opening up new applications in a wide array of industries such as optics, water treatment, semiconductors and sensors.

The 100 mm GaN-on-diamond wafer uses Element Six’s synthetic diamond to enable high performance semiconductor technology, allowing manufacturers to produce smaller, faster and higher power electronic devices.

## IMRE uses LayTec tool for 200mm GaN-on-silicon

The EpiCurve Triple TT in-situ monitoring system is being used to develop epiwafers for InGaN/GaN LEDs and GaN power electronic devices

In his invited talk at the LED Technology Forum in Singapore Sudhiranjan Tripathy of IMRE (Institute of Materials and Research Engineering, A\*STAR revealed the latest results of GaN growth on 200 mm diameter silicon.

The conference took place between 7th and 10th May.

Tripathy’s team uses LayTec’s *in-situ* monitoring system EpiCurveTriple TT to develop epiwafers for InGaN/GaN LEDs and GaN power electronic devices.

EpiCurve Triple TT is ideally suited for 200 mm real time wafer characterisation because of its 3 sensor heads for radial analysis of growth conditions. It provides wafer bow and temperature measurements, as well as simultaneous detection of growth rate and surface morphology.

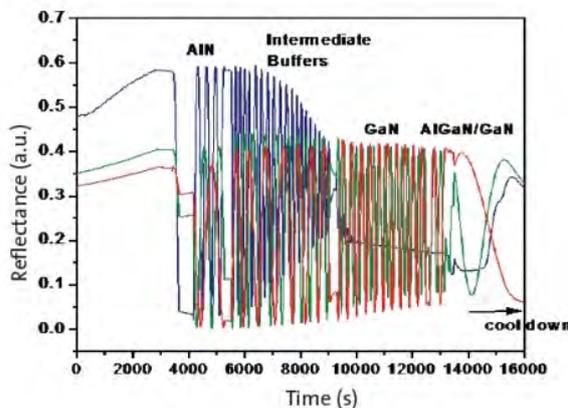


Fig. 1: Reflectance monitoring of AlGaIn/GaN HEMT structure grown on 1.0 mm thick 200 mm diameter Si (111) at IMRE: blue - 405 nm, green - 633 nm, red - 950 nm

Fig. 1 shows reflectance profiles at 3 wavelengths: 950 nm for emissivity correction of pyrometry, 633 nm for analysis of thick layers e.g. GaN buffer, and 405 nm for thin layers. Fig. 2 demonstrates how the 405 nm reflectance is used for individual *in-situ* tuning of each well and barrier within the multiquantum wells stack.

The *in-situ* signal (Fig. 2 - left) perfectly corresponds with the multi-quantum wells (MQWs), which can be seen in the scanning transmission electron microscopy (sTEM, Fig. 2 - right).

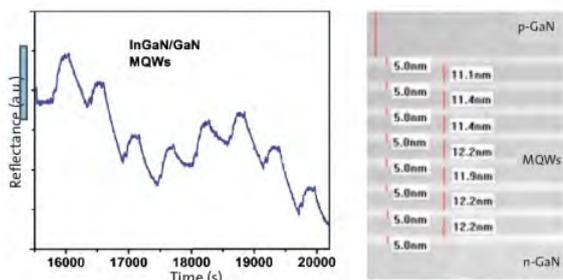


Fig. 2: 405 nm reflectance (left) of InGaN/GaN MQW stacks and the corresponding STEM image of the MQWs (right).

According to Tripathy’s team, LayTec *in-situ* metrology is a key element for identifying the epitaxial process potentials. In comparison to the time consuming, destructive *ex-situ* cross section transmission electron microscopy analysis, the *in-situ* tool provides real time information on growth thickness and homogeneity already during growth.

LayTec says its system has reduced significantly IMRE’s R & D cycles for epitaxial growth optimisation and enables faster industrialisation of the GaN-on-Silicon technology.

## Oxford Instruments hosts Asian seminars in the Far East

The talks included GaN-on-silicon, HB-LED, SiC and III-V developments

Oxford Instruments Plasma Technology has just completed its series of Asian seminars in Beijing, China and Hsinchu, Taiwan, attracting a record total attendance of over 250 people.



The seminar in Beijing was co-hosted by the Institute of Semiconductors, Chinese Academy of Sciences (IOS-CAS) one of the most important bases for the research and development of semiconductor science and technology in China. Its counterpart in Taiwan was co-hosted by ITRI, one of Taiwan’s leading non-profit R&D organisations with over 5,800 employees.

Both seminars featured a range of International and national speakers including Yang Fuhua from IOS-CAS in China and Chyi, Jen-Inn, Executive Vice President, National Applied Research Laboratories in Taiwan.

The talks covered a number of key areas including GaN on silicon power device development, SiC wide bandgap semiconductors for power electronics applications and MEMS devices, processes and trends.

Shao-Chung Hsu, Executive Director of ITRI South Campus gave a welcome address at ITRI, and commented, “At ITRI we actively encourage our collaborations with leading industrial companies, and are delighted to join Oxford Instruments this week and hold such an informative conference. Oxford Instruments has an excellent cleanroom facility established here at ITRI so it is fitting for us to host an event covering the wide range of applications that the Oxford Instruments systems can offer including MEMS, HBLED, ALD and III-V.”

He continued, “Talks about the recent progress in their research and development and future trends in the fabrication and applications in micro and nano structures, gave the audience from academia and industry much opportunity for discussion. We hope to hold more events like this with Oxford Instruments at ITRI.”

Frazer Anderson, Business Group Director at Oxford Instruments Plasma Technology introduced the company at both seminars and summarises the company’s pleasure at the events’ success last week,

“These technical seminars in China and Taiwan gave us and our audiences a great opportunity to spend time being updated by a wide range of eminent speakers, in a relaxed atmosphere where we can share experiences and learn more from our peers. As a company our ethos is to use innovation to turn smart science into world class products, and by working closely with partners at the top of their field and learning about their evolving requirements, their research and technological developments, we hope to achieve this,” he said.

## TriQuint expands gallium nitride offerings

The firm has released significant new GaN products and foundry services

TriQuint Semiconductor has announced 15 new GaN amplifiers and transistors along with two new GaN processes.

These products offer performance, size and durability advantages for communications, radar and defence RF systems.

James L. Klein, Vice President and General Manager for Infrastructure and Defence Products, remarked that GaN's performance advantages are now more accessible to RF manufacturers thanks to TriQuint's expansion of process and product solutions.

He adds, "This announcement shows the accelerated pace of TriQuint innovation. Customers have access to more world-class products in addition to three GaN processes supported by packaging, assembly and test services. TriQuint is comprehensively addressing the most demanding RF requirements with the flexibility to engage customers of all sizes."

Strategy Analytics foresees significant GaN growth. "While defence remains the largest GaN revenue source, infrastructure is growing fast. Sat-Com, power and CATV are ramping to higher revenues. Strategy Analytics forecasts that the market for GaN microelectronic devices will grow with a CAAGR of over 34 percent to approximately \$186 million by 2015," says Eric Higham, Director of Semiconductor Practice.

TriQuint's original quarter-micron process is now complemented by a high voltage variant, TQGaN25HV. The new process extends the drain operating voltage of 0.25µm GaN to 48V while delivering higher breakdown voltage, greater power density and high gain for DC-10 GHz applications.

These advantages enable more rugged devices that can withstand VSWR mismatches that might destroy other circuits while delivering more RF output power.

A new TriQuint product designed with this process is T1G4012036-FS/FL, a 120W packaged transistor for radar and infrastructure. It is nearly two-thirds smaller than similar LDMOS devices. Additional products built with TQGaN25HV are now available.

TriQuint has taken GaN technology to new limits with its third process, TQGaN15. It pushes the frequency range of GaN to 40 GHz while delivering high power density

and low-noise performance.

This 0.15µm GaN-on SiC-process was used to create TriQuint's new TGA2594 (5W) and TGA2595 (10W) Ka-band VSAT ground terminal amplifiers. They have up to 35 percent PAE and are three times smaller than comparable GaAs solutions. Additional products built using TQGaN15 are now available.

TriQuint's product portfolio of new GaN solutions also includes the ground-breaking TAT9988 direct-to-board MMIC amplifier for CATV and fibre to the home (FTTH) optic networks. It was created with the second-generation of TriQuint's original TQGaN25 process. The TAT9988 leads the industry in gain, composite distortion performance and surface mount convenience.

TriQuint's expanded range of GaN innovation is complimented by its integrated assembly services that include die-level device packaging, X-ray and testing. TriQuint is also a DoD-accredited 'Trusted Source'

### Product Solutions Technical Details:

#### Discrete RF Power Transistors

Description	Frequency Range (GHz)	P1dB (Psat) (dBm)	Gain (dB)	DE (%)	Voltage / Current (V / mA)	Package Style	Part Number
GaN120W-EPAR99	DC-35	120	13	52	26 / 360	Ceramic	T1G4012036-FS/FL
GaN10W-EPAR99	DC-6	40	18	53	32 / 50	SMD QFN	T1G6681032-SM

#### Amplifiers

Description	Frequency Range (GHz)	Saturated Power (W)	P1dB (Psat) (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
GaN S-Band PA	3-3.5	90	(49) / -	22	- / 55	28 / 125	Die	TGA2814
GaN S-Band PA	3-3.5	100	(50) / -	22	- / 55	28 / 150	Die	TGA2813
GaN C-X-Band HPA	6-12	30	(45) / -	30	- / 30	25 / 1100	Die	TGA2590
GaN X-Band PA	9-10	20	(43) / -	25	- / 50	25 / 150	Die	TGA2824
GaN X-Band PA	9-10	30	(43) / -	25	- / 45	25 / 250	Die	TGA2822
GaN X-Band PA	9-10	60	(48) / -	10	- / 35	24 / 2400	Die	TGA2312-FL
GaN X-Band PA	10-11	30	(45) / -	25	- / 45	25 / 250	Die	TGA2623
GaN X-Band PA	10-11	16	(42) / -	25	- / 45	25 / 150	Die	TGA2625
GaN Ka-Band PA	27-31	5	(37) / -	19	- / 30	20 / 280	Die	TGA2594
GaN Ka-Band PA	27-31	10	(40) / -	17	- / 25	20 / 580	Die	TGA2595

#### Driver Amplifier

Description	Frequency Range (GHz)	Saturated Power (W)	P1dB (Psat) (dBm)	Gain (dB)	NF / PAE (dB) / (%)	Voltage / Current (V / mA)	Package Style	Part Number
GaN2W Driver PA	2-6	2	33 / -	23	- / 30	25 / 170	Die	TGA2597

#### Low Noise Amplifiers

Description	Frequency Range (GHz)	P1dB / IP3 (dBm)	Gain (dB)	NF (dB)	Voltage / Current (V / mA)	Package Style	Part Number
GaN LNA	2-6	25	25	1	10 / 100	Die	TGA2611
GaN LNA	6-12	25	25	1.5	10 / 100	Die	TGA2612

## EPC opens GaN power library

Designers using gallium nitride power transistors can now go to one place to find a concentration of articles, videos, and textbooks to accelerate their products to market

Efficient Power Conversion Corporation (EPC) has redesigned its website, epc-co.com, to include a gallium nitride transistor library.



The redesign provides search and access to a trove of GaN transistor technology educational materials and product information.

From the home page, power design engineers have immediate access to a wealth of articles, videos and textbooks.

These materials will accelerate understanding and use of this new, rapidly emerging technology.

According to Alex Lidow, co-founder and CEO, "All new technologies have a learning curve that engineers must climb prior to implementing a new technology effectively and efficiently. At EPC we recognise our responsibility to the design community to make certain that engineers know the benefits and understand the intricacies of working with gallium nitride technology."

Lidow continues, "We have taken this education responsibility seriously and have generated and collected a vast amount of materials on GaN transistor technology and applications. Now these materials are concentrated in a single location. Engineers wanting to learn about GaN transistors simply can go to epc-co.com."

EPC's design and applications team are experts in the field of GaN transistor technology and their applications.

Since the founding of EPC in 2007, this team has published over 50 articles in professional journals and delivered more than 30 presentations at industry and academic conferences.

The firm says it has published the only textbook available on the subject, "GaN Transistors for Efficient Power Conversion."

## LAST POWER to boost SiC & GaN power microelectronics

A new European project based on silicon carbide and gallium nitride research should enhance power devices for a variety of applications

LAST POWER 1 is commencing a three-year program.



LAST POWER 1 is a European Union-sponsored program aimed at developing a cost-effective and reliable technology for power electronics.

The project is aimed at commercialising energy-efficient devices for industrial and automotive applications, consumer electronics, renewable-energy conversion systems, and telecommunications.

Launched in April 2010 by the European Nanoelectronics Initiative Advisory Council (ENIAC) Joint Undertaking (JU), a public-private partnership in nanoelectronics, LAST POWER links private companies, universities and public research centres.

They work in the field of wide bandgap semiconductors which are based on SiC and GaN technologies.

The consortium members are STMicroelectronics (Italy), project coordinator, LPE/ETC (Italy), Institute for Microelectronics and Microsystems of the National Research Council - IMM-CNR (Italy), Foundation for Research & Technology-Hellas - FORTH (Greece), NOVASiC (France), Consorzio Catania Ricerche -CCR (Italy), Institute of High Pressure Physics - Unipress (Poland), Università della Calabria (Italy), SiCrystal (Germany), SEPS Technologies (Sweden), SenSiC (Sweden), Acreo (Sweden), Aristotle University of Thessaloniki - AUTH (Greece).

The main achievements in SiC-related efforts were based on the demonstration by SiCrystal of large-area 4H-SiC substrates, 150mm in diameter, with a cut-off angle of 2° off axis.

The material quality, both in crystal structure and surface roughness, is comparable with the standard 100mm 4° off material available at the beginning of the project.

At LPE/ETC, these substrates have been used for epitaxial growth of moderately doped epi-layers suitable for the fabrication of 600-1200V JBS (Junction

Barrier Schottky) diodes and MOSFETs, owing to the development of a novel CVD (Chemical Vapour Deposition) reactor for the growth on large-area (150mm) 4H-SiC.

The quality of the epitaxial layer enabled the fabrication of JBS (Junction Barrier Schottky) diodes in the industrial production line at STMicroelectronics. The characterisation of the first lots showed electrical performance comparable with the state-of-the-art 4°-off material.

In this context, the fundamental technological step was the chemical mechanical polishing (CMP) process - StepSiC reclamation and planarisation.

These steps were implemented at NOVASiC. This is a key issue both for the preparation of the substrates before epitaxial growth and for the sub-nanometric control of the surface roughness of the device active layers.

Within the project, the same company also developed epitaxial growth capability for both MOSFET and JFET devices.

Additional research activities in SiO<sub>2</sub>/SiC interfaces have been carried out in collaboration with ST and IMM-CNR to improve the channel mobility in 4H-SiC MOSFETs.

Finally, novel technological modules for high-temperature 4H-SiC JFETs and MOSFETs have been developed in collaboration between Acreo and FORTH, with the support of CCR for the study of molding compounds and "lead-free" die-attach materials for reliable packaging solutions.

The LAST POWER project also researched the use of GaN-based devices in power-electronics applications.

In particular, ST successfully obtained the development of AlGa<sub>N</sub>/Ga<sub>N</sub> HEMTs epitaxial structures grown on 150mm silicon substrates, reaching a target of 3 μm thickness and 200V breakdown.

LAST POWER worked with IMM-CNR, Unipress, and ST to develop the technological steps for normally-off AlGa<sub>N</sub>/Ga<sub>N</sub> HEMTs with a "gold-free" approach. The process modules are fully compatible with the device-fabrication flow-chart set in the ST production line and are being integrated for HEMTs fabrication.

The fruitful interaction between the project partners working on material growth and device technology has enabled important steps towards monolithic integration of GaN-based and SiC-based devices, as both technologies have been successfully proven on 2° off axis 4H-SiC substrates.

## SEMI highlights the need for InP and GaAs

The organisation says that the restriction of the use of indium phosphide and gallium arsenide would have a negative impact on the semiconductor industry and Europe as a whole. SEMI has also described a new directive which will bring down patent application costs

According to Heinz Kundert, president of SEMI Europe, being able to quickly identify and seize the potential offered by new technologies and new markets is critical in the semiconductor industry. Keeping track of public policy developments is equally important.

Decisions made in a national Ministry or an EU institution can have a direct impact on the industry.

A new EU patent procedure, to be introduced by mid-2014, will significantly reduce the cost and time for a company to obtain a patent valid across 25 European states. The outcomes of the current review of substances under European EHS rules, for example, may have an impact on industry's research priorities or its access to the EU market.

This article covers these topics: 7th SEMI Brussels Forum; EU Patent Protection; GaAs and InP under Review (REACH); RoHS Exemptions Expiring; Banned Substances under RoHS; EU Conflict Minerals Debate.

The SEMI Brussels Forum is one of Europe's leading policy events for semiconductor equipment and materials, providing a unique platform for top-level executives and EU representatives to exchange views and debate how to reinforce Europe's competitiveness in the global market.

The 7th SEMI Brussels Forum will discuss how Europe's industry and policy-makers can increase their impact - both individually and jointly to reinforce Europe's position.

How can industry build on its leading positions and expertise and optimise synergies? How can Europe balance its values and rules on free competition on one hand, with the need to provide for a global level playing field on the other?

SEMI says this is the only event that brings together top-level management and EU representatives to exchange views on how to reinforce Europe's competitiveness. More information can be accessed via the link [www.semi.org/eu/brusselsforum](http://www.semi.org/eu/brusselsforum).

New EU Patent Procedure Offers Automatic Protection in 25 Countries and Brings Down Costs

The new 'EU Unitary Patent', to be made available by April 2014, is expected to reduce the administrative and

financial burden of patent protection across the EU. Companies will be able to fill out a single application to the European Patent Office. Once granted, the patent is automatically valid across 25 countries (all EU member states except for Italy and Spain). A single court will be created (Unified Patent Court) with jurisdiction over infringement proceedings in any of these countries.

Companies will no longer need to apply before each national body for their patent to have effect in that territory, nor satisfy local language and administrative requirements or pay local fees. Nor will they need to defend their patents in different jurisdictions and receive different, sometimes conflicting, rulings.

This new system is also expected to significantly bring down the costs of obtaining a patent. The European Commission estimates that today, a 'classic' European patent (that needs to be validated individually in 27 Member States) costs EUR (€)36 000. The new unitary patent system will bring the costs down dramatically to around €5 000, or one-seventh of today's cost.

#### GaAs and InP under Review for a Possible Restriction under REACH

A recent EU study collected information on the production, import and use of 44 substances, including GaAs and InP, in articles, as a first step towards assessing the need for a possible restriction on their use in the EU. Such a restriction (under Art. 68 REACH) could have an impact not only on European manufacturing but also on imports.

In a joint response with other industry associations, SEMI listed the applications where these compounds are used and the lack of risk to consumers when they are completely encapsulated. SEMI further highlighted the strategic importance of these compounds for micro- and nano-electronics.

Their restriction would have a negative impact not only on industry, but on Europe as a whole. It would curb the global competitiveness of the European semiconductor manufacturing supply chain and it would deprive the EU of the industry base and products Europe needs to achieve its strategic goals for the global digital market.

GaAs and InP are the first III-V compounds being examined under the REACH microscope and SEMI is actively monitoring developments. In its upcoming advocacy activities, SEMI will collect information on risk management measures the industry has in place to avoid exposure to workers and the environment – if your company can contribute, please contact [gourania@semi.org](mailto:gourania@semi.org).

EU RoHS Update: Exemptions are Expiring; More

#### Substances to be Banned under RoHS

The EU RoHS directive currently bans six substances from being used in electric and electronic equipment. Certain products of SEMI members are not covered by the Directive, such as PV panels going into fixed installations, large-scale stationary industrial tools (LSIT) and large-scale fixed installations. SEMI members also benefit from exemptions to the Directive, which allow for specific uses of the banned substances in specified quantities and for a limited period of time.

- A number of exemptions for specific applications will expire in July 2016. These exemptions can be renewed but applications for renewal need to be submitted by end of 2014. Now is therefore the time for industry to review the list of exempted applications, determine which ones are still needed and start pooling resources to draft the renewal application.

- Additional substances will be banned under RoHS by 22nd July 2014. An EU-funded study is currently underway to develop a methodology for evaluating the risk posed by hazardous substances and to determine whether they should be banned. By the end of 2013, this study will also propose additional substances that should be restricted. The European Commission will then decide on banning these substances under RoHS, the transition periods allowed for the manufacturing supply chain to adjust and start considering necessary exemptions.

The SEMI RoHS working is actively contributing to the drafting of the review methodology. For further information and to contribute to this work, please contact Sanjay Baliga at [sbaliga@semi.org](mailto:sbaliga@semi.org)

#### EU Conflict Minerals Debate is Launched – Potential Impact on Industry's Sourcing of Raw Materials from Conflict Zones

The EU is now also considering whether it needs to adopt EU measures to support responsible sourcing from conflict-affected or high-risk areas. It is not yet clear what minerals or what countries a possible EU initiative would focus on, nor whether its nature would be voluntary or binding. The question is also raised whether EU measures should address specific end-products or downstream industry sectors.

A number of initiatives on conflict minerals already exist, including the OECD guidelines on due diligence and the EU is looking to build on these and reinforce transparency through the supply chain. In the U.S., the Dodd-Frank act requires companies to report annually whether they or their suppliers are using conflict minerals (tin, tungsten, tantalum and gold originating from the Democratic Republic of Congo or an adjoining country)

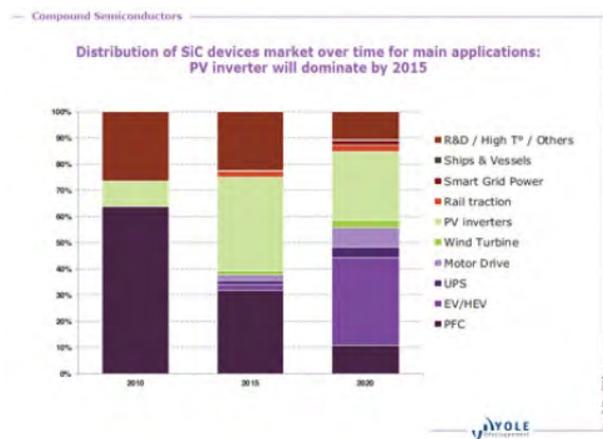
and the EU is seeking feedback on how these provisions are working in practice.

The adoption of an EU legislative measure would have significant implications for SEMI members, creating a traceability requirement across the entire manufacturing supply chain. The consultation is available online here – deadline for submissions is 26 June 2013. For further information, please contact [gourania@semi.org](mailto:gourania@semi.org)

Further information on SEMI advocacy activities in Europe and on the SEMI Europe Advocacy Partners program can be obtained from Rania Georgoutsakou ([gourania@semi.org](mailto:gourania@semi.org); +32 2 609 5334) or Heinz Kundert ([hkundert@semi.org](mailto:hkundert@semi.org)).

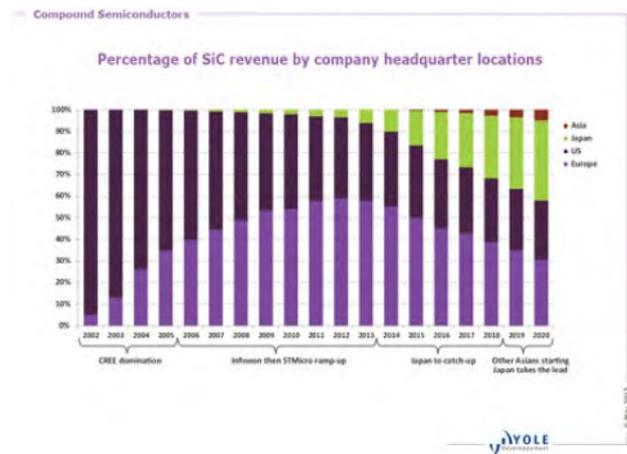
## Electric vehicle go-slow hits SiC power devices

Wide-bandgap transistor and diode growth potential is obscured by automotive qualification: PV inverter growth is a bright spot



Uncertainty hangs over the market for power devices made with wide-bandgap semiconductor SiC, due to a lack of clarity over whether and when electric vehicles will adopt them. “We have no firm estimate of when it will come,” said Philippe Roussel, business unit manager compound semiconductors, power electronics, LED & photovoltaics at market analysts Yole Développement in Lyon, France. “It’s still questionable.”

Automotive qualification can take up to five years, Roussel pointed out. So even if qualification for use in electric and hybrid electric vehicles (EV/HEV) is on-going it likely won’t be clear if SiC has been successful until 2015. And though qualification for EV/HEV charger inverters would be quicker, SiC faces a greater challenge there from silicon superjunction MOSFETs, IGBTs, and also wide-bandgap GaN devices.



As a result, when Yole releases its latest analysis on the SiC industry on May 8, it will describe two scenarios for SiC industry evolution. Its more optimistic scenario will see SiC devices used commercially in EV/HEV from 2015 onwards, taking 11% of the market from silicon IGBT devices by 2020. In the pessimistic scenario EV/HEV implementation doesn’t start until 2017/2018, making PV inverters the number one SiC application in 2020.

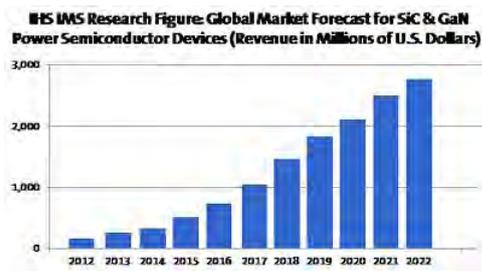
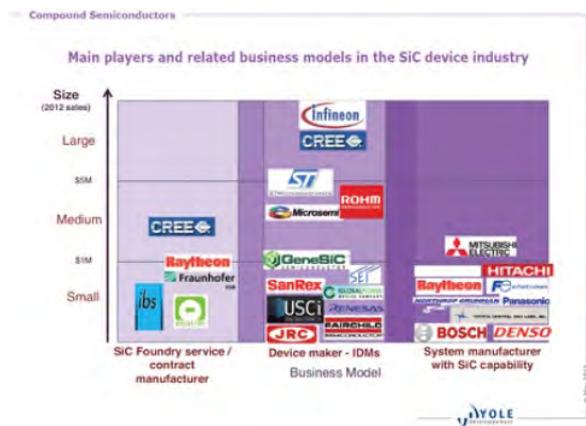
Today there remains much room for increasing SiC device usage in PV inverter applications, Roussel underlined. “Each inverter manufacturer’s product line-up has just one or two models with SiC in them, among dozens,” he said. “But it’s a very positive starting point.” That helped SiC power device industry revenues to \$76 million in 2012, including R&D but excluding military use. PV inverter producers are the second industry to broadly adopt SiC devices, after manufacturers using SiC for power factor correction in high-end server power supplies.

Some PV inverter manufacturers use a SiC diode and silicon IGBT or MOSFET, and some offer full SiC inverters. “They’re just the first attempt, as inverter makers have limited their SiC development investment,” Roussel said. “They’re doing a simple replacement for silicon devices, taking the minimum extra work.” But that means that inverter producers are selling more expensive SiC products on their efficiency, without fully exploiting the material’s benefits. “The next step will definitely be a full redesign within the inverter that should fit with SiC’s high frequency and temperature capabilities, reducing the number of capacitors and inductors needed,” Roussel said.

Working with reverse costing specialist System Plus Consulting, Yole has modelled the benefits of increasing the standard PV inverter switching frequency from 12 to 32 kHz. That shortens the payback time on the SiC investment, and would make large 50 kW SiC inverters cheaper than their silicon equivalents by 2020. Such benefits will help increase annual revenues for SiC

devices sold into PV inverters to \$200 million by 2020, Yole predicts.

Even though PV inverters are currently better established, EV/HEV inverter producers could still be more advanced in making full use of SiC. "Efficiency drives adoption, but putting SiC in any system could also make it smaller and lighter," Roussel stressed. "For EV/HEV, that is just fantastic."



SiC Schottky diodes have been around for more than 10 years, with SiC metal-oxide semiconductor field-effect transistors (MOSFET), junction-gate field-effect transistors (JFET) and bipolar junction transistors (BJT) appearing in recent years. In contrast, GaN power semiconductors are only just appearing in the market.

GaN is a wide bandgap material that offers similar performance benefits to SiC but has greater cost-reduction potential. This price/performance advantage is possible because GaN power devices can be grown on silicon substrates that are larger and lower in cost compared to SiC.

## GaN and SiC power device market set to boom by 18 times

From 2012 to 2022 silicon carbide and gallium nitride power revenues are set to soar from \$143 million to \$2.8 billion

The emerging market for SiC and GaN power semiconductors is forecast to grow a remarkable factor of 18 during the next 10 years.

This will be energised by the demand from power supplies, photovoltaic (PV) inverters and industrial motor drives.

Worldwide revenue from sales of SiC and GaN power semiconductors is projected to rise to \$2.8 billion in 2022, up from just \$143 million in 2012. This is according to a new report entitled "The World Market for SiC & GaN Power Semiconductors - 2013 Edition" from IMS Research, now part of IHS. Market revenue is expected to rise by the double digits annually for the next decade, as presented in the figure below.

"The key factor determining market growth will be how quickly GaN-on-silicon devices can achieve price parity and equivalent performance as silicon MOSFETs, insulated-gate bipolar transistors (IGBT) or rectifiers," says Richard Eden, senior market analyst for power semiconductor discretes and modules at IHS. "IHS expects this will be achieved in 2019, driving the GaN power market to pass the \$1 billion mark in 2022."

SiC Schottky diode revenue exceeded \$100 million in 2012, making it the best-selling SiC or GaN device currently. But even though SiC Schottky diode revenue is forecast to grow until 2015, it will decline when lower-priced 600V GaN diodes become available. Still revenue will recover to approach \$200 million by 2022, with sales concentrated at voltage ratings of 1200V and above.

By then, SiC MOSFETs are forecast to generate revenue approaching \$400 million, overtaking Schottky diodes to become the best-selling SiC discrete power device type.

Meanwhile, SiC JFETs and SiC BJTs are each forecast to generate less than half of SiC MOSFET revenues at that time, despite their likelihood of achieving good reliability, price and performance. End users now strongly prefer SiC MOSFETs, so vendors of SiC JFETs and BJTs have a major task ahead in educating their potential customers on the benefits of these technologies.

While IHS predicts strong growth for the SiC and GaN power semiconductor market in the years ahead, the forecast has been significantly reduced compared to the outlook from one year ago.

The main reason for the change is the reduced forecasts for shipments of equipment that use power components, resulting from today's gloomier view of the global economy. SiC adoption forecasts also have been slashed because device prices are not falling as fast as originally assumed a year ago.

In contrast, industry confidence in GaN technology has increased, with more semiconductor companies announcing GaN development projects. For instance, Transphorm has become the first company to achieve JEDEC qualification for its GaN-on-silicon devices.

## GaN Systems offers 20 percent off evaluation kit

The company will showcase its products at PCIM booth #523, Hall 9, Nuremberg Messe, taking place between 14th and 16th May

GaN Systems, a developer of gallium nitride power switching semiconductors, will exhibit at the PCIM conference and exhibition and conference.

The company has invited visitors to stand 523, Hall 9.

GaN Systems says customers will be able to take advantage of a special introductory offer covering the company's soon-to-be-available evaluation kits.

The evaluation kits consist of a 400 volt boost converter demo board and a pair of GaN Systems' GS30603M 600 volt GaN switches.

Customers who pre-order kits at PCIM will receive a 20 percent price reduction, and no deposit is required. Shipping will begin in Q3 2013.

Girvan Patterson, CEO of GaN Systems comments, "The special evaluation kit offer was very popular at the recent APEC USA power event, and we hope to have the same high level of interest at PCIM. Our aim is to enable design engineers to take advantage of the benefits of our new gallium nitride products and realise that gallium nitride is a very real 'now' technology, not some interesting laboratory future concept."

## Bridgelux to sell Toshiba its GaN-On-silicon related assets

The LED specialist has agreed to provide Toshiba

with its technology/chip licensing and manufacturing collaboration

Bridgelux and Toshiba have signed an agreement under which Bridgelux will sell to Toshiba its GaN-on-silicon technology and related assets.

The companies aim to strengthen and extend their strategic technology collaboration, through an expanded licensing and manufacturing relationship.

In January, 2012, Bridgelux and Toshiba entered into a Joint Development and Collaboration Agreement for the development of GaN-on-silicon LED technologies.

The success of that relationship was demonstrated by Toshiba's announcements of the achievement of the performance of its 8" GaN-on-silicon LED wafers and mass production of white LEDs.

Both of these milestones were achieved using Bridgelux's crystal growth and LED device processes as well as Toshiba's advanced silicon processes and manufacturing technologies.

The enhanced strategic relationship could provide a new business opportunity through the expanded collaboration for next generation LED chips and packages, or platforms, based on the jointly developed GaN-on-silicon technology, as well as a manufacturing arrangement securing Bridgelux a source of supply for GaN-on-silicon-based LED chips.

"Our agreement with Toshiba marks a tremendous milestone in our long history of working closely together, allowing Bridgelux to capitalise on our strong core LED technology platform, providing us with significant new capital for growth, and reducing our capital requirements," says Brad Bullington, Chief Executive Officer of Bridgelux.

"This agreement also allows us to focus on what we do best, and what we think the market needs most at this point in time: commercialising, productising and bringing to market LED-based solid state lighting technologies alongside a proven global scale semiconductor manufacturing partner. We are one step closer to becoming the world's leading solid state lighting technology architecture company," he explains.

"We are so excited with this deal that gaining GaN-on-silicon technology and related assets will contribute to drastically strengthening our LED business, and bring us a high performance and competitive product line-up. We fully expect our new Livermore team to play a leading role within Toshiba in the development and rapid market penetration of GaN-on-Silicon LED chips," says Makoto Hideshima, Executive Vice President of Semiconductor

and Storage Products Company, Corporate Vice President of Toshiba.

“Entering a new phase of our relationship with Bridgelux, we will be able to accelerate the scaled manufacturing of 8” GaN-on-silicon LED wafers, which will position both companies for strong growth in our respective LED businesses. The GaN-on-silicon technology that we acquire will also bring us a breakthrough for Power Devices development and production.”

The GaN-on-silicon assets included in the sale, and the related Bridgelux employees, will remain on site at Bridgelux’s headquarters in Livermore after the transaction closes to assure continued technical and business collaboration between the companies.

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## Equipment and Materials

### Can you rely on Hall to assess p doping of ZnO films?

Sometimes not. In samples which have been annealed at a high temperature, Hall measurements may indicate the wrong carrier type. In this case, other characterisation techniques, such as CV and photocurrent-based measurements, are more reliable

Hall effect measurements performed on ZnO films annealed after growth on InP substrates can be misleading with respect to the real nature of the analysed material.

That’s the key finding of a study by scientists at the Università di Palermo, Italy and Thales, Research & Technology in France. This team found, from Hall measurements, that a change in the electrical properties of the films, from *n*-type to *p*-type, was not confirmed by both capacitance voltage (CV) and photocurrent-based measurements. Instead, the ZnO films remained *n*-type after post-growth annealing.

The team’s findings are important, because ZnO is a very interesting material, which could be used for the manufacture of light sources and sensors in the portion of spectrum between blue and near UV. However, this material suffers from poor *p*-type doping, in terms of reliability, stability, and reproducibility, making it difficult to fabricate a high performing ZnO LED.

Investigations by the researchers from Italy and France involved measurements made on samples grown at 400°C and annealed afterwards in air at 600°C.

These results indicate that carrier type identification in ZnO films thermally treated after growth should be approached with caution, because of artefacts such as profound structural and electrical changes at the ZnO/Substrate interface. These arise in the samples following the high temperature annealing, which may falsify the Hall measurements, giving a different carrier type to the real one. In this case, other characterisation techniques, such as CV and photocurrent-based measurements are more reliable and could be used instead.

According to the team, over the years, different ways for realising *p*-type ZnO films have been undertaken, often with non reproducible and arguable results. Some of these results are even less convincing considering the high hole concentration and mobility which have been reported.

This is not in line with both the standard electron transport theory of ZnO and the majority of experimental research works that have been published. It is possible that many of the most controversial results may be ascribed to an incorrect assignment of the *p*-type doping after Hall effect measurements.

ZnO films were grown on undoped InP substrates by pulsed laser deposition (PLD) at 400°C and 10-2 mbar oxygen pressure, and subsequently annealed in air at different temperatures for 1 hour.

Hall effect measurements (resistivity, mobility, and carrier concentration) were performed before and after annealing together with a detailed photoelectrical investigation performed in aqueous solution and CV measurements.

The Hall effect measurements suggested that ZnO films annealed at 600°C for 1 hour exhibited an anomalously high *p*-type conductivity with hole concentrations up to  $9.2 \times 10^{19} \text{ cm}^{-3}$  and hole mobilities up to  $28.5 \text{ cm}^2/\text{V s}$ .

What’s more, the resistivity after annealing decreased by about an order of magnitude (from  $1.7 \times 10^{-2}$  to  $4.2 \times 10^{-3} \Omega \text{ cm}$ ), indicating an apparent profound change in the electrical properties of the films.

Photocurrent and CV measurements performed on the same samples revealed, instead, *n*-type conductivity. The photocurrent was, in fact, anodic, decreasing with the applied potential UE (Fig. 1), and the differential capacitance C of the film increased as the electrode potential moved toward the cathodic direction, as expected for a *n*-type semiconductor (Mott-Schottky representation, Fig. 2(a)).

$U_E$  is the electrode potential. It is the voltage applied to the electrode (the ZnO/InP sample) during the photoelectrical measurements performed in aqueous solution.

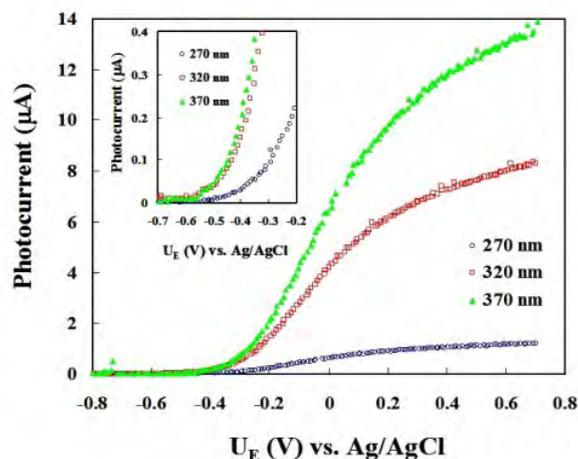


Figure 1. Photocurrent versus applied potential ( $U_E$ ) recorded at three different irradiating light wavelengths, solution: 0.1 M ABE and potential scan rate 10 mV s<sup>-1</sup>. The inset shows a zoom of the plot in the region where the photocurrent becomes zero. A flat band potential  $U_{FB}$  of about -0.6 V vs. Ag/AgCl is readable. All curves are related to a sample annealed in air at 600°C for 1 hour

The  $n$ -type conductivity of these samples was further confirmed by CV measurements employing a mercury probe (Fig. 2(b)).

The mechanism responsible of the  $p$ -type doping measured by Hall measurements can be ascribed to the formation of a very thin, high conducting layer at the ZnO/InP interface due to zinc ion migration into the InP substrate. This high conductive layer dominates the Hall effect measurements and instead is invisible to both CV and photocurrent-based methods.

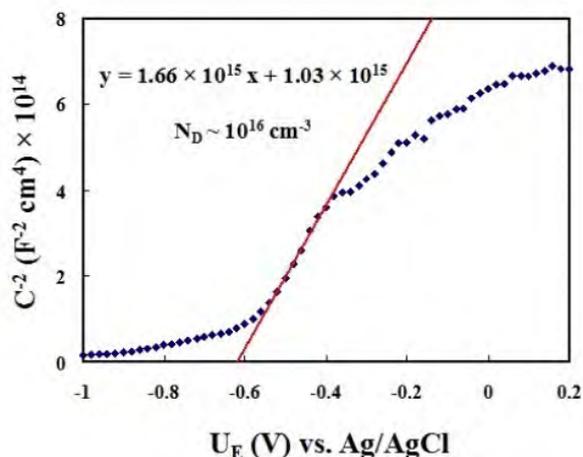


Figure 2 (a)  $C-2$  versus  $U_E$  plot recorded at  $f = 10$  kHz in 0.2 M Na<sub>2</sub>HPO<sub>4</sub> solution. The linear fitting allows calculating a donor concentration of about  $10^{16}$  cm<sup>-3</sup>.

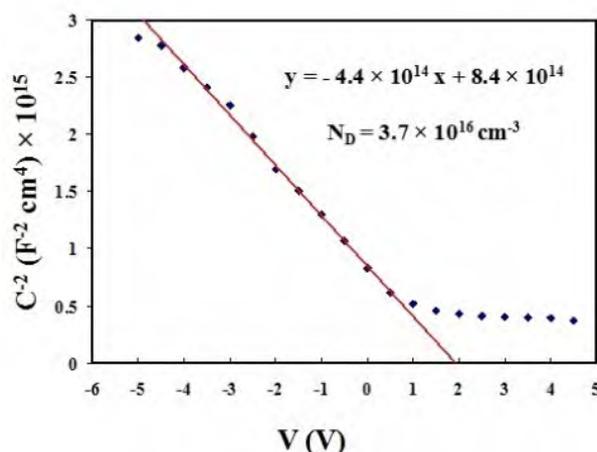


Figure 2 (b)  $C-2$  versus applied voltage for the Hg  $n$ -ZnO junction realised with a Hg contact area of 0.432 mm<sup>2</sup>. The linear fitting allows calculating a donor concentration of  $3.7 \times 10^{16}$  cm<sup>-3</sup>

All plots are related to a sample annealed in air at 600°C for 1 hour.

This work is described in detail in the paper, "Erroneous  $p$ -type assignment by Hall effect measurements in annealed ZnO films grown on InP substrate", by R. Macaluso *et al* in the *Journal of Applied Physics*, 113, 164508, published online on 30th April 2013. <http://dx.doi.org/10.1063/1.4803080>

## Europe to boost micro- and nanoelectronic industries

A new initiative is supporting research, development and innovation and improvement in the entire semiconductor ecosystem

The European Semiconductor Industry Association (ESIA) welcomes the European Commission's Communication "A European strategy for micro- and nanoelectronic components and systems".

The actions outlined in the Communication will strengthen the competitiveness and growth potential of the micro- and nanoelectronics industry in Europe, and build upon the European initiative on Key Enabling Technologies (KETs) and HORIZON 2020.

ESIA believes that this Communication takes a decisive approach to reinforce the European semiconductor industry, and to increase its contribution to the wider European economy.

ESIA commends the acknowledgment that semiconductors play a crucial role in driving business

transformation and responding to growing societal needs. This communication recognises the electronics industry as a key force to address the challenges the economy in the EU is facing.

ESIA fully supports the Commission's multi-level strategy including financial support for research, development and innovation (R&D&I), as well as the improvement and better use of relevant legislation. Given the very high diversity of the European market, ESIA is pleased to see the entire semiconductor ecosystem being addressed.

With a clear focus on R&D&I, market pull for new application areas, education and production, the strategy builds on the four pillars ESIA has been promoting as a basis for a dedicated European industrial policy for the micro- and nanoelectronics sector.

Rick Clemmer, ESIA President and CEO of NXP Semiconductors, states, "Pilot lines and prototyping are a welcome addition to the European R&D stimulation programme. But this concept should not be limited to semiconductor manufacturing as such. Joint semiconductor downstream application pilots will provide significant additional leverage in economic growth and employment in areas such as the Internet of Things and Smart Cities, including Intelligent Traffic Systems, Smart Buildings and Smart Grids."

Executing on this Communication has the potential to reverse the current trend in the European semiconductor market, which has seen production in Europe drop to less than 10% percent of world production in 2011.

"Leadership in innovation is key to developing a sustainable advantage for European industry and we need to build on the scientific excellence in Europe to turn great ideas into globally competitive technologies and related manufacturing," comments Carlo Bozotti, President and Chief Executive Officer of STMicroelectronics.

"With traditional strengths in analogue and power as well as more recent innovations in technologies, companies in Europe have the capability to continue to lead the development of the next wave of electronic products. The actions outlined in the Commission's Communication demonstrate a clear commitment to Europe's future," adds Bozotti.

Hendrik Abma, Director-General of ESIA, says, "ESIA welcomes the ambition and vision of the European Commission's strategy. ESIA has consistently underlined the importance of the European semiconductor industry to the competitiveness and vitality of the European economy, as well as to tackling the grand societal challenges, such as energy efficiency and aging populations."

ESIA looks forward to the full implementation of the European Commission's strategy for micro- and nanoelectronic components and systems. ESIA is fully aware that the strategy's successful execution requires significant alignments among all stakeholders.

## Hidden unveils SIMS tool family trio

Hidden Analytical is offering the choice of three initial equipment levels to suit a broad spread of budget capacities

Secondary ion mass spectrometry (SIMS) is a versatile, highly-sensitive technique for surface analysis and surface depth profiling of diverse materials.

The technique can reveal details of contamination in bubblers such as TMGa and TMAI used in the MOCVD growth of III-V semiconductors.

Hidden Analytical has expanded its primary system options to offer the choice of three initial equipment levels to suit a broad spread of budget capacities. All systems offer full UHV operation and expandability to the top-level specification.

The dual-mode MAXIM mass spectrometer features operation both in the secondary ion mode and in the secondary neutral (SNMS) quantification mode.

The Foundation SIMS System includes the IG20 fine-focus (50  $\mu\text{m}$ ) oxygen/argon ion gun, multiple sample holder and primary ion beam monitor.



An uplifted version - the SIMS Workstation - is configured for higher throughput rates with the addition of a sample load lock and sample manipulator, together with charge-neutralising electron flood gun and system bakeout facility.

The SIMS Workstation Plus has the most comprehensive specification with the addition of the IG5C Caesium ion gun for electronegative species, having a spot size of just 20  $\mu\text{m}$ .



SIMS Workstation

The MASsoft Professional SIMS PC data system provides automated measurement of positive and negative ions and of neutral species. It enables full control of the mass spectrometer and ion gun operating parameters and ion beam raster, with acquired data presented in real time.

The ESM LabVIEW SIMS Imaging program acquires, stores and displays the data for presentation in the form of elemental surface maps with both 2D and 3D view capabilities.

Times for analysis are down to just 150 milliseconds.

## IMRE uses LayTec tool for 200mm GaN-on-silicon

The EpiCurve Triple TT in-situ monitoring system is being used to develop epiwafers for InGaN/GaN LEDs and GaN power electronic devices

In his invited talk at the LED Technology Forum in Singapore Sudhiranjan Tripathy of IMRE (Institute of Materials and Research Engineering, A\*STAR) revealed the latest results of GaN growth on 200 mm diameter silicon.

The conference took place between 7th and 10th May.

Tripathy's team uses LayTec's *in-situ* monitoring system EpiCurveTriple TT to develop epiwafers for InGaN/GaN LEDs and GaN power electronic devices.

EpiCurve Triple TT is ideally suited for 200 mm real time wafer characterisation because of its 3 sensor heads

for radial analysis of growth conditions. It provides wafer bow and temperature measurements, as well as simultaneous detection of growth rate and surface morphology.

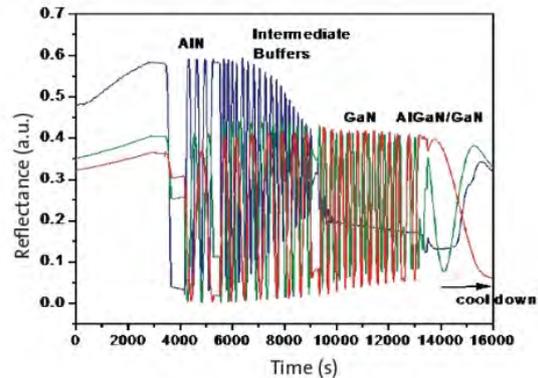


Fig. 1: Reflectance monitoring of AlGaIn/GaN HEMT structure grown on 1.0 mm thick 200 mm diameter Si (111) at IMRE: blue - 405 nm, green - 633 nm, red - 950 nm

Fig. 1 shows reflectance profiles at 3 wavelengths: 950 nm for emissivity correction of pyrometry, 633 nm for analysis of thick layers e.g. GaN buffer, and 405 nm for thin layers. Fig. 2 demonstrates how the 405 nm reflectance is used for individual *in-situ* tuning of each well and barrier within the multi-quantum wells stack.

The *in-situ* signal (Fig. 2 - left) perfectly corresponds with the multi-quantum wells (MQWs), which can be seen in the scanning transmission electron microscopy (sTEM, Fig. 2 - right).

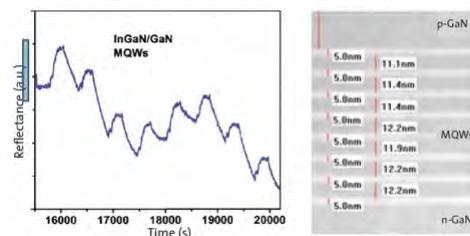


Fig. 2: 405 nm reflectance (left) of InGaIn/GaN MQW stacks and the corresponding STEM image of the MQWs (right).

According to Tripathy's team, LayTec *in-situ* metrology is a key element for identifying the epitaxial process potentials. In comparison to the time consuming, destructive *ex-situ* cross section transmission electron microscopy analysis, the *in-situ* tool provides real time information on growth thickness and homogeneity already during growth.

LayTec says its system has reduced significantly IMRE's R & D cycles for epitaxial growth optimisation and enables faster industrialisation of the GaN-on-Silicon technology.

## Aixtron to slash 20 percent of jobs in Germany

The firm has agreed on a 5-point plan aimed at returning to sustainable profitability

At today's Annual General Meeting, Martin Goetzeler, the new CEO of Aixtron SE since March, will set out the measures which the Executive Board intends to implement together with Aixtron's team to return the company to sustainable profitability.

"We have to focus more closely than ever on our core competence - optimally supporting our customers to reach their targets by offering efficient high-tech equipment for use in complex material deposition. Here, we aim to regain our position of leadership, and that on a sustainably profitable basis. That is what we are working towards," Goetzeler explains.

He points out that the challenges currently faced by Aixtron resulted from both internal and external factors. "Processes and responsibilities are two particular areas where we have to do our homework," he says.

Initial measures have already been initiated in recent weeks. These firstly include a project to enhance efficiency in the company's product development. Secondly, the Executive Board has decided to cut more than 20 percent of jobs in Germany - an "inevitable, albeit very painful" decision. Further measures introduced in the 5-Point Program intend to contribute decisively towards a sustainable profitability.

Although the weakness is still apparent on the demand side, the Executive Board has stressed that the positive medium and long-term outlook is still intact for the MOCVD, silicon, and organic deposition technologies provided by Aixtron.

Key aspects of the 5-Point Aixtron Program are presented below.

### 1. Customer - focusing on customer benefit

To optimally address customer needs, such as product quality and productivity, Aixtron will compile roadmaps together with its customers that are then factored into the relevant development programs. The business model is being reviewed to boost the service business.

### 2. Technology and products - putting unique product portfolio to more effective use, further strengthening future products

To be sustainably profitable, the firm is building on its technology in complex material deposition and aims

to regain market leadership in the area of MOCVD technology in LED production.

### 3. Efficiency – systematically optimising process and project structures

A cross-functional project will optimise the timing and use of resources in product development and thus make it possible to achieve outstanding development results at lower expense. The company will also step up its partnership-based cooperation with suppliers.

### 4. Finance - value oriented financial targets

Aixtron's Executive Board sees management by clear financial targets as the basis for achieving sustainable profitability. Here, it will focus on four superordinate key financial figures which are Revenues, EBIT, Free cash flow and return on capital employed > cost of capital over business cycle (ROCE > WACC).

The current priority has been to rapidly adjust costs to present circumstances. For the current year, the Executive Board already decided in March to cut operating expenses - excluding restructuring and transformation expenses - by 20 percent compared with the previous year, and thus to reduce the breakeven point.

### 5. Employees – strengthening Aixtron culture, taking individual responsibility, fortifying communication

Following some tough quarters, Aixtron aims to reinforce one of its key qualities - its employees' sense of identification with the firm. What's more, the Executive Board wants to further develop management culture and to adapt it to new challenges. To accomplish this, the firm is agreeing clear goals and closely monitoring their achievement.

In its future financial reporting, the Executive Board will regularly report both internally and externally on the status of this company program.

The CEO Martin Goetzeler will provide further details about the 5-Point Program in his presentation at today's Annual General Meeting in Aachen. The prepared notes of the speech will be available for download following the presentation at [www.aixtron.com/](http://www.aixtron.com/)

## Oxford Instruments hosts Asian seminars in the Far East

The talks included GaN-on-silicon, HB-LED, SiC and III-V developments

Oxford Instruments Plasma Technology has just completed its series of Asian seminars in Beijing, China and Hsinchu, Taiwan, attracting a record total attendance of over 250 people.



The seminar in Beijing was co-hosted by the Institute of Semiconductors, Chinese Academy of Sciences (IOS-CAS) one of the most important bases for the research and development of semiconductor science and technology in China. Its counterpart in Taiwan was co-hosted by ITRI, one of Taiwan's leading non-profit R&D organisations with over 5,800 employees.

Both seminars featured a range of International and national speakers including Yang Fuhua from IOS-CAS in China and Chyi, Jen-Inn, Executive Vice President, National Applied Research Laboratories in Taiwan.

The talks covered a number of key areas including GaN on silicon power device development, SiC wide bandgap semiconductors for power electronics applications and MEMS devices, processes and trends.

Shao-Chung Hsu, Executive Director of ITRI South Campus gave a welcome address at ITRI, and commented, "At ITRI we actively encourage our collaborations with leading industrial companies, and are delighted to join Oxford Instruments this week and hold such an informative conference. Oxford Instruments has an excellent cleanroom facility established here at ITRI so it is fitting for us to host an event covering the wide range of applications that the Oxford Instruments systems can offer including MEMS, HBLED, ALD and

III-V. "

He continued, "Talks about the recent progress in their research and development and future trends in the fabrication and applications in micro and nano structures, gave the audience from academia and industry much opportunity for discussion. We hope to hold more events like this with Oxford Instruments at ITRI."

Frazer Anderson, Business Group Director at Oxford Instruments Plasma Technology introduced the company at both seminars and summarises the company's pleasure at the events' success last week,

"These technical seminars in China and Taiwan gave us and our audiences a great opportunity to spend time being updated by a wide range of eminent speakers, in a relaxed atmosphere where we can share experiences and learn more from our peers. As a company our ethos is to use innovation to turn smart science into world class products, and by working closely with partners at the top of their field and learning about their evolving requirements, their research and technological developments, we hope to achieve this," he said.

## LayTec and Evatec engage in OEM partnership

The OEM partnership enables an ongoing close cooperation for integration of advanced in-situ metrology in Evatec's reactors

LayTec has signed a strategic OEM agreement with Evatec Ltd. based in Switzerland. Evatec is a supplier of thin film deposition systems to semiconductor and optical device manufacturers.

LayTec will equip Evatec with high precision *in-situ* metrology tools for versatile process control.

Evatec's evaporation, sputter and PECVD systems are used in the optoelectronics, precision optics, MEMs, and other semiconductor markets.

LayTec's metrology tool EpiCurve TT is already successfully applied on Evatec sputter systems for stress management of metal multi-layers for wafers used for optoelectronic applications.

EpiCurve TT enables strain-engineering of the multi-layer structures by real-time tuning of the sputter parameters. The results were presented at CS International Conference in March 2013.

Evatec's Senior Process Engineer Silvia Schwyn

Thöny comments, “With LayTec’s state-of-the-art *in-situ* metrology we are able to meet the growing demands on precise process control and optimisation, which is the key to high yields and low costs.”

«For LayTec, an OEM cooperation with Evatec is of strategic importance,” adds LayTec’s CEO Thomas Zettler. “It will enable implementation of our metrology into processes beyond LayTec’s established applications. And when Swiss precision meets German quality standards, the expectations can never be too high.”

LayTec develops and manufactures integrated *in-situ* and in-line metrology for thin-film deposition and other high value generating processes. Currently, the company has more than 1500 metrology systems installed worldwide and offers a global customer support and service network including local representations.

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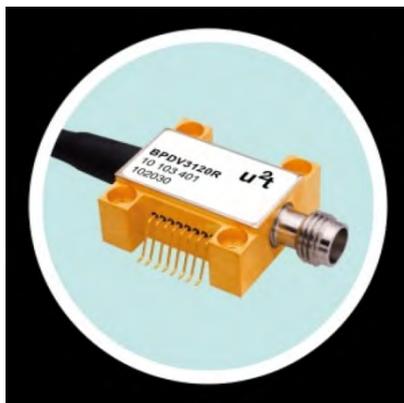
## u<sup>2</sup>t unveils 1550nm photodetector

The III-V based detector supports systems for next generation networks using 400 Gbit/s or 1 Tbit/s coherent detection-based optical transmission

u<sup>2</sup>t Photonics AG, a provider of optoelectronic components, says it has developed the world’s fastest balanced photodetector offering a 3dB bandwidth of 70 GHz.

The BPDV3120R complements u<sup>2</sup>t’s product portfolio of ultra high speed photodetectors and receivers.

The optical frontend consisting of a monolithic balanced photodetector chip with on-chip biasing has been successfully tested in a system environment and will be used in Test & Measurement (T&M) equipment, such as optical modulation analysers, for the test of next generation coherent network components and modules.



BPDV3120R

The coaxial single-ended output can detect up to 64 GBaud polarisation diversity x-QAM signals featuring highly reliable results for common mode rejection ratio, linearity and optical input power.

This means the device can be used in next generation long haul transmission systems at data rates of 400 Gbit/s and beyond. At the same time, the BPDV3120R is well suited for T&M applications as well as ongoing R&D activities at high Baud rates.

“While 100G coherent systems are being widely deployed today, we can already see that 400 Gbit/s or even 1 Tbit/s systems will be required in a few years to support the continued exponential growth of data traffic in mobile and fixed networks,” says u<sup>2</sup>t Photonics CEO Andreas Umbach. “Our 70 GHz balanced photodetector provides one of the key building blocks that will enable systems providers to build and deploy systems operating at 400G per wavelength or higher.”

u<sup>2</sup>t started sampling the BPDV3120R in March 2013 and will start its production in June.

u<sup>2</sup>t Photonics AG is a privately-held company headquartered in Berlin, Germany. It offers a comprehensive and fully TELCORDIA qualified portfolio.

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## Veeco receives NASDAQ notice about late 10-Q filing

The MOCVD system manufacturer did not file its quarterly report on Form 10-Q for the quarter ended March 31st 2013 in time with the SEC

Veeco Instruments received a letter from the NASDAQ Stock Market LLC on May 13th, 2013 that it is not in compliance with NASDAQ Listing Rule 5250 (c).

As previously announced, this Form 10-Q, as well as the company’s annual report on Form 10-K for the year ended December 31st, 2012 and quarterly report on Form 10-Q for the quarter ended September 30th, 2012, were not filed in time.

This was because Veeco was reviewing the timing of the recognition of revenue and related expenses on the sale of certain of its products. The accounting review was announced on November 15th, 2012.

The company intends to file its Forms 10-Q and 10-K as soon as reasonably practicable after these accounting matters have been resolved.

Veeco had previously announced that it had submitted to

NASDAQ a plan to regain compliance with requirements for continued listing and that NASDAQ had granted an extension, to May 20th, 2013, for the company to regain compliance with NASDAQ's requirements for continued listing.

However, the company does not expect to regain compliance with NASDAQ's requirements for continued listing by May 20th, 2013.

So Veeco intends to request a hearing before the NASDAQ Listing Qualifications Panel to request additional time to regain compliance with NASDAQ's requirements for continued listing.

The firm also intends to request that NASDAQ allow its securities to remain listed on the NASDAQ Global Select Market until such time as the hearing process concludes and any resulting exception period expires.

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## AMP launches arsenic removal media

The high capacity makes the application suitable for use in MOCVD growth where other adsorbent materials are impractical

An Oklahoma based startup, Associated Material Processing, LLC, has developed a proprietary arsenic removal media for industrial waste water remediation.

Oklahoma State University Professor Allen Apblett, invented the new polymeric adsorbent media, AMP-25, with unprecedented affinity for arsenic.

AMP-25's capacity for arsenic can reach up to 150 mg As/g of the adsorbent, which is almost an order of magnitude higher than conventional arsenic adsorbents. This high capacity makes it suitable for use in applications where other adsorbent materials are impractical.

What's more, with its high capacity, the selectivity for arsenic is high with the product able to reduce arsenic from 100 ppm to below detection limits (0.0005 ppm) in a single batch contact. Also, it is not significantly affected by the presence of other ions.

Applications for AMP-25 involve removal of arsenic from GaAs processing waste, mining operations and metal finishing facilities.

Associated Material Processing, LLC (AMP) is a chemical technology company with innovative solutions to remediate hazardous and unwanted chemicals.

Oklahoma based AMP was launched by Cowboy Technologies, LLC in November 2011 to commercialise Apblett's invention. AMP has developed proprietary arsenic adsorption products, AMP-25 for semiconductor industry application and AMP-35 for drinking water treatment.

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## Rubicon to showcase optical-grade sapphire products

The provider of sapphire substrates and products to the LED, semiconductor, and optical markets will exhibit its products at the Laser World of Photonics in Munich, Germany 21st Laser World of Photonics Show

Rubicon Technology will show off its line of optical products for use in defence and aerospace, instrumentation and analytical processing, sensors and detectors, semiconductor process equipment, and medical and laser applications at the 21st Laser World of Photonics International Trade Fair.

Sapphire can be used as a component in electro-optic products used to detect or measure the presence or features of light in a number of optical applications. Rubicon provides a wide range of sapphire products that can be integrated into existing opto-electronic applications including sapphire cores, ingots, windows and blanks.

"As opto-electronic technology and applications evolve, the demand for optical-grade, high-quality sapphire has grown," says Raja M. Parvez, President and CEO, Rubicon Technology. "Based on sapphire's unique strength and hardness, chemical inertness, and transparency in the visible and IR spectrum, there's growing interest in using sapphire in products that are used to detect or measure light. Sapphire becomes very desirable in extreme environments such as military and industrial applications where material durability is just as important as optical clarity."

Until now, existing methods used to produce optical-grade sapphire windows haven't met demands for thickness and size in certain military and other applications. The company recently developed a new horizontal growth process to produce monolithic sapphire sheets large enough for use in next generation optical windows for military and industrial applications.

Rubicon will have a number of optical sapphire products of different sizes and orientations on display in Hall B2, Stand #163 at Laser World of Photonics, including sapphire cores, ingots, windows, domes and blanks. Rubicon will also be displaying large diameter wafers

ranging in size from 4, 6 and 8 inches.

## Henniker reveals ultra sensitive spectrometer for gas analysis

The new tool can be used in the monitoring of MOCVD grown III-V compound semiconductors

The Extrel MAXCS-50 Series quadrupole mass spectrometer from Henniker Scientific has been released and directly addresses research applications requiring high sensitivity gas analysis of low molecular weight species.



*High Resolution Quadrupole Mass Spectrometer*

At the heart of the instrument is a high specification quadrupole mass filter assembly, featuring a precision machined 19mm quadrupole rod set with RF-only pre- and post-filter stages, stabilising rods and the latest high stability CS Series RF generator that in combination deliver exceptional transmission, resolution and abundance sensitivity characteristics at low masses.

Typical applications include geochronology isotope ratio measurements and helium-deuterium gas purity analysis, where the instrument's exceptional resolution is able to resolve adjacent mass peaks separated by only a few hundredths of an atomic mass unit even at low concentration.

The MAXCS-50 is available as a fully UHV compatible bolt-on probe or with application matched pressure reduction stages which address a wide range of atomic, molecular and surface analysis studies.

## SEMI highlights the need for InP and GaAs

The organisation says that the restriction of the use of indium phosphide and gallium arsenide would have a negative impact on the semiconductor industry and Europe as a whole. SEMI has also described a new directive which will bring down patent application costs

According to Heinz Kundert, president of SEMI Europe, being able to quickly identify and seize the potential offered by new technologies and new markets is critical in the semiconductor industry. Keeping track of public policy developments is equally important.

Decisions made in a national Ministry or an EU institution can have a direct impact on the industry.

A new EU patent procedure, to be introduced by mid-2014, will significantly reduce the cost and time for a company to obtain a patent valid across 25 European states. The outcomes of the current review of substances under European EHS rules, for example, may have an impact on industry's research priorities or its access to the EU market.

This article covers these topics: 7th SEMI Brussels Forum; EU Patent Protection; GaAs and InP under Review (REACH); RoHS Exemptions Expiring; Banned Substances under RoHS; EU Conflict Minerals Debate.

The SEMI Brussels Forum is one of Europe's leading policy events for semiconductor equipment and materials, providing a unique platform for top-level executives and EU representatives to exchange views and debate how to reinforce Europe's competitiveness in the global market.

The 7th SEMI Brussels Forum will discuss how Europe's industry and policy-makers can increase their impact - both individually and jointly to reinforce Europe's position.

How can industry build on its leading positions and expertise and optimise synergies? How can Europe balance its values and rules on free competition on one hand, with the need to provide for a global level playing field on the other?

SEMI says this is the only event that brings together top-level management and EU representatives to exchange views on how to reinforce Europe's competitiveness. More information can be accessed via the link [www.semi.org/eu/brusselsforum](http://www.semi.org/eu/brusselsforum).

New EU Patent Procedure Offers Automatic Protection in 25 Countries and Brings Down Costs

The new 'EU Unitary Patent', to be made available by April 2014, is expected to reduce the administrative and financial burden of patent protection across the EU. Companies will be able to fill out a single application to the European Patent Office. Once granted, the patent is automatically valid across 25 countries (all EU member states except for Italy and Spain). A single court will be created (Unified Patent Court) with jurisdiction over infringement proceedings in any of these countries.

Companies will no longer need to apply before each national body for their patent to have effect in that territory, nor satisfy local language and administrative requirements or pay local fees. Nor will they need to defend their patents in different jurisdictions and receive different, sometimes conflicting, rulings.

This new system is also expected to significantly bring down the costs of obtaining a patent. The European Commission estimates that today, a 'classic' European patent (that needs to be validated individually in 27 Member States) costs EUR (€)36 000. The new unitary patent system will bring the costs down dramatically to around €5 000, or one-seventh of today's cost.

#### GaAs and InP under Review for a Possible Restriction under REACH

A recent EU study collected information on the production, import and use of 44 substances, including GaAs and InP, in articles, as a first step towards assessing the need for a possible restriction on their use in the EU. Such a restriction (under Art. 68 REACH) could have an impact not only on European manufacturing but also on imports.

In a joint response with other industry associations, SEMI listed the applications where these compounds are used and the lack of risk to consumers when they are completely encapsulated. SEMI further highlighted the strategic importance of these compounds for micro- and nano-electronics.

Their restriction would have a negative impact not only on industry, but on Europe as a whole. It would curb the global competitiveness of the European semiconductor manufacturing supply chain and it would deprive the EU of the industry base and products Europe needs to achieve its strategic goals for the global digital market.

GaAs and InP are the first III-V compounds being examined under the REACH microscope and SEMI is actively monitoring developments. In its upcoming advocacy activities, SEMI will collect information on risk management measures the industry has in place to avoid exposure to workers and the environment – if your company can contribute, please contact [gourania@semi.org](mailto:gourania@semi.org).

#### EU RoHS Update: Exemptions are Expiring; More Substances to be Banned under RoHS

The EU RoHS directive currently bans six substances from being used in electric and electronic equipment. Certain products of SEMI members are not covered by the Directive, such as PV panels going into fixed installations, large-scale stationary industrial tools (LSIT) and large-scale fixed installations. SEMI members also benefit from exemptions to the Directive, which allow for specific uses of the banned substances in specified quantities and for a limited period of time.

- A number of exemptions for specific applications will expire in July 2016. These exemptions can be renewed but applications for renewal need to be submitted by end of 2014. Now is therefore the time for industry to review the list of exempted applications, determine which ones are still needed and start pooling resources to draft the renewal application.

- Additional substances will be banned under RoHS by 22nd July 2014. An EU-funded study is currently underway to develop a methodology for evaluating the risk posed by hazardous substances and to determine whether they should be banned. By the end of 2013, this study will also propose additional substances that should be restricted. The European Commission will then decide on banning these substances under RoHS, the transition periods allowed for the manufacturing supply chain to adjust and start considering necessary exemptions.

The SEMI RoHS working is actively contributing to the drafting of the review methodology. For further information and to contribute to this work, please contact Sanjay Baliga at [sbaliga@semi.org](mailto:sbaliga@semi.org)

#### EU Conflict Minerals Debate is Launched – Potential Impact on Industry's Sourcing of Raw Materials from Conflict Zones

The EU is now also considering whether it needs to adopt EU measures to support responsible sourcing from conflict-affected or high-risk areas. It is not yet clear what minerals or what countries a possible EU initiative would focus on, nor whether its nature would be voluntary or binding. The question is also raised whether EU measures should address specific end-products or downstream industry sectors.

A number of initiatives on conflict minerals already exist, including the OECD guidelines on due diligence and the EU is looking to build on these and reinforce transparency through the supply chain. In the U.S., the Dodd-Frank act requires companies to report annually whether they or their suppliers are using conflict minerals (tin, tungsten, tantalum and gold originating from the

Democratic Republic of Congo or an adjoining country) and the EU is seeking feedback on how these provisions are working in practice.

The adoption of an EU legislative measure would have significant implications for SEMI members, creating a traceability requirement across the entire manufacturing supply chain. The consultation is available online here – deadline for submissions is 26 June 2013. For further information, please contact [gourania@semi.org](mailto:gourania@semi.org)

Further information on SEMI advocacy activities in Europe and on the SEMI Europe Advocacy Partners program can be obtained from Rania Georgoutsakou ([gourania@semi.org](mailto:gourania@semi.org); +32 2 609 5334) or Heinz Kundert ([hkundert@semi.org](mailto:hkundert@semi.org)).

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## Oclaro's shorter wavelength diode delivers higher power

Technology breakthrough was accomplished by developing new processes

Oclaro, Inc, a provider and of optical communications and laser solutions, has announced the introduction of the HL63153AT product, a red laser diode which delivers a 150 mW single-transverse-mode optical output power at a wavelength of 638 nm.

The Oclaro HL63153AT laser diode, the company says, offers a more brilliant image display over previous versions, enabling high-lumen pico projector or miniature displays for personal computers, and other mobile devices such as smartphones, gaming, and digital cameras, making it possible to project a bright image of multimedia and information content anytime, anywhere.

The company says that the HL63153AT laser diode offers the highest single-transverse-mode optical output power at a red wavelength available on the market, with 25% more power than its predecessor. This technology breakthrough was accomplished by developing new processes including an optimized waveguide structure and fine-tuning the laser device structural parameters.

The HL63153AT laser diode has a low power consumption of 0.6 W at 150 mW optical output power, operates in the 638 nm wavelength range, and comes in a very small, 3.8 mm-diameter TO industry-standard package facilitating very compact integration.

"This newest red laser diode product has been designed as a direct result of customer requests for a shorter wavelength diode that delivers higher power in a thin package," said Takayuki Kanno, President, Oclaro Japan

and GM of the Modules and Devices Business Unit. "We are able to deliver this light source with high brightness, high operating temperature range and small-form-factor package, so that system designers can develop compact RGB modules for the mobile display market which is experiencing rapid growth leading into 2014."

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## Oxford Instruments restructures for the future

Restructuring will sharpen focus on main target customer groups, and build on existing strengths

Oxford Instruments Plasma Technology, a provider of plasma etch and deposition systems, has announced a restructuring that will sharpen the focus on its main target customer groups, and build on the company's existing strengths in its markets.

Effective April 1st 2013, the company has been redefined into three discrete Business Groups, made up of multi-disciplined teams which will be directly aligned to the needs of its customers. The Groups will encompass product management, technical review and sales support, product and process configuration and development, backed by the company's excellent sales and customer support teams worldwide.

"We are confident that our decision to reshape the company will result in even better effectiveness, innovation and customer experience. Our customers are the key to Oxford Instruments Plasma Technology's success, and we are sure that this structural change will enhance our customers' experience through the increased focus our teams will bring to bear on their areas of expertise," comments Dan Ayres, Managing Director at Oxford Instruments Plasma Technology, "Our business has trebled in size since 2006, and building on the success of recent years, we are creating a structure and environment aligned with our strategy that supports our further growth."



Dan Ayres, Managing Director,

Oxford Instruments Plasma Technology

Dan Ayres continues, "It is important that we respond to

the needs of our customers, by better aligning ourselves to the markets we address, to ensure maximum product performance. In today's demanding markets, we have taken the opportunity at the start of our financial year to restructure and focus on this challenge. This, together with the confidence that our strategy and investment in product and process will drive further expansion in the near future, will enable our business to grow both efficiently and profitably."

## EV Group Rolls out Next-Generation Automated Resist Processing System

Flexible tool suited for thick-film processing of compound semiconductor devices.

EV Group (EVG), a supplier of wafer bonding and lithography equipment for the MEMS, nanotechnology and semiconductor markets, has introduced the latest version of its EVG 120 automated resist processing system.

The EVG120 boasts new features and improved productivity in an ultra-small footprint design: the system supports coating and developing applications for a variety of markets, including MEMS, advanced packaging and compound semiconductors. The flexible tool can be configured with combined spin and spray coating modules—a unique feature that maximizes productivity and optimizes cost of ownership (CoO).

Dr. Thomas Glinsner, head of product management for EV Group, noted, "Our new EVG120 system reflects EVG's 15 years of experience in resist coating and developing, and our unique process skills. In independent surveys, our customers consistently attribute the highest scores to EVG's lithography equipment, and we've listened to their feedback to create a more optimized system. Based on a proven platform, the next-generation EVG120 coater/developer offers increased functionality and reliability in a highly customizable and economical package."

The EVG120 automated resist processing system features a new robot with dual arms for fast wafer swapping and additional processing chambers, which result in enhanced throughput and overall productivity. To optimize throughput and overall productivity, the new EVG120 runs the same EVG CIM Framework software as EVG's high-end XT Frame systems and offers full software integration with SECS/GEM standards. Two customizable wet processing bowls are complemented by 10 stacked modules for vapour prime, soft and hard bake, and chill processes. Like its predecessor, the

EVG120 system can accommodate wafers up to 200 mm in diameter.

Other new features of the EVG120 system include EVG's innovative CoverSpin rotating bowl cover that allows improved coating uniformity across the substrate regardless of substrate shape. A new, temperature-controlled chuck further enhances EVG's proprietary OmniSpray coating technology, which specifically allows conformal coating of high-topography surfaces via its proprietary ultrasonic nozzle. OmniSpray coating is ideally suited for ultra-thin, fragile or perforated wafers and can the company says result in an 80-percent or greater reduction in material consumption compared to traditional spin coating.

The company says the improved serviceability and low CoO make the EVG120 system a versatile, high-quality production tool for an entry-level budget. The EVG120 system is suited for a wide variety of markets and applications, including: high-topography coating and spray coating for MEMS; thick-film resists and bumping for advanced packaging; and passivation, dielectrics and thick-film processing for compound semiconductor devices.

## AXT, Inc. Announce First Quarter 2013 Financial Results

Revenues as expected says CEO

AXT, Inc, a manufacturer of compound semiconductor substrates, has reported financial results for the first quarter ended March 31, 2013.

Q1 2013 revenue was reported as \$22.4 million compared with \$18.9 million in the fourth quarter of 2012.

Total gallium arsenide (GaAs) substrate revenue was \$11.7 million for the first quarter of 2013, compared with \$11.3 million in the fourth quarter of 2012.

Indium phosphide (InP) substrate revenue was \$1.8 million for the first quarter of 2013, compared with \$1.6 million in the fourth quarter of 2012.

Germanium (Ge) substrate revenue was \$2.6 million for the first quarter of 2013 compared with \$1.7 million in the fourth quarter of 2012. Raw materials sales were \$6.3 million for the first quarter of 2013, compared with \$4.3 million in the fourth quarter of 2012.

Revenue trends in the first quarter came in largely as expected in each of our product categories, although our

performance in germanium substrates and raw materials outperformed our plan,” said Morris Young, chief executive officer.

Gross margin was 15.6 percent of revenue for the first quarter of 2013. By comparison, gross margin in the fourth quarter of 2012 was 19.5 percent of revenue. The decrease of 3.9 percentage points in gross margin in the first quarter was expected.

Morris Young, chief executive officer comments “With our industry continuing to evolve, both in terms of the customer landscape and technology trends, we experienced a continuation of the softness in semi-insulating substrates that we began to see in the second half of 2012. The wireless industry, while growing in terms of devices, is transitioning to new technologies for certain devices in order to maximize cost efficiency, reduce size requirements and increase performance capabilities. These transitions are likely to occur throughout 2013, and continue to constrain our semi-insulating substrate results as customers evaluate their ongoing requirements. However, we are seeing renewed growth in our semi-conducting gallium substrate business as well as improving demand for our indium phosphide substrates, germanium substrates and raw materials. While the changes to the wireless side of our business have been challenging, we remain optimistic that new opportunities, coupled with improving market conditions in other product lines will allow us to drive improved shareholder value in 2013.”

## **IQE’s Galaxy announce state of the art characterisation tool**

Tropel Flatmaster Surface Form Analysis System for the measurement of substrate flatness revealed

Galaxy Compound Semiconductors Inc., a member of the IQE Group, supplier of advanced semiconductor materials, has announced enhanced measurement capabilities with the installation of the Tropel FM200 Flatmaster Surface Form Analysis System for the measurement of substrate flatness.

The new, state of the art characterisation tool is configured to measure substrates up to 8” (200mm) in diameter and will be used to offer customers superior materials characterisation to meet the the growing demand for large diameter InSb and GaSb products engineered for specific device size applications.

The new equipment has been installed and commissioned within the cleanroom polishing area at the

Company’s manufacturing facility in Spokane, WA. The non-contact, high throughput measurement capabilities of the FM200 will also support the rapid collation of substrate characterisation data processed in real time for customer review.

Patrick Flint, Galaxy’s Director of Technology and Business Development, said:

“The FM 200 enables us to provide SEMI-standard, high resolution flatness maps to all of our InSb and GaSb customers.

“The powerful data analysis capabilities of Tropel’s Flatmaster system is proving to be very valuable and allows us to manufacture substrates with custom flatness profiles that are delivering benefits to our customer’s yield improvement programs.”

## **Laytec reveals non-destructive metrology tool for solar cell analysis**

The firm says its new tool results in a perfect lamination process, which is the key to high-quality modules

One of the reasons why solar modules fail in the field is the insufficient cross-linking of ethylene vinyl acetate (EVA) caused by vacuum lamination process deviations or unstable EVA foil materials.

Laytec says the current standard tests are slow, destructive, manual, inaccurate and patchy.



*X-Link in action*

LayTec’s new off-line metrology system X Link provides

fast, automated, non-destructive and accurate evaluation of EVA cross-linking degree immediately after lamination. It can be integrated in every solar module production line and offers 100 percent coverage for process and quality control.

The high precision measurements are performed through the backsheets without damaging the laminated surface.

They take only a few seconds, do not influence the performance of the tested module and have a precision of  $\pm 1.5$  percent.

With X Link's direct feedback, the lamination process can be quickly optimised for better cross-linking quality by adjusting the heating zones and the duration of lamination. Laytec claims the result is a perfect lamination process, which is the key to high-quality modules.

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## ARC Energy selects Elmet to supply components for sapphire

Elmet Technologies is now manufacturing refractory metal crucibles and furnace components for ARC Energy's CHES sapphire growth furnaces

ARC Energy has selected Elmet Technologies as a preferred supplier of crucibles and furnace components for ARC Energy Controlled Heat Extraction System (CHES) furnaces.

After an intensive qualification and review process, ARC Energy is confident that Elmet has the capacity and expertise to produce high-quality replacement crucibles and components in

support of CHES furnace operators world-wide.

ARC Energy CHES furnaces grow high quality synthetic sapphire up to 260mm diameter.

Synthetic sapphire is a critical building block for LED light manufacturing, high performance glass for mobile devices, silicon-on-sapphire (SOS) semiconductor substrates, military grade windows, and other applications.

"At ARC Energy, we strive to provide our customers with innovative, efficient furnaces for large diameter 6" sapphire," says Rick Schwerdtfeger, co-founder and chief technology officer for ARC Energy. "By partnering with Elmet, we feel secure knowing our customers have access to quality crucibles and furnace components

manufactured to the highest standards in the industry."

"The market for synthetic sapphire is increasing rapidly, and Elmet is continually investing to support the growing demand for sapphire crucibles and precision-formed furnace components," explains Sandeep Jain, senior VP of sales and marketing for Elmet. "We have unique capabilities on which the sapphire industry can capitalise to keep up with the demand for their products."

Headquartered in Nashua, N.H., the Advanced RenewableEnergy Company, LLC (ARC Energy), was

founded in 2007 to commercialise cutting-edge technologies for LED and other clean energy markets.

Established in 1929, Elmet is a global supplier of high performance materials with a specialisation in molybdenum and tungsten.

With 400,000 square-feet at three manufacturing sites in Maine, Georgia, and China, Elmet produces mill, machined, and fabricated products for sapphire growth, FPD manufacturing, medical imaging, high temperature furnace, and many other industries.

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## Wireless chip producer orders more Plasma-Therm tools

The VERSALINE processing tools will support backside GaAs RF power amplifier and switch chip production

A leading US wireless compound semiconductor device manufacturer has placed capacity driven, follow-on orders with Plasma-Therm LLC for VERSALINE wafer processing, etch modules.

The process systems will support RF power amplifier and switch chip production with advanced backside GaAs via formation. These chipsets are used primarily in handsets and other RF applications.

The process modules include Plasma-Therm's EndPointWorks technology and unique active

feedback chamber temperature management to ensure maximum etch yield, reproducibility and uptime productivity.

These orders compliment an installed base of Plasma-Therm VERSALINE and Versalock systems at this site for multiple plasma-processing steps that includes both deposition and etch.

David Lishan, Director-Technical Marketing explains, "Based on a history of repeat orders, Plasma-Therm has been a key supplier to wireless compound semiconductor manufactures for many years.

Follow-on orders are especially encouraging as they confirm we are continuously providing solutions that meet the expectations of our customers. On time solutions, whether for capacity or technology needs, are a result of close collaboration with our customers."

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## Veeco affected by weak MOCVD and data storage market

The firm's system shipments were at very low levels and bookings were the weakest since early 2009

Veeco Instruments is providing select financial metrics and business highlights for the quarter ended March 31st, 2013.

Due to the accounting review announced on November 15th, 2012, the company is unable to report revenue and earnings information.

The company's unaudited cash balance at March 31st, 2013 was \$588 million, up from \$579 million at December 31st, 2012.

First quarter system shipments declined sharply, on a sequential basis, in both MOCVD and Data Storage.

With few MOCVD deals available, Veeco continues to experience significant competitive pricing pressure.

John R. Peeler, Veeco's Chairman and Chief Executive Officer, comments, "First quarter business conditions remained extremely challenging, with system shipments at very low levels and bookings the weakest we have seen since early 2009. We are pleased that Veeco continues to weather this business downturn with a strong cash position."

"Looking ahead, end market signals in MOCVD are mixed but appear to be trending in a positive direction," adds Peeler. "Some key LED customers are operating at close to full utilisation rates, and we are now booking some rush purchase orders - the first we have seen in two years. In particular, some Chinese customers with committed funding for MOCVD equipment are planning fab expansions. In Data Storage, customers are making technology buys and we are seeing an increase in

quotations for MBE systems for research applications. While visibility remains limited, we anticipate meaningfully higher bookings in the second quarter."

Peeler concludes, "It is a top priority to conclude our accounting review as soon as possible. Veeco's other key focus areas for 2013 are our plans to fortify and build on our leadership positions in our core markets, especially in LED lighting which we believe is a huge market opportunity in front of us, and to leverage our technologies into adjacent markets like power electronics, OLED, MEMS and EUV."

Veeco's process equipment solutions enable the manufacture of LEDs, power electronics, hard drives, MEMS and wireless chips. The firm provides MOCVD, MBE, Ion Beam and other advanced thin film process technologies.

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## SAMCO expands in Silicon Valley

The company was one of the first Japanese venture companies to open an R&D centre in Silicon Valley

On April 15th 2013, SAMCO Inc, head quartered in Kyoto, Japan expanded its OPTO Films Research Laboratory in California's Silicon Valley.

The firm did this to strengthen its research structure and after-sale process support.

Placing an emphasis on interaction with cutting edge research SAMCO is expanding its research and development activities at its three global R&D centres – The 'Kyoto Research and Development Centre'; the Silicon Valley 'OPTO Films Research Laboratory'; and 'Cambridge Research Centre' located in England's Cambridge University.

SAMCO was the first Japanese venture company to open an R&D centre in the Silicon Valley. The OPTO Films Research and Development Centre in Silicon Valley was established in 1987 as SAMCO's first overseas research and development centre.

Since its establishment it has lead the research of carbon type materials such as diamond thin films, diamond like carbon (DLC), and materials for electrodes etc., as well as the development of thin film deposition systems.

What's more, the facility also plays an important role in joint research with universities.

Highlighting SAMCO's plans for business expansion

and the strengthening of its research and development structure, the new facility is about twice as large as the one it replaces.

Also, in order to maximise research efficiency, the laboratory is again located in the Silicon Valley, a hub of company research centres and ventures.

The new laboratory is equipped with SAMCO CVD systems, dry etching systems, cleaning systems, and a suite of thin film measurement systems. Research will continue on thin films of carbon-based materials and new research will begin on MEMS (Micro Electro Mechanical Systems) fabrication for the bio-medical industries. Recruitment of local researchers is also progressing, with plans for up to ten researchers to be based at the facility (currently six).

Along with the expansion of the Silicon Valley facilities, SAMCO has also increased sales personnel in its East Coast Sales and Service Office located in North Carolina's 'Research Triangle Park'. The new OPTO films Laboratory will play an important role, as a demo laboratory, in supporting the expansion of North American sales.

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## SAES purchases Power+Energy hydrogen purifier business

Power+Energy aims to focus exclusively on advanced hydrogen generation, separation, and analysis including palladium technology

On 19th April 2013, Power + Energy sold the intellectual property and all other rights to manufacture and market its low cost, high efficiency, Palladium micro-channel purifiers to SAES Pure Gas Inc.

Power + Energy's future business focus will provide innovative products and technologies to the growing markets for syn-gas and hydrogen generation, separation, and analysis.

Commenting on the sale, Power + Energy's CEO, Peter Bossard says, "I am very pleased that SAES has recognised the value of Power + Energy's hydrogen purification technology. We are looking forward to fully supporting the transition of the Palladium Hydrogen Purifiers from Power + Energy to SAES Pure Gas. And of course, I am excited by the prospect of being able to focus Power + Energy's future work on delivering innovative, energy efficient, low cost products to the growing hydrogen economy."

SAES Pure Gas will expand its manufacturing facility at its San Luis Obispo CA plant to build the Palladium micro-channel purifiers for ultra-high purity hydrogen applications.

Power + Energy will continue to build purifiers for SAES Pure Gas at its Ivyland PA plant until the SAES Pure Gas facility has been completed and will continue to provide warranty support for its existing purifier customers.

"The Palladium Membrane Technology fits perfectly within the purification portfolio of SAES Pure Gas. We are proud to offer this Palladium Membrane technology to our customers in conjunction with our other ultra-high purity technologies for Hydrogen (adsorber, heated getters) and other bulk gases which include Nitrogen, Argon, Helium, Ammonia, CDA, and Oxygen," comments Tim Johnson, SAES Pure Gas CEO. This acquisition comes at a crucial moment for Palladium Membrane technology, with the increased use of Hydrogen within the Electronics industry.

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# Novel Devices

## Europe to boost micro- and nanoelectronic industries

A new initiative is supporting research, development and innovation and improvement in the entire semiconductor ecosystem

The European Semiconductor Industry Association (ESIA) welcomes the European Commission's Communication "A European strategy for micro- and nanoelectronic components and systems".

The actions outlined in the Communication will strengthen the competitiveness and growth potential of the micro- and nanoelectronics industry in Europe, and build upon the European initiative on Key Enabling Technologies (KETs) and HORIZON 2020.

ESIA believes that this Communication takes a decisive approach to reinforce the European semiconductor industry, and to increase its contribution to the wider European economy.

ESIA commends the acknowledgment that semiconductors play a crucial role in driving business transformation and responding to growing societal needs. This communication recognises the electronics industry as a key force to address the challenges the economy in the EU is facing.

ESIA fully supports the Commission's multi-level strategy including financial support for research, development and innovation (R&D&I), as well as the improvement and better use of relevant legislation. Given the very high diversity of the European market, ESIA is pleased to see the entire semiconductor ecosystem being addressed.

With a clear focus on R&D&I, market pull for new application areas, education and production, the strategy builds on the four pillars ESIA has been promoting as a basis for a dedicated European industrial policy for the micro- and nanoelectronics sector.

Rick Clemmer, ESIA President and CEO of NXP Semiconductors, states, "Pilot lines and prototyping are a welcome addition to the European R&D stimulation programme. But this concept should not be limited to semiconductor manufacturing as such. Joint semiconductor downstream application pilots will provide significant additional leverage in economic growth and employment in areas such as the Internet of Things and Smart Cities, including Intelligent Traffic Systems, Smart Buildings and Smart Grids."

Executing on this Communication has the potential to reverse the current trend in the European semiconductor market, which has seen production in Europe drop to less than 10% percent of world production in 2011.

"Leadership in innovation is key to developing a sustainable advantage for European industry and we need to build on the scientific excellence in Europe to turn great ideas into globally competitive technologies and related manufacturing," comments Carlo Bozotti, President and Chief Executive Officer of STMicroelectronics.

"With traditional strengths in analogue and power as well as more recent innovations in technologies, companies in Europe have the capability to continue to lead the development of the next wave of electronic products. The actions outlined in the Commission's Communication demonstrate a clear commitment to Europe's future," adds Bozotti.

Hendrik Abma, Director-General of ESIA, says, "ESIA welcomes the ambition and vision of the European Commission's strategy. ESIA has consistently underlined the importance of the European semiconductor industry to the competitiveness and vitality of the European economy, as well as to tackling the grand societal challenges, such as energy efficiency and aging populations."

ESIA looks forward to the full implementation of the European Commission's strategy for micro- and nanoelectronic components and systems. ESIA is fully aware that the strategy's successful execution requires

significant alignments among all stakeholders.

## 3M and Nanosys stunningly enhance LCDs with quantum dots

Pumped with a blue source, such as the gallium nitride (GaN) LED, quantum dots can be made to emit at any wavelength beyond the pump source wavelength with over 90 percent quantum yield

3M has announced it is in the final stages of scale-up for its new 3M Quantum Dot Enhancement Film (QDEF).

The new film allows up to 50 percent more color than current levels in liquid crystal display (LCD) devices.

3M has teamed up with Nanosys, to produce the 3M QDEF solution specifically to deliver more colour, and to make devices such as smart phones, tablets and televisions, lighter, brighter and more energy efficient.

Current LCDs typically are limited to displaying 35 percent or less of the visible color spectrum. This means the viewing experience on an LCD can be vastly different than what a person sees in the real world. Wide colour gamut displays will allow consumers to enjoy more visceral, more immersive and truer-to-life colour.



Comparison of LCDs without (left) and with (right) 3M's QDEF solution. (Photo: 3M)

"One of the many advantages of the new 3M QDEF solution is the film's ability to deliver richly-saturated colours, while minimising power consumption - a difference you can clearly see," says Ty Silberhorn, vice president and general manager, 3M Optical Systems Division. "We will have qualification material available to customers for design cycles starting late second quarter this year."

Over the years, 3M light management technologies have made LCDs thinner, lighter and more energy

efficient. Colour performance of LCDs industry-wide has gone largely unchanged until now. 3M research data shows that devices with 3M QDEF-enabled wide colour gamut will be noticeably different from other standard LCD devices, prompting the human eye to dwell on the display longer than less-saturated displays.

QDEF utilises the light emitting properties of quantum dots to create an ideal backlight for LCDs, which is one of the most critical factors in the colour and efficiency performance of LCDs.

Unlike conventional phosphor technologies such as YAG that emit with a fixed spectrum, quantum dots can actually convert light to nearly any color in the visible spectrum.

Pumped with a blue source, such as a GaN LED, they can be made to emit at any wavelength beyond the pump source wavelength with very high efficiency (over 90 percent quantum yield) and with very narrow spectral distribution (only 30 - 40nm FWHM.)

The real magic of quantum dots is in the ability to tune the colour output of the dots, by carefully controlling the size of the crystals as they are synthesised so that their spectral peak output can be controlled within 2nm to nearly any visible wavelength.

A quantum dot, which is 10,000 times narrower than a human hair, can be tuned to emit light at very precise wavelengths. This means display makers can create a highly-optimised backlight that only produces the exact wavelengths of red, green and blue light needed by an LCD for optimal colour and energy performance.

Trillions of these quantum dots protected by barrier film fit inside an LCD backlight unit. The new film replaces one already found inside LCD backlights, which means the manufacturing process requires no new equipment or process changes for the LCD manufacturer.

“Improving colour performance for LCDs with simple, drop-in manufacturing solutions will create a stunning new visual experience for consumers,” comments Jason Hartlove, president and CEO, Nanosys, Inc.

“Working together with 3M and utilising their outstanding design and supply chain capabilities will allow our quantum dot technology to be widely deployed across all product segments, ensuring availability to all customers,” he adds.

## A new era of atomic-scale semiconductor devices

Scientists have demonstrated the semiconductor molybdenum sulphide can be grown in layers only one atom thick without compromising its properties

Researchers at North Carolina State University have developed a new technique for creating high-quality semiconductor thin films on the atomic scale where the films are only one atom thick.

The technique can be used to create these thin films on a large scale, sufficient to coat wafers that are two inches wide, or larger.

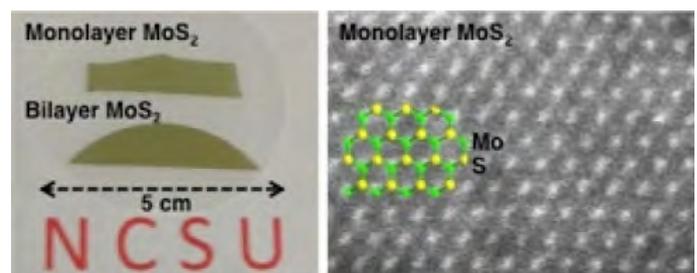
“This could be used to scale current semiconductor technologies down to the atomic scale, lasers, LEDs, computer chips, anything,” says Linyou Cao, an assistant professor of materials science and engineering at NC State and senior author of a paper on the work. “People have been talking about this concept for a long time, but it wasn’t possible. With this discovery, I think it’s possible.”

The researchers worked with molybdenum sulphide (MoS<sub>2</sub>), an inexpensive semiconductor material with electronic and optical properties similar to materials already used in the semiconductor industry.

However, MoS<sub>2</sub> is different from other semiconductor materials because it can be grown in layers only one atom thick without compromising its properties.

In the new technique, researchers place sulphur and molybdenum chloride powders in a furnace and gradually raise the temperature to 8500C, which vaporises the powder. The two substances react at high temperatures to form MoS<sub>2</sub>. While still under high temperatures, the vapour is then deposited in a thin layer onto the substrate.

“The key to our success is the development of a new growth mechanism, a self-limiting growth,” Cao says.



MoS<sub>2</sub> structure

The researchers can precisely control the thickness of the MoS<sub>2</sub> layer by controlling the partial pressure and vapour pressure in the furnace. Partial pressure is the tendency of atoms or molecules suspended in the air to condense into a solid and settle onto the substrate. Vapour pressure is the tendency of solid atoms or molecules on the substrate to vaporise and rise into the air.

To create a single layer of MoS<sub>2</sub> on the substrate, the partial pressure must be higher than the vapour pressure. The higher the partial pressure, the more layers of MoS<sub>2</sub> will settle to the bottom.

If the partial pressure is higher than the vapour pressure of a single layer of atoms on the substrate, but not higher than the vapour pressure of two layers, the balance between the partial pressure and the vapour pressure can ensure that thin-film growth automatically stops once the monolayer is formed. Cao calls this “self-limiting” growth.

Partial pressure is controlled by adjusting the amount of molybdenum chloride in the furnace - the more molybdenum is in the furnace, the higher the partial pressure.

“Using this technique, we can create wafer-scale MoS<sub>2</sub> monolayer thin films, one atom thick, every time,” Cao explains. “We can also produce layers that are two, three or four atoms thick.”

Cao’s team is now trying to find ways to create similar thin films in which each atomic layer is made of a different material. Cao is also working to create field-effect transistors and LEDs using the technique. Cao has filed a patent on the new technique.

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## QD Vision breaks QLED efficiency barriers

The firm’s CdSe-CdS emitters are suited to applications such as electronic displays and solid-state lighting

QD Vision, a manufacturer of ‘Color IQ’ optical components for LCD applications, says it has made a breakthrough in next generation quantum dot light emitting devices (QLEDs), which are currently in the advanced development stage.

QLEDs are a quantum dot-based light emitting technology, which in the future will be used in applications such as electronic displays and solid-state lighting.



*Semiconductor nanocrystal technology that emits light very precisely. So when it’s used in LCD screens like TVs, you see a more dynamic range of colours and the true, natural palette encoded in the picture. QD Vision says Color IQ adds up to 50 percent more colour into the TV picture*

The firm’s QLEDs are composed of an inverted organic-inorganic hybrid device structure and colloidal CdSe-CdS (core-shell) quantum-dot emitters. The strong electronic coupling of quantum dots to an adjacent layer of ZnO nanocrystals (which form the electron transport layer) facilitates charge transfer, which is responsible for both injecting electrons and maintaining an optimal charge balance for the quantum dot emitters.

QD Vision’s latest QLED performance results have been published in the 21st April 2013 issue of *Nature Photonics*. In the article, QD Vision reports achieving 18 percent External Quantum Efficiency which puts QLEDs near the fundamental efficiency limit of the technology.

The firm claims these results are double the efficiency of previously reported QLED devices.

QD Vision says its current and luminous power efficiency are better than the best evaporated OLED result of the same colour coordinate, and significantly better than what solution-processed OLEDs have thus far achieved.

“This paper clearly demonstrates the fundamental efficiency advantage that QLEDs have over any other emissive display technology. Achieving this milestone is a great breakthrough and the result of years of hard work and dedication to achieving what others may have thought impossible,” says QD Vision co-founder Seth Coe-Sullivan.

While at an earlier stage of development and commercialisation than QD Vision’s Color IQ products, QLED performance is already suitable for use in certain products that require precision colour solutions in an ultra-slim form factor. These include monochrome visible and infrared displays, and lighting devices for machine and night vision applications.

Further details of this work have been published in the paper, "High-efficiency quantum-dot light-emitting devices with enhanced charge injection," by Benjamin S. Mashford *et al* in *Nature Photonics* (2013), 407-412. DOI:10.1038/nphoton.2013.70

## GaAs nanowires harvest solar power

A novel 3 dimensional geometry based on gallium arsenide enables trapping more light than planar structures, such as silicon solar devices, and with less material

How can we harvest the energy of the sun at a better quality and at a cheaper cost?

To find out, Anna Fontcuberta and her team in the STI Laboratory of Semiconductor Materials (LMSC) at EPFL are working on novel solutions to produce the solar cells of tomorrow.

The research of Fontcuberta, a professor in the STI LSMCL, focuses on new ways to engineer semiconducting structures, mainly with the use of nanotechnologies.

Semiconductors, thanks to their physical properties, have increased the functionality of many objects in our daily lives (microwave ovens, cars, DVD player or computers e.g.) and at the same time our quality of life.

The LSMC works on new geometries using nanowires. These are needle-like crystals of a diameter between 20 and 100 nm and several microns long.

The objective is to increase their functionality by understanding their properties and finding new ways to fabricate them. Among the many applications using nanowires is one of a higher interest to Fontcuberta and her team: solar cells.

Because of the world's urgent need to harvest greener energies, nanowire solar cells have a huge societal and industrial potential for the future.

"We are working on nanowire solar cells using GaAs in their core, a high conducting material which absorbs light at the ideal range with respect to the solar spectrum", explains Fontcuberta.

For example, in the 1990's, GaAs solar cells took over from silicon devices in photovoltaic arrays for satellite applications, or power the robots that are exploring the surface of Mars.

In the LMSC, gallium and arsenide atoms are engineered (or "tricked") in a way that they organise themselves to form wires rather than horizontal layer on layer structures (which they tend to do naturally).

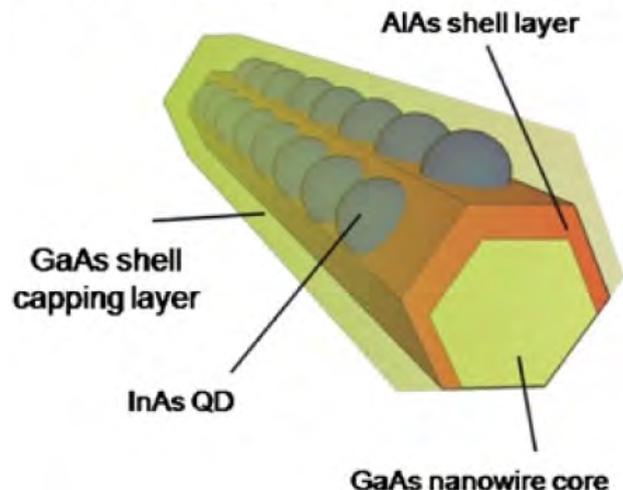
This 3 dimensional geometry is a novelty as it enables the trapping of more light than planar structures, such as silicon solar devices, and with less material.

Each vertical nanowire becomes a device that produces current. The combination of the nanowires' small scale (one micron) and revolutionary 3D geometry (a little bit like hair standing up), enables a significant decrease of the solar cell's cost per watt - compared to commonly used solar cells.

Apart from enhancing the light absorption, Fontcuberta and her team are working on ways to optimise it. For example, they combine the nanowire's GaAs core with other nanoscale materials in both axial and radial directions. As an example, InAs quantum dots (or "islands") on the nanowire play the role of stimulants for a better absorption of the light.

An illustration of an example structure is shown below.

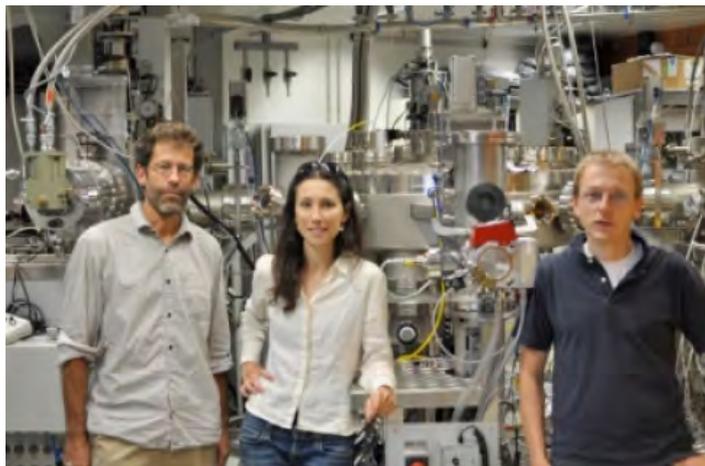
### GaAs-core nanowire structure



Nanowire solar cells represent the 3rd generation of solar cells because they are made on a very small scale and can be combined in many different ways, enabling the extraction of more energy at a lower cost.

Despite encouraging applications, "It might take ten more years before nanowires can be found on the market", explains Fontcuberta.

This is an objective, which the LMSC will pursue at EPFL.



From left to right, Francois Morier Genoud (Laboratory of Quantum Optoelectronics), Anna Fontcuberta and Emanuele Uccelli (Laboratory of Semiconductor Materials) in front of the MBE machine which is used for nanowire research, and which both groups share

## SEMI highlights the need for InP and GaAs

The organisation says that the restriction of the use of indium phosphide and gallium arsenide would have a negative impact on the semiconductor industry and Europe as a whole. SEMI has also described a new directive which will bring down patent application costs

According to Heinz Kundert, president of SEMI Europe, being able to quickly identify and seize the potential offered by new technologies and new markets is critical in the semiconductor industry. Keeping track of public policy developments is equally important.

Decisions made in a national Ministry or an EU institution can have a direct impact on the industry.

A new EU patent procedure, to be introduced by mid-2014, will significantly reduce the cost and time for a company to obtain a patent valid across 25 European states. The outcomes of the current review of substances under European EHS rules, for example, may have an impact on industry's research priorities or its access to the EU market.

This article covers these topics: 7th SEMI Brussels Forum; EU Patent Protection; GaAs and InP under Review (REACH); RoHS Exemptions Expiring; Banned Substances under RoHS; EU Conflict Minerals Debate.

The SEMI Brussels Forum is one of Europe's leading policy events for semiconductor equipment and

materials, providing a unique platform for top-level executives and EU representatives to exchange views and debate how to reinforce Europe's competitiveness in the global market.

The 7th SEMI Brussels Forum will discuss how Europe's industry and policy-makers can increase their impact - both individually and jointly to reinforce Europe's position.

How can industry build on its leading positions and expertise and optimise synergies? How can Europe balance its values and rules on free competition on one hand, with the need to provide for a global level playing field on the other?

SEMI says this is the only event that brings together top-level management and EU representatives to exchange views on how to reinforce Europe's competitiveness. More information can be accessed via the link [www.semi.org/eu/brusselsforum](http://www.semi.org/eu/brusselsforum).

### New EU Patent Procedure Offers Automatic Protection in 25 Countries and Brings Down Costs

The new 'EU Unitary Patent', to be made available by April 2014, is expected to reduce the administrative and financial burden of patent protection across the EU. Companies will be able to fill out a single application to the European Patent Office. Once granted, the patent is automatically valid across 25 countries (all EU member states except for Italy and Spain). A single court will be created (Unified Patent Court) with jurisdiction over infringement proceedings in any of these countries.

Companies will no longer need to apply before each national body for their patent to have effect in that territory, nor satisfy local language and administrative requirements or pay local fees. Nor will they need to defend their patents in different jurisdictions and receive different, sometimes conflicting, rulings.

This new system is also expected to significantly bring down the costs of obtaining a patent. The European Commission estimates that today, a 'classic' European patent (that needs to be validated individually in 27 Member States) costs EUR (€)36 000. The new unitary patent system will bring the costs down dramatically to around €5 000, or one-seventh of today's cost.

### GaAs and InP under Review for a Possible Restriction under REACH

A recent EU study collected information on the production, import and use of 44 substances, including GaAs and InP, in articles, as a first step towards assessing the need for a possible restriction on their use in the EU. Such a restriction (under Art. 68 REACH) could have an impact not only on European

manufacturing but also on imports.

In a joint response with other industry associations, SEMI listed the applications where these compounds are used and the lack of risk to consumers when they are completely encapsulated. SEMI further highlighted the strategic importance of these compounds for micro- and nano-electronics.

Their restriction would have a negative impact not only on industry, but on Europe as a whole. It would curb the global competitiveness of the European semiconductor manufacturing supply chain and it would deprive the EU of the industry base and products Europe needs to achieve its strategic goals for the global digital market.

GaAs and InP are the first III-V compounds being examined under the REACH microscope and SEMI is actively monitoring developments. In its upcoming advocacy activities, SEMI will collect information on risk management measures the industry has in place to avoid exposure to workers and the environment – if your company can contribute, please contact [gourania@semi.org](mailto:gourania@semi.org).

EU RoHS Update: Exemptions are Expiring; More Substances to be Banned under RoHS

The EU RoHS directive currently bans six substances from being used in electric and electronic equipment. Certain products of SEMI members are not covered by the Directive, such as PV panels going into fixed installations, large-scale stationary industrial tools (LSIT) and large-scale fixed installations. SEMI members also benefit from exemptions to the Directive, which allow for specific uses of the banned substances in specified quantities and for a limited period of time.

- A number of exemptions for specific applications will expire in July 2016. These exemptions can be renewed but applications for renewal need to be submitted by end of 2014. Now is therefore the time for industry to review the list of exempted applications, determine which ones are still needed and start pooling resources to draft the renewal application.

- Additional substances will be banned under RoHS by 22nd July 2014. An EU-funded study is currently underway to develop a methodology for evaluating the risk posed by hazardous substances and to determine whether they should be banned. By the end of 2013, this study will also propose additional substances that should be restricted. The European Commission will then decide on banning these substances under RoHS, the transition periods allowed for the manufacturing supply chain to adjust and start considering necessary exemptions.

The SEMI RoHS working is actively contributing to the drafting of the review methodology. For further information and to contribute to this work, please contact Sanjay Baliga at [sbaliga@semi.org](mailto:sbaliga@semi.org)

EU Conflict Minerals Debate is Launched – Potential Impact on Industry's Sourcing of Raw Materials from Conflict Zones

The EU is now also considering whether it needs to adopt EU measures to support responsible sourcing from conflict-affected or high-risk areas. It is not yet clear what minerals or what countries a possible EU initiative would focus on, nor whether its nature would be voluntary or binding. The question is also raised whether EU measures should address specific end-products or downstream industry sectors.

A number of initiatives on conflict minerals already exist, including the OECD guidelines on due diligence and the EU is looking to build on these and reinforce transparency through the supply chain. In the U.S., the Dodd-Frank act requires companies to report annually whether they or their suppliers are using conflict minerals (tin, tungsten, tantalum and gold originating from the Democratic Republic of Congo or an adjoining country) and the EU is seeking feedback on how these provisions are working in practice.

The adoption of an EU legislative measure would have significant implications for SEMI members, creating a traceability requirement across the entire manufacturing supply chain. The consultation is available online here – deadline for submissions is 26 June 2013. For further information, please contact [gourania@semi.org](mailto:gourania@semi.org)

Further information on SEMI advocacy activities in Europe and on the SEMI Europe Advocacy Partners program can be obtained from Rania Georgoutsakou ([gourania@semi.org](mailto:gourania@semi.org); +32 2 609 5334) or Heinz Kundert ([hkundert@semi.org](mailto:hkundert@semi.org)).

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## Monitoring UV exposure with the help of AlGaN

Aluminium gallium nitride technology can withstand continuous exposure to UV light without damage

UV lamps are used to cure coatings and adhesives in many industrial manufacturing processes. And special sensors are used to measure the intensity of the UV light applied to these surfaces.

But because these sensors age too quickly, they can only be used to record intermittent measurements.

Now, Fraunhofer researchers have developed a new generation of sensors capable of continuously monitoring UV intensity.

“UV exposure” is a term that tends to ring alarm bells, as most people associate it with sunburn and the risk of skin cancer. But ultraviolet (UV) light can also be beneficial, or indeed essential; the human body needs it to produce vitamin D.

Industry, too, makes use of UV light, for example to cure adhesives or the coatings applied to food packaging, and also to disinfect water.

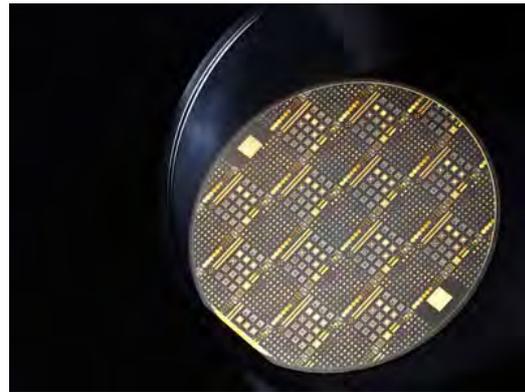
On the other hand, surfaces can be damaged if they are exposed to too much UV light, and poorly regulated UV lamps also waste energy and generate excessive amounts of ozone. UV sensors are therefore used to optimise light intensity.

Usually these sensors are made of silicon or SiC. The problem with silicon sensors is that they only deliver useful results if visible light is excluded from the measurement by external filters. Unfortunately, the filters used are very expensive and not particularly resistant to ultraviolet light. So to reduce ageing, measurements can only be taken intermittently, as snapshots.

SiC sensors have the advantage of being able to withstand longer exposure to UV light, but they only operate in a narrow spectral band. In the majority of industrial curing processes, it is the longer wavelengths that are of interest – precisely the area in which these sensors are least accurate.

Researchers at the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg have now developed a new UV sensor in collaboration with colleagues at the Fraunhofer Institutes for Manufacturing Technology and Advanced Materials IFAM, for Optronics, System Technologies and Image Exploitation IOSB, for Silicon Technology ISIT and for Physical Measurement Techniques IPM.

“Our sensor is based on aluminium gallium nitride technology and can withstand continuous exposure to UV light without damage,” says IAF project manager Susanne Kopta. “This enables it to be used not only for intermittent snapshots but also for permanent inline monitoring.” A sapphire wafer serves as the substrate for the sensors. The researchers apply epitaxial growth to deposit layers of the active material onto the substrate, in other words the layers have a crystalline structure.



*Processed AlGaN-based UV sensors on a sapphire wafer (© Fraunhofer IAF)*

#### Sensor for high UV intensities

The particular strength of this novel sensor is its suitability for applications involving very high UV intensities – and for tasks that require the monitoring of specific spectral ranges. This is due to the fact that the detectors can be set to operate in two different ways.

The first option is to define a maximum wavelength threshold. In this case the sensor detects all UV light emitted at wavelengths below the set limit. The alternative is to define two wavelength thresholds, thus “cutting out” certain parts of the spectrum.

“The narrowest range we have been able to achieve is a separation of 20 nanometres,” reports Kopta. This makes it possible to manufacture one sensor for UV-A, another for UV-B, and a third for UV-C.

But how do the researchers set the wavelengths to be detected by the sensor?

Kopta replies, “We do this by varying the ratio of gallium to aluminium in one of the AlGaN layers.”

Defining this ratio is one of the challenges that the researchers are working on at present. Another challenge is growing the AlGaN crystal – the heart of the sensor – in such a way that it is free of structural defects and impurities.

Failure to do so would result in unreliable measurements because different areas of the sensor would absorb light at different wavelengths. “The hardest part is dealing with the wide range of parameters that affect the manufacture of thin crystal films, which demands a great deal of experience,” explains Kopta.

A few demonstration models have already been produced. In the next stage of the project, the researchers aim to optimise crystal growth and obtain more sharply defined wavelength limits. They are

also investigating the component durability, with very encouraging results so far.

“Initial tests have confirmed that the sensors are capable of operating for 1000 hours under high UV exposure without suffering any damage,” reports Kopta.

UV sensors as team players

The UV sensors are not only excellent “solo artists”; they are also great team players. By placing more than 100 detectors side by side in a strip, you obtain a UV camera. This device can be used to monitor plasma deposition processes, such as those employed to coat solar cells with an antireflective film.

The sensor strip can also serve as a spectrometer. In this case, the UV light is first passed through a diffraction grating which splits the light into its various spectral components, like the colours of a rainbow. Each individual sensor detects a specific wavelength and provides information on the intensity of light at that wavelength.

This would be a good way of conducting ageing tests on the mercury lamps commonly used for water disinfection or UV curing. Does the lamp still emit light of the desired intensity throughout the entire spectrum, or are certain wavelengths weaker than they ought to be?

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## EU funds program to speed up energy storage and solar energy production

The project will also focus on in-line high throughput manufacturing technologies for light weight construction for aerospace

LayTec is participating in the Seventh Framework Programme (FP7) funded by the European Union ([cordis.europa.eu/fp7](http://cordis.europa.eu/fp7)).

Together with several other companies, LayTec will work in a research project led by Germany’s largest research organisation – Fraunhofer-Gesellschaft.

The goal is the development of in-line high throughput manufacturing technologies for application in energy storage, solar energy production and light weight construction for aerospace.

LayTec will contribute to the development of process control concepts based on in-line monitoring methods allowing direct correlation of synthesis parameters with

nanomaterial structure and composition.