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## BiHEMTs

Simpler die boost  
battery life

## VCSELs

Faster emitters  
eye chip-to-chip  
interconnects

## SiC wafers

Scrutinizing  
surfaces with novel  
inspection tools

## Gas analysis

Insider reveals  
how to succeed  
in this sector

## Solid-state lighting

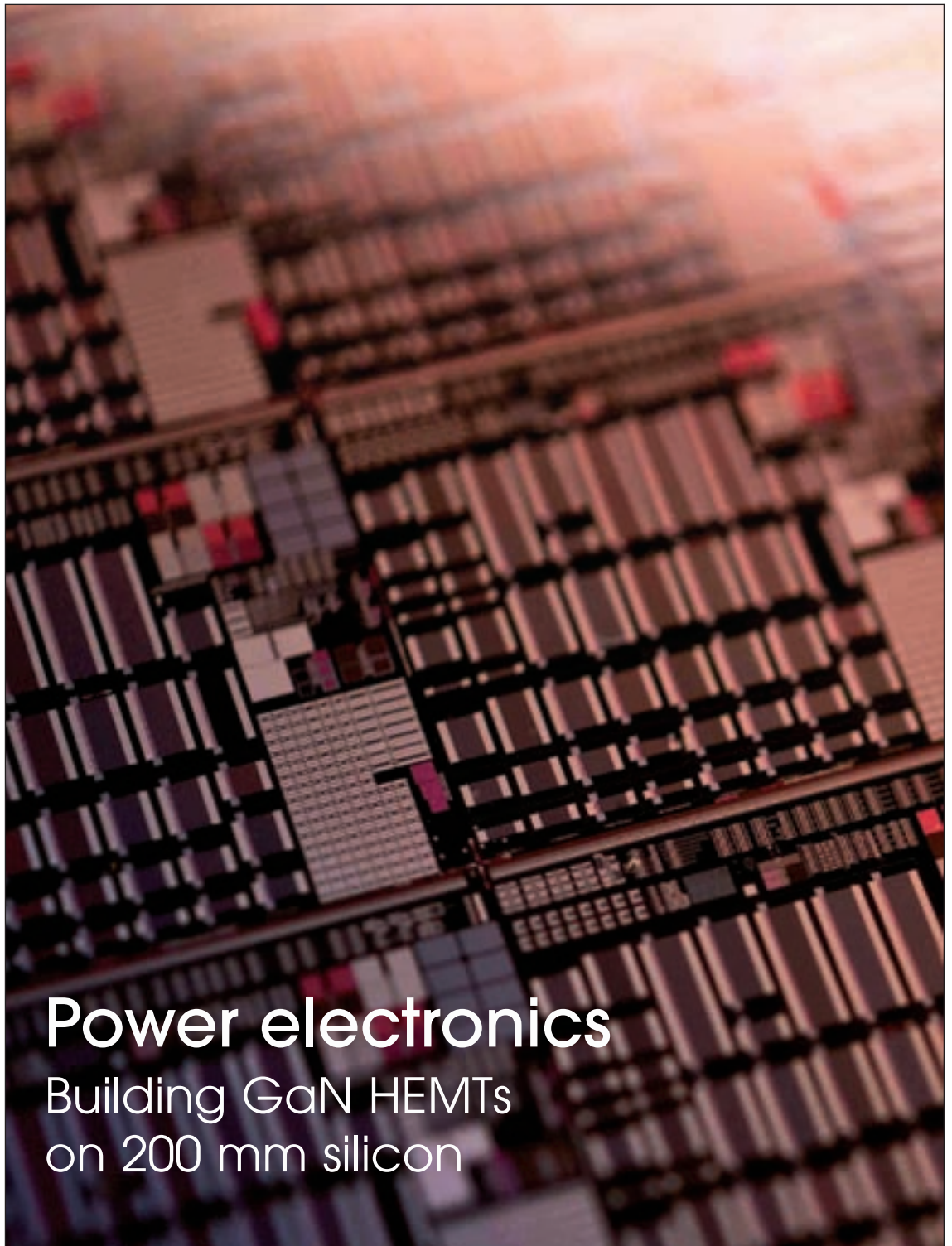
Uncovering  
imperfections in  
LED packages

## GaN substrates

Unconventional  
technique yields  
dislocation free  
material

## LEDs

Adding InGaN  
combats droop

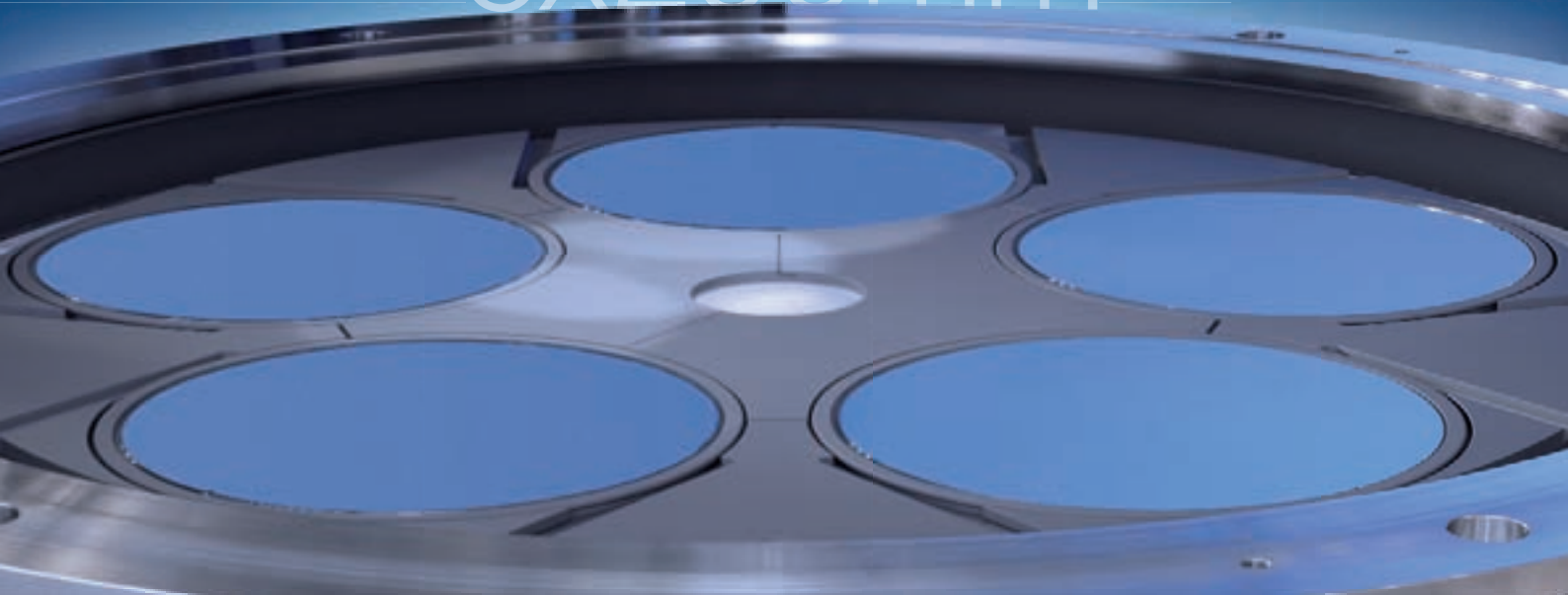


**Power electronics**  
Building GaN HEMTs  
on 200 mm silicon

**AIXTRON**

# 200mm GaN-on-Si Batch Reactor

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## AIX G5+



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

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controlled bow behavior,  
using standard Si substrates.

October 2012  
Volume 18 Number 7

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# Improving the foundations

GREAT FOUNDATIONS underpin great structures. And when they are not there, what you build can rapidly deteriorate, with cracks and defects appearing before the entire structure finally falls apart.

You can see this happening in many different situations, from the sandcastles that I built with my family this summer to the vast array of compound semiconductor devices developed and manufactured by our community.

The devices with the fewest defects are underpinned with the most established substrates – GaAs and InP. The material quality of both of these platforms is incredibly high, and today's manufacturers of these products focus on improving yield and bringing down cost, rather than developing revolutionary technologies for boule growth.



Substrates made from wide bandgap materials are far less mature, sell for significantly higher prices, and often contain more imperfections. But quality will improve as crystal growers refine their technologies and equipment manufacturers introduce new tools to scrutinise substrates.

One metrology firm that has recently produced tools for inspecting SiC substrates is LaserTec. Its pieces of equipment feature the combination of confocal microscopy and differential interferometry, and they are claimed to expose incredibly shallow scratches and small pits on the sample surface (see page 30 for details).

Although this tool will help to increase the quality of SiC substrates – they can exhibit a variety of defects, including those with esoteric names, such as triangles and carrots – the biggest opportunity for improvement lies with GaN. Dislocations in typical substrates number more than a million per square centimetre, and it appears that the only way to bring this figure down by several orders of magnitude is to turn to a new technology for forming boules.

One attractive option that can banish dislocations has recently been unveiled by researchers at Osaka University, Japan (see page 53). Engineers begin by taking a film of GaN grown on sapphire, placing a sapphire substrate with millimetre-sized apertures on top, and inserting this combination in a stainless steel tube. This is filled with a metal melt of gallium, sodium and carbon, plus nitrogen gas at a pressure of 3.6 MPa. GaN seeds form in the apertures, and can grow and coalesce to yield high-quality, defect free crystals. So far, these are only a few millimetres in size, but the Japanese engineers have set their sights on producing 8-inch material.

If they succeed, this could revolutionize GaN substrate manufacture. And in the meantime, as they build devices on their small pieces of dislocation-free GaN, they will answer a question that has intrigued and evaded us for many years: How much better is a GaN device when it is built on a perfect foundation? I'll leave you to ponder the answer to that.

Dr Richard Stevenson  
Editor





# Network with leading industry professionals of the III-V chip making industry at the 3rd CS International conference in Germany

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**industry & technology**

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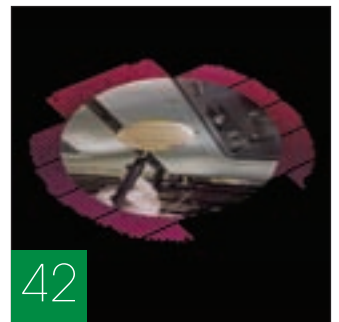
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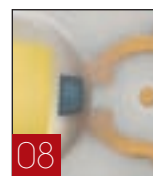
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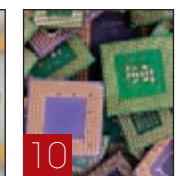
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# Combining logic and light on GaN-on-silicon chips

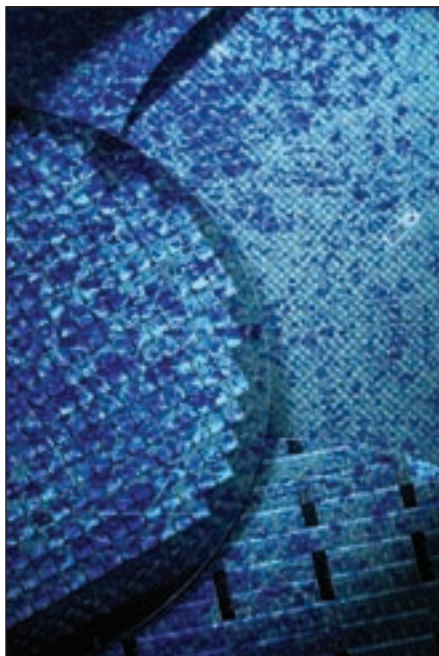
A NEW project using Aixtron systems to promote energy efficiency has been launched in Singapore. It combines the expertise in III-V semiconductors with silicon technology, to advance the commercialisation of LEDs, lasers and power semiconductors on large silicon wafers.

The research project Low Energy Electronics Systems (LEES) has started its work with a kick-off meeting. The program's initiator is the Singapore MIT Alliance for Research and Technology (SMART) Centre based in Singapore.

The LEES team consists of eminent research and science specialists and is targeting the development of cutting-edge technology to increase energy efficiency and advance high-tech industries that complement microelectronics.

Two Aixtron CRIUS 1 x 200 mm systems, will form the technological foundation basis for the LEES project work. They will be available for use in the project from the fourth quarter of 2012.

SMART is a collaborative project between the Massachusetts Institute of Technology (MIT) and the National Research Foundation of Singapore (NRF). Its objective is to develop ways to integrate optical and electronic components on a



chip, cost-effectively, using the highly promising III-V-on-silicon technology. By 2016, the researchers aim to have developed novel material compounds, process technologies, and integrated circuits on 200 mm CMOS-compatible silicon wafers.

Eugene A. Fitzgerald from MIT's Department of Materials Science and Engineering (DMSE) is the Lead-Principal

Investigator for the project with Soon F. Yoon from the Electrical and Electronic Engineering Department (EEE) at Nanyang Technological University (NTU), as Co-Lead.

"Given the increasing scarcity of energy resources, we are being challenged to provide integrated circuits that have more functionality and higher performance, and use less power," says Fitzgerald. Therefore, research is also focusing on the search for solutions that improve energy efficiency by using the latest most efficient storage devices, such as ultra-capacitors and nanobatteries.

Michael Heuken, Vice President of Research and Development at Aixtron, was appointed as a member to the LEES scientific advisory board. "LEES combines the advantages of expertise in III-V semiconductors with the already established silicon technology," he comments. "Our particular interest lies in the production of LEDs, lasers, and power semiconductors on large silicon wafers on an industrial scale."

Researchers have high expectations, especially in regard to the integration of AlInGaN and AlInGaAsP based III-V semiconductors in silicon-based CMOS circuits and the progress that will be made in conjunction with this to save energy.

In the future, the new circuit designs will be used in multifunctional LED colour displays of mobile phones, televisions, and computers, as well as in the printing, power electronics, and LED lighting industries.

## Global CS market to soar to \$47.5 Billion by 2017

Global sales from compound semiconductor components totalled nearly \$25.5 billion in 2011 and should surpass \$27 billion in 2012.

Total sales are expected to reach almost \$47.5 billion in 2017 after increasing at a five-year compound annual growth rate (CAGR) of 11.9 percent according to a report by companiesandmarkets.com. The Americas are expected to have sales worth nearly \$5.2 billion in 2012 and \$8.8 billion in 2017, a CAGR of 11.4 percent. The EMEA region should have sales totalling nearly \$8.5 billion in 2012 and nearly \$16.4 billion in 2017, a CAGR of 14 percent.

One of the greatest values that compound semiconductors bring to the table is that of variety and customisation. It is not surprising then that compound semiconductors are the prime ingredients of some of the most complex semiconductor components ever synthesised and that this market is on the incline. The advantages that compound semiconductors offer are higher operating speed, lower power consumption, lower noise, higher operating temperature, light emission/detection, and superior photovoltaic attributes compared to silicon. What's more, these attributes change from compound to compound, offering considerable design flexibility.

On the flip side, the variety of compounds works unfavourably in terms of scale and consequent pricing. Considering that these materials are pitted against silicon, the most widely available material with the most refined and cost-efficient fabrication process, there is a real danger of the competition being rendered lop-sided in favour of silicon.

However, it is not entirely accurate to compare and confine compound semiconductors to the benchmarks set by silicon. These materials have a distinct character of their own and they spawn several use-cases of application that can be catered to only by them.

# Kyma joins GaN growth equipment market

KYMA TECHNOLOGIES has announced its entrance into the market for GaN crystal growth equipment in support of the growing demand for energy efficient lighting and power electronics.

The market for nitride semiconductor devices was around \$9 billion in 2011 and is expected to surpass \$60B over the long term, including \$30B in visible lighting applications and \$30B in power electronics applications.

The firm's GaN crystal growth system is based on the hydride vapour phase epitaxy (HVPE) growth process which is a proven high growth rate approach for producing high purity crystalline compound semiconductor materials including GaN, GaAs, InP, and CdS. HVPE is the dominant process used today for production of free-standing GaN substrates and recently has been used by

Kyma and others to produce high quality GaN on sapphire templates and GaN on silicon templates. HVPE grown GaN templates have major advantages over free-standing GaN in terms of cost per unit area and diameter scalability. Kyma's new product offering is called the Kyma100 HVPE System and leverages over a decade of company experience in the design, construction, and application of HVPE process equipment for manufacturing GaN materials.

It's high purity, vertical flow, hot wall design supports production of n-type conductive GaN at growth rates up to 500  $\mu\text{m}$  per hour. The background impurity concentration is less than  $1 \times 10^{17} \text{cm}^{-3}$ . Complete with a process for production of high quality GaN on sapphire templates, the system can grow up to three 2-inch diameter wafers or one 4-inch diameter wafer at a time.



"Demand for our AlN and GaN template products is growing, yet many of our volume customers prefer to bring the template manufacturing process in-house," says Keith Evans, Kyma president & CEO. "Adding HVPE equipment to our product line is a natural step in Kyma's growth, and represents the first of several new equipment product offerings we plan to announce in the coming weeks."

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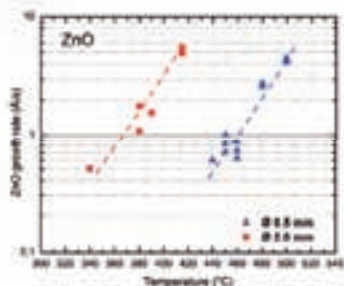
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# Nantong Tongfang chooses Veeco

NANTONG TONGFANG SEMICONDUCTOR has received a Veeco's TurboDisc K465i MOCVD System for research of GaN-on-silicon high brightness LEDs.

The system was delivered to Tongfang's new LED Technology Centre in Nantong, China. Liu Gang, General Manager of Nantong Tongfang Semiconductor,

says, "We successfully utilise Veeco's MOCVD systems in our current production of GaN-on-sapphire based LEDs. It was the logical choice to select Veeco for our new research into GaN-on-silicon based LED devices. This is going to be a significant focus of our future R&D investment over the next few years."

Jeff Hawthorne, Veeco's Senior Vice President, MOCVD, adds, "Many of our LED customers are developing GaN-on-silicon technology, which offers the potential to accelerate the adoption of solid-state lighting by reducing the cost of making LEDs without compromising end-product quality. We are glad to support Tongfang in their research efforts."

The K465i features high film quality and low defects, which are key for GaN-on-silicon processing. The reactor also incorporates Veeco's Uniform FlowFlange technology for superior uniformity and excellent run-to-run repeatability. Low maintenance TurboDisc technology enables highest system availability, excellent particle performance and high throughput. Veeco says the K465i provides ease-of-tuning for fast process optimisation on wafer sizes up to 8 inches and fast tool recovery time after maintenance. Nantong Tongfang Semiconductor Co., Ltd., a subsidiary of the publicly traded Tsingua Tongfang Co., Ltd., produces and develops LED modules and LED lighting products.

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## Microsemi: 700W GaN-On-SiC Transistor

MICROSEMI CORPORATION has unveiled the 1011GN-700ELM, the first in a family of radio frequency (RF) transistors for high-power air traffic control (ATC), secondary surveillance radio (SSR) applications. SSR is used to send a message to an aircraft equipped with a radar transponder and collect information that allows air traffic controllers to identify, track and measure the location of that particular airplane.

Microsemi's new 700 watt (W) peak 1011GN-700ELM operates at 1030 megahertz (MHz) and supports short and long-pulsed extended length message (ELM). The new transistor is based on GaN on SiC, which is ideal for high-power electronics applications. Microsemi's upcoming product line includes multiple high-pulsed power GaN on SiC transistors for both L, S and C-band radar systems.



# GaAs-on-graphene hybrid for optoelectronics

CRAYONANO is introducing GaAs nanowires on graphene, a patented hybrid material with competitive properties. Semiconductors grown on graphene are expected to become the basis for new types of device systems, and could fundamentally change the semiconductor industry. The new patented hybrid material offers excellent optoelectronic properties, says Helge Weman, CTO and co-founder of CrayoNano AS. "We have managed to combine low cost, transparency and flexibility in our new electrode," he adds. The patented method of growing semiconductor nanowires on atomically thin graphene employs MBE to grow the nanowires.

"We do not see this as a new product," Weman says. "This is a template for a new production method for semiconductor devices. We expect solar cells and light emitting diodes to be first in line when future applications are planned."

"Graphene is experiencing tremendous attention worldwide," Weman notes. "Companies like IBM and Samsung are driving this development in the search for a replacement for silicon in electronics as well as for new applications, such as flexible touch screens for mobile phones. Well, they need not wait any more. Our invention fits perfectly with the production machinery they already have. We make it easy for them to upgrade consumer electronics to a level where design has no limits."

This invention is thus thought to be an enabler for a future platform for electronics and optoelectronics devices. One possible device with very large market potential is a nanowire solar cell. This type of solar cell has the potential to be efficient, cheap and flexible at the same time. The invention



also makes it possible to imagine a future with self-powered nanomachines and advanced 3D integrated circuits built on graphene and semiconductor nanowires, enabling smaller and more efficient electronics.

Weman himself envisions flexible self-powered consumer electronics integrated into everything from clothes to notepads, and of course traditional cell phones, tablets and exercise accessories. "Semiconductors grown on graphene could become the basis for new types of device systems, and could transform the semiconductor industry by introducing graphene as a preferred substrate for many applications," he says.

The scientific results that led to the development of the new material have recently been published in the paper, "Vertically Aligned GaAs Nanowires on Graphite and Few-Layer Graphene: Generic Model and Epitaxial Growth," by A. Mazid Munshi et al, in Nano Letters. DOI: 10.1021/nl3018115

CrayoNano AS has its origins in the III-V semiconductor nanowire research done at the Department of Electronics and Telecommunications at the Norwegian University of Science and Technology (NTNU). This research has been strongly supported by the Research Council of Norway since 2007. The project is embedded in the NTNU NanoLab, MBE Lab and Nano-Photonics Laboratory. The technology has been patented by NTNU Technology Transfer of which CrayoNano is a spin-off company. The founders, Helge Weman and Bjørn-Ove Fimland, are both responsible for important research groups and labs at NTNU. CrayoNano AS was founded in June 2012 in order to develop and commercialise the new semiconductor/graphene hybrid technology, and holds exclusive licenses for all relevant fields of use.

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## Samsung invests in Voltaix

VOLTAIX, a provider of materials that enhance the performance of semiconductor chips, solar cells, and other electronic devices has secured growth financing from Samsung Venture Investment Corporation (SVIC), the global investment arm of Samsung. Both companies have remained tight-lipped about the amount invested.

Voltaix manufactures electronic chemicals and gases used in semiconductor manufacturing processes at major integrated circuit fabs worldwide. The company also supplies deposition precursors for the production of advanced photovoltaic cells. New Voltaix materials will also enable next generation LED and power electronics advancements and cost reductions. "The financing from SVIC will enable us to continue building our



worldwide infrastructure and will further accelerate our new product pipeline development activities," says Peter Smith, CEO of Voltaix. "We believe our materials innovations will help drive new device architectures and manufacturing technologies to high volume manufacturing," Smith adds.

Dong-Su Kim, SVIC Senior Investment Director notes, "The increasing demand for novel gases and materials in electronics fabrication has attracted our attention. Based on our analysis of the future demand and the players in the space, we found Voltaix to be the leader and are quite excited about our equity investment."

The firm manufactures specialty materials that enhance the performance and manufacturability of semiconductors and photovoltaics. Voltaix's products are custom designed for applications, including SiGe transistors for wireless communications chips.

Voltaix materials enable solar cells to absorb a broader portion of the solar spectrum, and they improve manufacturability by minimising defect formation and increasing machine throughput.

## Agnitron designs MOCVD flange to improve GaN growth

AGNITRON TECHNOLOGY has completed design activities for its proprietary MOCVD Monolithic Dual Flow Gas Injection Flange and has started to fabricate a prototype. The new MOCVD injection flange was designed as an upgrade for E300 GaNzillas I & II reactors. These are used or refurbished MOCVD GaN reactors, usually originally manufactured by Veeco, Emcore or Aixtron.

The flange is suited for use in the growth of III-nitrides, ZnO and MgZnO but can also be configured for the growth of any material. It can also be used for Atomic Layer Deposition and is compatible with remote plasma sources and induction heating. Device applications include UV LED and HEMT structures. The component enables adjustable velocity and density matching between alkyls and

hydrides. Alkyl and hydride injection is completely isolated and the firm says the solid design makes H<sub>2</sub> leakage impossible. Agnitron says the use of the flange will provide superior thickness and photoluminescence uniformity across wafer and from wafer-to-wafer. Radical disturbances in the boundary layer are now easily prevented by process tuning of alkyl and hydride gases flow velocity and density.

"The Monolithic Dual Flow Gas Injection Flange concept has been a desire for process engineers over the years. Agnitron Technology's development of the revolutionary flange was in response to this unmet industry need," says Dennis Stucky, who managed field services for Emcore and Veeco, and is collaborating with Agnitron on several projects.

## US gives BluGlass patent the green light

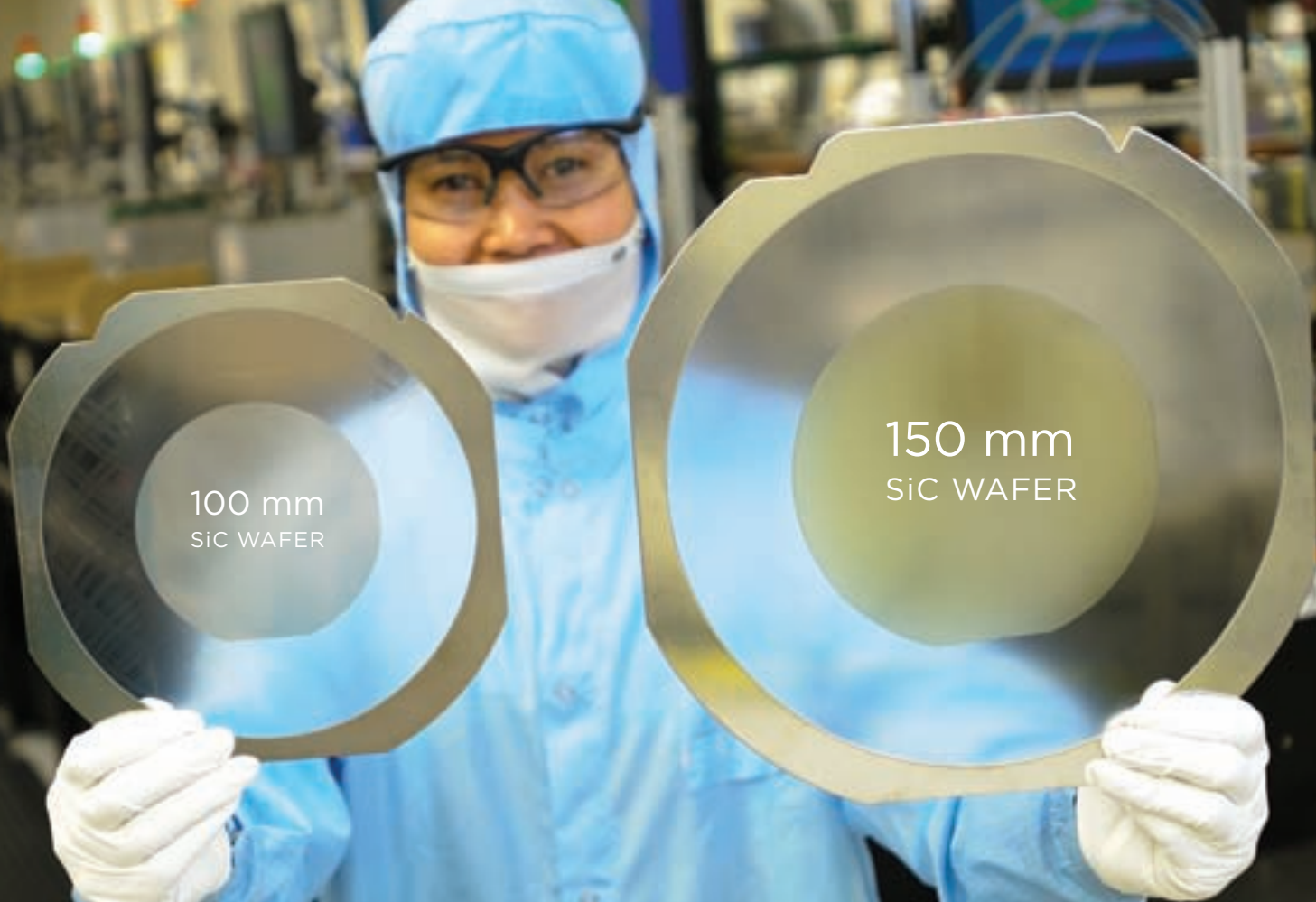
AUSTRALIAN clean-tech innovator BluGlass has announced that its patent US2008272463, "Method and apparatus for growing a group (III) metal nitride film" has now been allowed in the U.S.

This patent, once granted in the coming weeks, brings the company's international patent portfolio up to 16 granted patents in key semiconductor markets including the U.S., Europe, Japan, Korea and China. These patents help to provide the company with broad protection of its Remote Plasma Chemical Vapour Deposition (RPCVD) technology and underpin the commercial opportunities for BluGlass in the production of high efficiency semiconductor devices such as LEDs and solar cells.

BluGlass says its RPCVD technology has many advantages over conventional manufacturing technologies such as MOCVD. It is a lower temperature process which leads to potential performance and cost advantages in the production of LEDs and solar cells. Following further technical advancements made by the company, BluGlass has recently lodged two additional patents through its joint venture EpiBlu. BluGlass CEO, Giles Bourne says, "We are pleased that we had another core patent accepted in the U.S. which will further help us to protect BluGlass technology assets, enabling the company to continue to move towards commercialising the RPCVD technology."

Building upon and continuing to expand a broad based international patent portfolio is fundamental to the commercialisation of the BluGlass technology. In addition to the 16 granted patents, BluGlass now has 17 provisional patents in four patent families filed in key semiconductor manufacturing countries. Apart from its JV, EpiBlu, the company also has a subsidiary, BluSolar, which is now exploring the process viability of RCPVD in photovoltaic (solar) applications.





REVOLUTIONARY SiC AND GaN MATERIALS

## INDUSTRY-LEADING PORTFOLIO, INNOVATION AND SCALE

### MATERIALS PORTFOLIO

#### Supported diameters:

- 76.2 mm
- 100.0 mm
- 150.0 mm

#### SiC substrates:

- n-type
- p-type
- High Purity SI

#### SiC epitaxy:

- n-type
- p-type
- thick epitaxy

#### GaN epitaxy:

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

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# Mitsubishi Electric's Ku-band GaN HEMT goes into orbit

MITSUBISHI ELECTRIC CORPORATION has developed a GaN high-electron mobility transistor (HEMT) Ku-band (12–18GHz) amplifier for satellite earth stations.

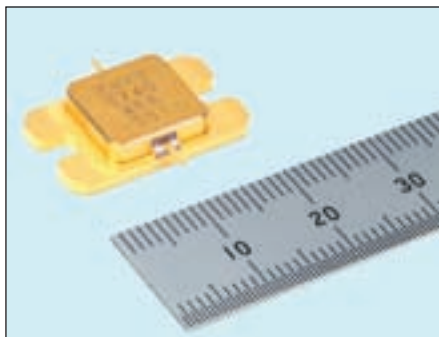
The MGFK47G3745 features an output power of 50W at 24V high-voltage operation, linear gain of 9dB and power added efficiency of 30 percent, 10 points greater than its predecessor, the MGFK44A4045.

Mitsubishi says it expects the device to reduce the number of high frequency amplifiers by half and contribute to greater power saving and downsizing for power transmitter equipment.

The module also has an output power meeting 3rd-order inter modulation (IM3) of -25dBc of 43dBm and is internally impedance-matched. The IDQ (Quiescent Drain Current) is 1A and the frequency is 13.75 – 14.5 GHz (Ku band).

Simplified schematic of amplifier

In recent years, the use of GaAs amplifiers in microwave power transmitters has been increasingly replaced with GaN amplifiers due to their high breakdown-voltage,



power density and saturated electron speeds.

Satellite-based communication, especially in the Ku-band, enables communication to be established under adverse conditions, such as during natural disasters, and in areas where communication facilities are hard to build. Mobile earth-based stations require in-vehicle portability and must be easy to install, so power-saving measures and downsized power transmitters are highly useful in helping to minimise the size of earth stations.

Mitsubishi Electric will begin shipping samples of the MGFK47G3745 on October 1st.

## First Solar and PG&E unite for 72 MW California projects

First Solar has signed power purchase agreements with Pacific Gas and Electric Company (PG&E) for 72 MW AC of solar electricity to be generated at two photovoltaic power plants that First Solar is developing in central California.

The 32-megawatt (MW) Lost Hills project in Kern County and the 40-MW Cuyama project in Santa Barbara County are expected to create up to 600 jobs at peak construction.

Project construction could start in 2013 as soon as the development process is complete, depending on plans of the projects' eventual owners.

Together, Lost Hills and Cuyama will produce enough clean, renewable energy

to power some 24,000 California homes, offsetting approximately 45,000 metric tons of CO2 annually - the equivalent of taking about 8,900 cars off the road each year.

"We are very pleased to add these projects to PG&E's solar portfolio, helping it and California reach their renewable energy goals," said Brian Kunz, First Solar Vice President of Project Development. "Grid-friendly utility-scale power plants from First Solar are readily integrated into the electrical infrastructure."

The power purchase agreements - each with a delivery term beginning in 2019 - are subject to approval by the California Public Utilities Commission, whose decision is expected in the first half of 2013.

## Lumileds boosts lumens per watt by 27 percent

PHILIPS LUMILEDS has unveiled the LUXEON H50-2 LED. With a typical efficacy of more than 80 lumens per watt, the LUXEON H50-2 LED improves on the efficacy of the existing LUXEON H 50V LED by 27 percent. What's more, it offers 10 percent more lumens per watt and 30 percent higher luminous flux than other competitive products, as well as lumen maintenance that exceeds rigorous ENERGYSTAR requirements. Designed for space constrained, retrofit bulbs such as the A19, the compact LUXEON H50-2 has a high voltage architecture that enables more form factors and lowers costs through the use of cost-efficient drivers.



Unlike other high voltage LED products, every LUXEON H50-2 LED is hot tested at 850C to guarantee performance at operating conditions, and is colour binned into three and five SDCM to ensure consistency among LED packages. In addition to A-line retrofits, the LUXEON H50-2 can drive down the costs of other space-constrained lamps such as candelabra and GU10 lamps. For specialty applications such as undercabinet, track and poultry lighting, LUXEON H50-2 has a smaller form factor that allows for even more streamlined solutions.

"We continually work with our customers to help them address the challenges through the introduction of innovative new LED packages such as the LUXEON H50-2," says Viji Krishnamurthy, Product Manager at Philips Lumileds. "This new LED package, works with simple, highly efficient drivers enabling lighting designers to create unique form factors at lower costs, while still offering LUXEON performance and quality."



# Soraa inches closer to affordable GaN crystals

AS MANUFACTURERS of LEDs strive to deliver cheaper yet more efficient lamps, many in the industry doubt whether structures grown on sapphire or silicon substrates will make the grade.

Complex epi-layer stacks with high defect densities, caused by crystal lattice mismatches between the substrate and GaN-based active layers, don't exactly point the way to cheap and easy manufacturing. And this doesn't even factor in the tricky issue of handling large diameter wafers bowed by thermal expansion mismatches.

So what to do? According to a niche, but growing, band of industry players, LED manufacturers should look beyond non-native substrates as well as the conventional vapour phase epitaxy processes used to grow LED layers on them.

Instead, high current density GaN structures could be cost effectively fabricated on quality GaN substrates, which, crucially, have been grown via a novel, but established process called ammonothermal crystal growth.

California-based Soraa is exploring this strategy and was recently selected by the US Advanced Research Projects Agency-Energy (ARPA-E) to lead a project to develop bulk GaN substrates. The LED manufacturer already sells LED-based lamps fabricated on the same HVPE-grown GaN substrates used in laser diodes for Blu-ray applications, but hopes to cut manufacturing costs and raise substrate quality with its ammonothermal growth technique.

The technique is based on an analogous method used to grow synthetic quartz crystals, in which seed crystals are crystallised within thick-walled steel autoclaves that withstand the high temperatures and pressures required for crystal growth.

As Soraa vice president of bulk technology, Mark D'Evelyn, says: "[This growth process] is highly scalable and inexpensive, bringing the promise of excellent manufacturability and crystal quality to ammonothermal GaN crystal growth."

However, growing GaN crystals in this way demands higher temperatures and pressures, stretching your standard steel pressure vessel beyond its limits. To counter this, other GaN crystal makers have constructed sophisticated autoclaves based on nickel super-alloys, which has come at a cost.

"These super-alloys have better high-temperature properties, including strength and creep resistance, but are much more expensive and difficult to scale up," he says.

"In addition, the crystal growth rates [within these autoclaves] are quite low." To tackle these problems, D'Evelyn and colleagues have developed a proprietary GaN crystal growth technique, called SCoRA - Scalable Compact Rapid Ammonothermal - that they believe will cut the costs associated with existing GaN ammonothermal crystal growth, and produce commercial-grade substrates. Instead of using a super-alloy autoclave, the team has constructed a robust steel reactor lined with an insulating ceramic layer to protect the steel from high, internal processing temperatures.

As D'Evelyn explains, the crystal growth components are placed within a compartment inside the two-layer pressure apparatus, which is filled with ammonia and then internally heated to kick-start crystal growth. "The outer metal is cooled externally, doesn't get very hot, so steel works fine for us, thank you very much," he adds.

But has Soraa successfully grown high quality GaN crystals? Yes. A laboratory-scale reactor, built prior to the ARPA-E funding of early 2011, demonstrated the technique's feasibility. And with the government cash, the team has since built a pilot-scale reactor and grown crystals at, says D'Evelyn, higher growth rates than rival companies.

"[Competitors] have demonstrated two-inch crystals of extremely high quality,"

*Right: Soraa's MR16 flagship product, the GaN on GaN LED*

asserts D'Evelyn. "We have grown two-inch crystals. There is a range in the quality of our crystals, with the very best crystals tending to be smaller and the largest ones not yet ready for manufacturing, but we are developing the growth process for high yield and high growth rates, and expect to produce extremely high quality four inch crystals in the future."

While both D'Evelyn and his colleague, Mike Krames, chief technology officer at Soraa, assert these four-inch crystals will have a lower defect density than any HVPE-grown equivalent, neither will say exactly when these will be produced.

"We have more work to do on ammonothermal growth and frankly, still have a lot more legs to go on HVPE substrates," adds Krames. Still, the future looks very bright for Soraa. Recent reviews of the firm's GaN on GaN LEDs cite a more vibrant and consistent beam compared to existing halogen lamps.

And excitingly, progress on their ammonothermal growth process will feed into the company's laser diode division, which is developing devices for displays and hand-held projector markets. "Using our technique, we have already demonstrated high quality [substrates] from the *m*-plane non-polar, semi-polar and *c*-plane polar planes of GaN crystals," says D'Evelyn.

"As our laser team explores a range of crystallographic planes we have told them that whatever they decide they need, we can make."

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## Green light for laser diodes?

Researchers at a small, Canadian start-up have unveiled simple test structures that emit incredibly bright green light. Have they filled the green gap, asks Compound Semiconductor?

**A**s organisations worldwide race to commercialise a direct green laser diode to plug the much-coveted green gap, Canadian start-up Meaglow could well reach the finishing line first, and with a truly unique approach.

The company recently developed a series of test InGaN *p-n* junctions, which in the words of chief scientist, Scott Butcher, “are

a hell of a lot brighter than any *p-n* junction I’ve seen in nitrides before.” So how have Meaglow researchers achieved this? The company’s test structures are grown using a novel technique called migration enhanced afterglow that circumvents the shortcomings of MOCVD and MBE growth. Based on methods of migration enhanced epitaxy developed for MBE, the technique involves saturating a substrate surface with the active metal to



growth processes. Meanwhile, maintaining a CVD environment removes the wide area deposition issues that plague MBE.

Factor in the company's high intensity hollow cathode plasma source - that side-steps oxygen contamination associated with other plasma sources - and you have an effective route to fabricating InGaN laser diodes.

"By processing in the CVD environment, we can go to higher pressures than we could with MBE, which also turns out to be very important for high indium content structures," adds Butcher. "[During deposition] we have a lot more gas collisions with the plasma source, eliminating more of the energetic species that damage the films." And the results look good. The researchers recently worked with McGill University, Quebec, to produce InN layers, which as Butcher puts it: "had some of the sharpest, low temperature, PL ever achieved." They then went onto produce thick - 50 nm to 250nm - InGaN layers approaching device smoothness, and have constructed simple *p-n* junction structures to test the electroluminescence.

These structures consisted of 170 nm thick, *n*-type InGaN layers grown on MOCVD *p*-GaN buffer layers, on sapphire. Part of the *p*-GaN was masked during growth to provide a step on which to mount an electrode while a second electrode was placed directly onto the InGaN layer.

Butcher has been genuinely shocked by the results. "These structures blow me away they are so bright," he says. "I'm not sure we understand everything that's happening here and we're still looking at why they are so luminescent."

What is clear at this stage however, is that growing thick, higher In-content GaN layers, seems to reduce - to a certain extent - the strains that typically arise from lattice mismatches between the GaN and InGaN layers. "If we grow our layers directly on sapphire we see segregation, so growing on the MOCVD template is one way around this," he says. "However, even with this, we still see the effects of strain on the thin GaN layers. But now we find we're able to grow the layers thick enough to ignore this effect."

So where next for the Canadian start-up? According to Butcher, his team are now collecting electroluminescent spectra for a number of InGaN compositions and also working on fabricating multi-quantum well structures. Devices will also be built with *p*-type GaN at the top, rather than growing on this layer.

"I think we'll be able to fabricate quantum well [structures] by the end of the year and we'll start seeing some nice bright devices," says Butcher. "Our technology has produced some of the best results to date for higher indium content InGaN... it has really caught a lot of attention as emission is right in the green gap."

*The yellow emission as shown is from a high carrier concentration sample whose emission is broadened by a Moss-Burstein effect*

ensure high quality crystal growth can take place at the low processing temperature of 550°C. Crucially, this all takes place in a CVD environment, and with a high pressure 2Torr, scalable hollow cathode plasma source.

As Butcher explains, the method works well for several reasons. Low growth temperatures alleviate epiwafer bow on large diameter wafers that typically takes place during high temperature MOCVD

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## Trying times spawn long-term success

Returning home in the early 1980s without a job to go to, Ian Neale had a big decision to make about his future. Hindsight shows that he got it right when he decided to launch Hiden Analytical, a highly successful metrology firm that is now celebrating its thirtieth anniversary. Richard Stevenson reports.

Lossing your job is always painful. It's not just the immediate loss of income that you have to deal with. There are also the nasty, nagging questions that circle round and round in your head: Why me? Why not him? How can they fail to appreciate all my hard work? Why can't they realise what a big mistake they've made?

It's natural to ask yourself these questions. But dwelling on them for too long is not a good idea, because you may fall into the depths of self-pity, where hope for a better future vanishes. For some

that are fired, their career will take a backward step and never fully recover, but for others it can be the beginning of a better, brighter future. In the case of Ian Neale, his dismissal has turned out to be a blessing. His career in scientific sales had led him to leave the UK for the US, and he was fired 18 months into his new role with a manufacturer of residual gas analysers (RGAs) based on mass spectrometers.

After packing his bags and returning home, he used his negative experiences as a catalyst for kick-starting a new career. He dreamed of being his own boss and he felt that his previous employer, which dominated the RGA market, was not delivering a great product. So he launched a rival, Hiden Analytical, which would give customers exactly what they want.

Neale explains that his primary US competitor had been the first to bring out an RGA with a digital display: "I rapidly learnt that people wanted one, but couldn't afford it. That was the incentive to launch our first product." One of the biggest markets for this tool would be the developers and manufacturers of semiconductor devices, because RGAs can identify the nature of gas leaks and expose impurities in a vacuum chamber.

Starting the business required a partnership. Neale had worked in the scientific vacuum industry since leaving school and had plenty of business nous, but he didn't have the necessary electronics skills. "I desperately needed an electronics person. [The electronics] are more involved than the mechanical or the vacuum side."



From its founding in 1982 until its move to the Gemini Business Park in 1996, Hiden's premises were lock-up sheds – initially one, and later an adjacent pair. In this photo from the early years of the company, its founder, Ian Neale, is wearing a tie and standing towards the centre of the group



It appeared that this trim, down-to-earth entrepreneur had found the perfect match in a former colleague who had wanted him to start a company. But this engineer didn't have the courage to leave his current employer, so Neale spent six more months searching for the right person. This turned out to be another engineer that he had worked with in the past, John Smith. The duo founded Hiden in 1982, in a lock-up garage on the south side of Warrington, a town with industrial roots that is nestled between Liverpool and Manchester. Within a few months they recruited their first employee, Tom Russell, a software engineer they both knew. Russell went on to become a director and has made key contributions to the company's long-term success.

### Getting going

A recession gripped the UK in the early 1980s, with unemployment exceeding ten percent and double-digit inflation driving up the cost of borrowing. To raise the capital required to get his start-up off the ground, Neale had to dip into his own pockets. But he also accessed up to three-quarters of the cash that he needed by tapping into a government-backed bank loan from the Small Firm Loan Guarantee Scheme. This had to be paid back within six years.

The financing helped the fledgling firm to build its first RGA. The founders had no intention of building it from scratch, because that approach makes no sense – the right way to do it is to source the various components from good suppliers, and



Hiden launched its DSMS system in 1984



In 1999 Hiden broadened its portfolio with the launch of secondary ion mass spectrometers. An example of this range of products is shown on the left

assemble them together on site. Neale had worked with many of these suppliers in the 1970s, and rather fortuitously, he reacquainted himself with quite a few of them in the run up to the launch of Hiden, when he found a couple of months of temporary work in this industry.

Hiden's first product did not offer a superior technical performance to those already on the market. Instead, it appealed to customers by excelling in an area that it not supposed to matter to scientists and engineers. Hiden's first RGA had more 'sex appeal' than its rivals, thanks to a higher feature count and greater ease of use.

To win sales of their first product, Neale would set off at the crack of dawn and travel up and down the length and breadth of the UK to meet potential customers. Back then Britain was a major chipmaker: National Semiconductor, IBM and Motorola (now Freescale) had a significant presence in southern Scotland; British Telecom had a major InP-based research laboratory in East Anglia; GaAs transistors were being developed and produced at the Plessey-owned Caswell site; and several other firms around the UK, both large and small, were making semiconductor devices.

In many industries, customers can be reluctant to switch from an established supplier to a smaller start-up, fearing that they may never deliver the product, it may break down, and if the company folds, after-sales service could disappear. But Neale found that many potential customers did not worry about such matters, while some welcomed the opportunity to support the underdog.



The quadrupole element used to build Hiden's first RGA, which initially retailed for about £4,000

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## Before we moved, we had a customer in testing a system. He didn't have room to sit during an acceptance test

Researchers at GEC bought Hiden's first product and sales followed at TI in Cambridge and at Herriot Watt University. Hindsight shows that these first customers did not need to have concerns relating to the reliability of their purchases – Hiden has recently had one of its RGAs from the 1980s back in, but for calibration, rather than repairing a fault.

Like many start-ups, getting the first product out of the door took longer than expected. In this case, it took 15 months, with the cash injection providing welcome relief to a balance sheet that had started to look rather precarious.

More success followed. "In 1984, we had our first order for a large system, and that got us out of the overdraft situation," say Neale. During this time, the company had to cope with interest rates on its borrowing peaking at 18 percent. It weathered the storm, and by 1988 it had fully repaid its loan.

### Growing the business

To grow the company, Neale took on school leavers on the government-backed Youth Training Scheme. This programme has been widely criticised for the low wages paid to youngsters, who would find themselves out of a job at the end of the scheme.

However, that's certainly not happened to some of the teenagers that Neale took on: Three are still with the company today. They form part of a diverse workforce that includes many staff with a strong academic background – about one-in seven of those at Hiden have a PhD.

As the company began to establish itself, customers started to want their RGAs to be hooked up to PCs, rather than operating as standalone units. To keep pace with customer wishes, Hiden started to build a new generation of tools, tapping into support from a range of government grants.

The company also started to grow its overseas business, which now accounts for 85 percent of its turnover. Initially it worked with distributors: The first provided access to the US markets, another to France and Germany, and a third provided a presence in South Korea. According to Neale, back in the mid 1980s these countries represented nearly all of the potential market for Hiden's tools.

As sales ramped, the company required more

space to make its products. It doubled its footprint in 1985 by renting the lock-up garage next door, and when this pair of premises became too cramped, it moved to the leafy Gemini Business Park on the northern outskirts of Warrington, a site that it is still on today.

Hiden moved into its first unit in 1987 and stayed until 1996 when bigger premises were essential. "Before we moved, we had a customer in testing a system. He didn't have room to sit during an acceptance test," recalls Neale.

The company's product portfolio continues to expand to this day, driven by requests from customers for new tools. The key to offering such a wide range of equipment is to work with a set of common building blocks. For example, just before the turn of the millennium, Hiden launched a secondary ion mass spectrometer, which is used to determine the atomic constituents of a solid. The key component in this tool is a mass spectrometer, Hiden's core technology.

In 1996 the company set up Hiden Analytical Inc. to increase the sales of all of its products and provide better support for them. There are now offices in



*Hiden moved into its current premises on the Gemini Business Park in 1996*

## Monitoring deposition rates in MBE chambers



One of Hiden's more recent products is an 'XBS system'. This features a quadrapole mass spectrometer and it is designed for monitoring multiple molecular beam sources simultaneously.

It offers beam acceptance through a 70° cone and can be used for a wide variety of tasks, including: monitoring and controlling MBE

processes; studying molecular beams; analysing multiple beam sources; tracking outgassing and desorption; and uncovering contaminants in the process chamber.

To account for variations in source positions between different chambers, beam acceptance apertures are configured individually for each specific process chamber source position. Protection from the radiant heat sources is realised with a water-cooled, fully shrouded probe.



*Hiden's latest residual gas analysis interface*

Livonia, MI, San Francisco, CA and Peterborough, NH. In addition, the company has steadily increased its global network of sales offices, which now number in excess of twenty.

A broadening product portfolio has been coupled with an increase in headcount, which now stands at around 90, and diversification into new markets. This has been aided by the 2002 launch of Hiden Isochema, a subsidiary that focuses on the production of tools for characterising gas sorption.

Today, the Hiden group makes products for many different industries, including pharmaceuticals, automotive and aerospace, and its portfolio of tools

can be employed for a vast range of applications, including characterising plasmas, understanding the behaviour of catalysts and tracking the evolution of gases.

There have also been changes at the top. Although Neale is still heavily involved with the company, for the last few years he has moved to part-time working, with Peter Hatton taking over as Managing Director.

Where will Hiden head in the coming years? Given its success over several decades, there is every reason to believe that it could have a highly lucrative launch on the stock market. But that's not on the cards – the passing of time has not lessened Neale's desire to be his own man, and it is clear that he does not want the company to be distracted by appeasing to the wishes of shareholders. Instead, Hiden will focus on what it excels at – not trying to second-guess what its customers want, but listening carefully to their needs and meeting them with high-quality, reliable products.

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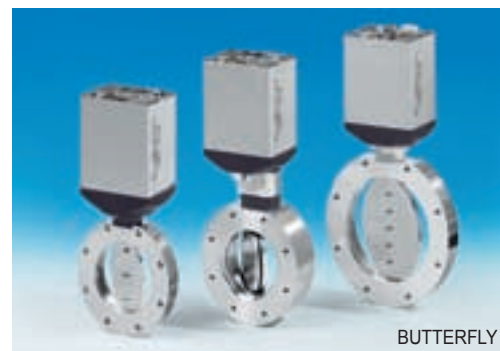
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## Unveiling structural anomalies in LEDs

The performance of LED light bulbs is impaired when delamination occurs within or between the parts that make up a packaged device. These deficiencies cannot be detected by widely used characterisation techniques such as X-ray and infrared microscopy, but they are exposed with acoustic imaging at very high frequencies, according to Tom Adams, a consultant to Sonoscan.

**W**e are on the cusp of a lighting revolution. Although today's homes are generally lit with a mix of incandescents and fluorescents, LED light bulbs are starting to make inroads, and they will dominate by the end of this decade.

If you look hard today, you'll find that manufacturers are already offering products at eye-watering prices. These will come down, but how far and how fast suppliers drop their prices will not be the only factors determining their success – the quality and amount of light will also play a major role in the relative popularity of the various brands of LED bulb.

As LED sales rise and consumers learn more about their virtues, it will become clear how much homeowners are willing to pay for their 75 W-equivalent bulbs and how long they expect them to last. What is sure to infuriate them is if a bulb fails

abruptly due to an electrical failure in its power supply or control circuitry. They will hope that the multiple LED chips in the bulb's array will work for tens of thousands of hours. Slow dimming during that time is acceptable, while outright failure of a significant proportion of the chips will not be tolerated. A household LED bulb is generally considered to have fallen below an acceptable level of performance when its total output dips below 70 percent of its initial brightness.

Electrical failures of individual LED chips often stem from either structural anomalies in the packaging processes and materials of a semiconductor die, or in the epilayers built up on the die. These imperfections, which may have had their origin in assembly processes or in handling, include non-bonds, delaminations, cracks and voids.

In general, these weaknesses cause two types of problem: Die to overheat and fail, due to gaps at interfaces between die, die attach, substrate and heat sink that can block all the heat that needs to be removed from the assembly; and LED light output to diminish, due to the formation of unintended insulators resulting from gaps among the contact

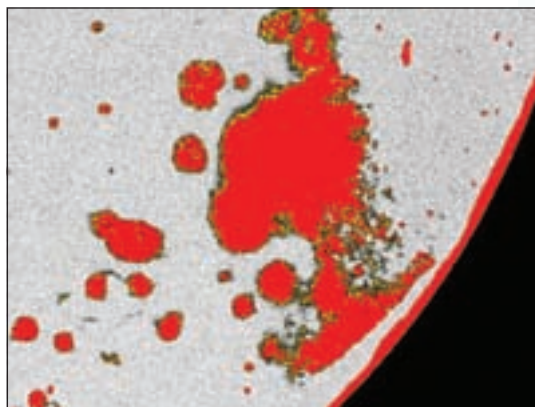


Figure 1. Sonoscan's S-CAM acoustic imaging tool reveals gap-type defects (shown in red) in a LED wafer with a sapphire base



layers, blocking layers and other layers built up on the surface of the die.

Making matters worse, thermal cycling, which is inevitable when operating an LED bulb, can cause these structural gaps to expand and become more effective thermal blockers or electrical insulators.

Although LED modules are typically tested for voltage and light output, they are rarely scrutinised for internal structural defects, which can play havoc with production yield and device lifetime. Widely used techniques in the fabs, such as X-ray and infrared microscopy are unable to expose these imperfections. However, they are easily revealed with acoustic micro imaging systems based on VHF or UHF ultrasound. At Sonoscan of Elk Grove Village, IL, we have recently developed an instrument with this capability, the C-SAM system. It can be used for process control, revealing defects during production, and it can be a valuable aid for failure analysis.

Acoustic imaging may be carried out on an undiced LED wafer, or on LED arrays during assembly. In both cases, our system's scanning transducer needs a flat surface into which to pulse the ultrasound signals. Wafers and the heat sink surface of an assembled LED are both flat; as is, at some points in production, the face of the LED. To probe an LED incorporating a lens, it may be necessary during failure analysis to grind this optical element flat to permit acoustic imaging.

The ultrasonic transducer emits pulses into the surface of the undiced wafer or individual chip, and a few millionths of a second later it reads the return echoes, resulting from reflections at interfaces. Boundaries between two solid materials tend to produce echoes of medium amplitude, while the highest amplitude echoes are returned by the solid-to-gap interfaces encountered at internal defects. The transducer carries out its pulse-echo role thousands of times a second while traversing across the sample at speeds well in excess of 1 m/s.





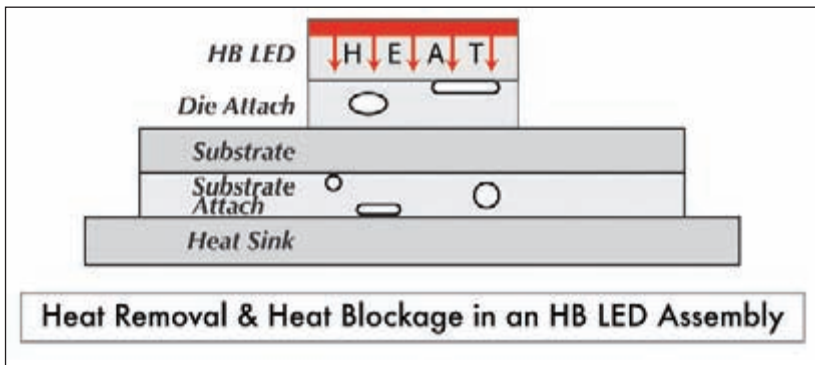


Figure 2. The intended pathway for thermal dissipation from a single LED is downward (red arrows) to the heat sink at the bottom. Gap-type defects, chiefly in the attachment materials, block heat and lead to early die failure. Note that the gaps shown in this figure are greatly exaggerated in their vertical dimension; gaps that are effective heat blockers and that provide high-amplitude reflection for acoustic imaging can be as thin as a fraction of a micron

### Imaging epiwafers...

Most LED wafers feature a stack of nitride-based epitaxial layers on a substrate, typically sapphire. When imaging these wafers, our C-SAM system tends to expose delaminations and other gap-type defects, either in the sapphire substrate or the epitaxial film. These defects and anomalies may be just 5  $\mu\text{m}$  or so in size, so to operate with a sufficiently high spatial resolution the transducer pulses a high frequency, such as 230 MHz. It is



possible to perform manual and automated acoustic imaging with C-SAM systems. Today, the latter option is more common, with a technician placing one or more wafers on a tray, initiating the scan and examining the acoustic image to mark defective die for removal. Manual imaging makes sense when the wafer diameter is small, the value of each LED is high, and the application is critical. Typically up to sixteen 75 mm wafers can be scanned simultaneously. If the wafer is large, or if die are very small, automated inspection may be preferred.

Today, the most common LED wafer is 75 mm (3 inches), but dimensions range from 50 mm (2-inch) to 150 mm (6 inches). Eventually, 200 mm (8-inch) and 300 mm (12-inch) wafers will be used in order to gain economies of scale. This means that wafers will accommodate more die than ever before – if they are 0.3 mm x 0.3 mm in size, a common dimension for today's LEDs, then a 300 mm wafer could yield about 700,000 chips. Such high volumes will make manual inspection more difficult and favour automated inspection.

The defects that our C-SAM system identifies are often incredibly thin delaminations. When one of the thousands of ultrasonic pulses entering the wafer each second hits the interface between solid material and a delamination, more than 99.99 percent of the ultrasound is reflected to the transducer. This incredibly high level of reflection occurs when the gap is as thin as 0.01  $\mu\text{m}$ , due to the massive difference in the material properties of the solid material and the air in the delamination. This scenario produces the highest amplitude signal and identifies an internal gap. Continued scanning reveals the total area of the delamination.

With manual imaging, a technician visually identifies defective LED die in the acoustic image, so that they can be discarded from production. In

*Left: Based on Sonoscan's well-known C-SAM acoustic microscope systems and launched in 2011, the AW300 300 mm bonded wafer inspection system automates the entire inspection system from carrier attachment and wafer selection through aligning and acoustic imaging to drying and sorting. Analysis software automatically measures the percentage of bonded and unbonded interface between the two wafers, and the sizes and number of voids. Accept/reject decisions are made automatically according to the user's specific criteria*

comparison, with automated imaging, analysis software reports the positions of defective die via the user's factory automation system. This allows sub-standard devices to be discarded after dicing.

If individual devices are very small, it may be prudent to program the software to remove the eight die that are adjacent to the defective one. This makes sense when the defect is large relative to the die area, and may consequently degrade nearby die.

An example of the capability of our tool is provided in Figure 1, which shows, in very high resolution, an acoustic image of a small portion of one LED wafer. Pale grey regions indicate an absence of defects, while red features represent regions of high-amplitude reflections. These areas consist of numerous tiny gap-type defects, such as delaminations, located between various layers built up on the substrate.

Often LED die are small in area, and when the wafer is diced the delaminations can cause the die to fall apart. Even if these delaminations are very small, the chip can separate when scribing is used to cut up the wafers. Defective or potentially defective die must be uncovered and removed from the production process to improve the efficiency of the manufacturing process. To do this using automated analysis of images, an overlay map is employed to precisely locate each device and key each defect to a specific die for subsequent automatic removal.

### ...and LED assemblies

Common features of a completed LED assembly include one or more LED chips, die attach material for bonding the LED to a substrate, and attachment material for bonding the substrate to a heat sink (see Figure 2).

The substrate on which the LED rests may be a PC board; problems with FR4 boards – a very common, flame-retardant backbone for rigid printed circuit

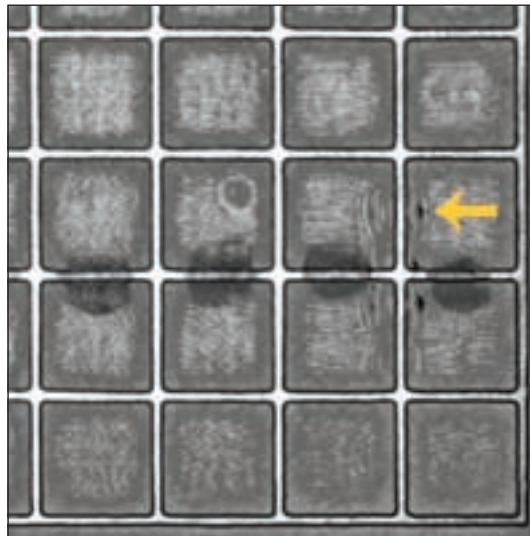


Figure 3. Acoustic imaging performed on the topside of an array of LEDs can reveal cracks, such as that highlighted by an arrow, in the sapphire chips. This array had no lens, and the depths of interest were the LEDs and their attachment to the substrate

boards – are that they have relatively high thermal resistance and transmit ultrasound poorly.

Engineers design the assembly so that it removes heat from the LED at a fast enough rate to prevent overheating – if an LED operates above its rated temperature, it will have a shorter life span. The key consideration is the total thermal resistance of the materials above and below the heat-generating LED chip.

The biggest problem – and the target of acoustic imaging – is gap-type defects. They are frequently found in: an attachment material layer or die attach layer; or between attachment material or die attach and the adjacent die, substrate or heat sink. Even extremely thin gaps can block heat transmission, leading to a hike in junction temperature and a plummeting life span for the LED.

Process engineers have the option to use our tool to inspect the topside of an LED assembly or the bottom side that features the heat sink. Scanning the latter can expose voids and other gaps in the

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Often LED die are small in area, and when the wafer is diced the delaminations can cause the die to fall apart. Even if these delaminations are very small, the chip can separate when scribing is used to cut up the wafers. Defective or potentially defective die must be uncovered and removed from the production process to improve the efficiency of the manufacturing process

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Figure 4. After the lens has been ground flat, topside acoustic imaging of this tiny LED can reveal essentially total delamination of the polymer from the substrate

solder between the heat sink and substrate, and between the substrate and the die. Such defects will be visible as bright features in the acoustic image. Meanwhile, scanning the top surface of the LED surface – so long as either no lens is in place, or it has been ground to create a flat scannable surface – can offer an insight into the internal features of the device.

Structural defects that are not related to heat removal can also be revealed in acoustic images. For example, images of one corner of an LED array can show features that are probably vertical cracks in the die (see Figure 3, which has a yellow arrow that marks out one of these features).

In addition, there are some lighter-coloured features of similar structure in same area, which are probably cracks that reflect ultrasound differently, due to variations in

depth and orientation; and there are four round, dark features, which are electrical connections below the die. The die themselves display a light-to-medium grey texture, indicating that they are well bonded to the substrate. There are no bright areas here that could indicate the presence of voids or disbonds (the latter are separations at an adhesive bond line in a bonded joint).

Imaging from the topside can provide valuable insights into the workings of an LED. Our acoustic imaging tool has uncovered deficiencies in a single, 0.3 x 0.3 mm die that was inspected after removing part of the polymer lens covering the die.

Pulsing ultrasound through the remaining polished lens material revealed that the square shape of the die, at centre, is somewhat distorted, due to wires attached to its upper right and lower left corners (see Figure 4).

This image also shows the leads, which appear as large white features on the left and right. The red region completely surrounding the die reveals that the polymer is completely disbonded from the substrate below the die. It is possible that the disbond may already extend into the die attach material below the die, where it would reflect heat back to the die.

Expansion of the disbond under the die could also take place at a later time. This can cause individual LEDs to fail in service and to lower the efficacy of the luminaire.

Exposing these issues, which can ultimately lead to improvements in the quality of LED lighting, is one of the hallmarks of our acoustic imaging tool. As awareness of its capabilities grows, and engineers in the fabs increase their understanding of this instrument and its strengths, it will play an ever-increasing role in the solid-state lighting revolution.

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# Uncovering imperfections in SiC

The miniscule scratches and pits found on the surface of SiC substrates spawn yield-killing defects in the epiwafers. It is not possible to pick-up these minor imperfections and track their consequences with conventional light-scattering inspection tools, but this can be done with our detection systems employing confocal optics and differential interferometry, argues Yuji Asakawa from Lasertec Corporation.

To reduce carbon dioxide emissions and meet the rapidly growing energy demand in emerging economies, engineers are installing more eco-friendly energy sources and trying to increase the efficiency of many different products. These efforts can be aided by the introduction of a range of new technologies that increase the efficiency of electronic devices.

Today, the vast majority of electronic devices are made from silicon. This material is relatively cheap to process, but it cannot deliver device efficiencies as high as equivalents built from wide bandgap semiconductors. These alternatives promise to enhance electric power conversion efficiency in a wide range of applications, including electric vehicles, inverters for solar systems and air-conditioning.

A handful of companies have already brought diodes and transistors made from wide bandgap materials to market, but in general, this industry is still in the development stage. For sales to rise, the quality of these products must improve and their production costs fall, so that they can be seen as genuine competitors to the silicon incumbents.

Introducing inspection tools that set a new benchmark for scrutinizing substrates and epiwafers will help to make better products and drive up device yields. At Lasertec Corporation, an inspection tool manufacturer with headquarters in Yokohama, Japan, we have launched a range of tools that do just this: the SICA61 series, which is designed to inspect SiC material and is discussed in the remainder of this article; and TROIS, an instrument for scrutinizing other wide bandgap materials, which is described in the box "Inspecting and reviewing wide bandgap semiconductors", which can be found on page 34.



*Left: Lasertec's SICA series is capable of identifying scratches with a depth of less than 1 nm in SiC substrates*

## The upward curve for SiC

Today, the SiC power device market is significantly bigger than that for GaN, its biggest wide bandgap rival. According to the market analysis firm Yole Développement of Lyon, France, SiC device sales should be worth \$71 million in 2012, and will grow throughout the decade to reach almost \$1 billion by 2020. During the next few years, 6-inch substrates for SiC devices will appear on the market from more and more substrate suppliers, which are planning to ramp their production capacity. Announcements at the 2011 International Conference on SiC and Related Materials indicate that substrate production capacity, evaluated in terms of surface area, will increase twenty-fold from 2011 to 2015. During this timeframe, device manufacturers are projecting a four-fold increase in the use of SiC substrates.

These substrates are being used to make several different classes of SiC power device, which are in various stages of development and production. European chipmaker Infineon launched SiC diodes back in 2001, while SiC MOSFETs are still in their infancy. US firm Cree has recently launched this form of transistor onto the market, but prices are high, and it will take several years for the SiC MOSFET to become a mainstream device.

All makers of SiC devices can improve the quality of their products by reducing the density of various types of performance-degrading defects. These can cause devices to fail or malfunction – either initially or after many hours of use – and have led some to question the long-term reliability of SiC devices. Additional challenges that must be overcome in order for SiC devices to have long-term commercial success in the power electronics market are increasing production yield and driving down costs.

## Classifying defects

Three major types of defects are found in SiC, each originating from a different production process: Slicing of ingots can lead to crystallographic damage in the substrates; planarization processes can generate fabrication defects; and defects can be found in the epilayers, resulting from imperfect film growth. All forms of defect can drag down device production yields, so it is of paramount importance to detect them with high accuracy and then take effective countermeasures.

SiC quality will then increase, spurring greater commercial success, thanks to higher yields. This will not only result in better devices, but cheaper ones too – substantial savings are possible, because a typical 4-inch epitaxial wafer currently costs thousands of dollars.

Efforts to improve the quality of SiC substrates and

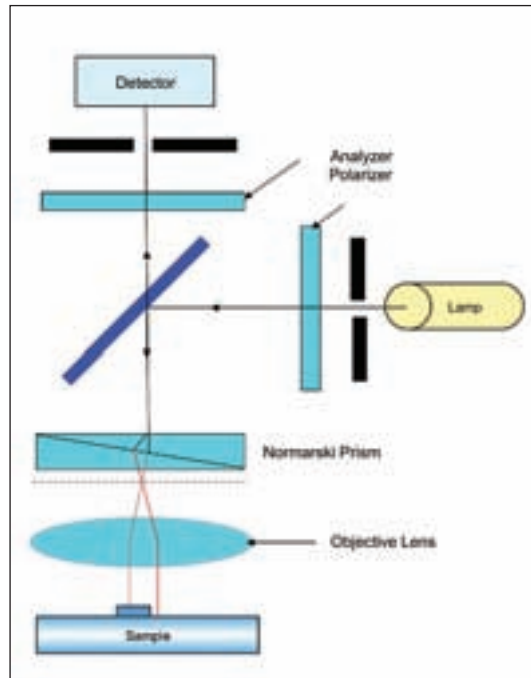


Figure 1. The Lasertec SICA series features confocal optics and differential interference. SiC substrates are transparent, so light reflects from their back surface and can inhibit attempts to detect features on the wafer surface. This stray light is rejected with a confocal system, because only light from the sample surface is focused by the objective lens and passes through the pinhole in front of the detector. The SICA tools also have a much higher resolution and contrast than conventional instruments, thanks to less interference from scattered light

epiwafers have been underway for many years. They have generally involved the use of inspection tools that expose relatively large defects – including epitaxial defects such as triangles, downfalls and carrots. These imperfections are often the cause of initial malfunctioning in SiC devices. However, these conventional inspection tools rarely reveal minor defects, such as pits and scratches underneath gate oxidation films. These undetected deficiencies may well have an impact on the long-term reliability and performance of SiC MOSFETs.

Recently, we addressed this shortcoming with the launch of the SICA61, the first inspection tool designed to detect minor defects with high accuracy. It is based on two of our core technologies – confocal optics and differential interferometry (see Figure 1 for details).

Wafer Process	Process	Type of Damage
	Crystal growth	Dislocation
	Slice and Lapping	Deep scratches Shallow scratches
	CMP	Scratches need to be removed completely, but more than 5 hours may be required due to hardness.
	Epitaxy	Step bunching may appear along scratches.

Figure 2. Defects present in the ingots and that result from the slicing and lapping processes can degrade device performance

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When SiC substrates are formed by slicing discs from an ingot and polishing them with a machine, defects are created, such as scratches. Even if they are shallow, they impact the quality of the epitaxial layer by inducing other types of defects to form, such as step bunching and continuous carrots

One of the great strengths of using confocal optics is that it is able to capture accurate information of a sample surface, because the detector does not receive light reflected from the back surface of the substrate. Very small pits and shallow scratches with a depth of just 1 nm or less can be uncovered, thanks to the incorporation of differential interferometry. In comparison, inspection tools based on light scattering are generally unable to resolve such small deficiencies in SiC material, which are known to impair device performance. We launched the SICA61 in 2009, and last year we addressed the request for a higher throughput tool with the addition of the SICA6X. This is designed to detect and review defects generated during each process of SiC production – from SiC crystal growth to planarization to epitaxial film growth – and to evaluate the entire production processes with high efficiency.

### Tool capabilities

When SiC substrates are formed by slicing discs from an ingot and polishing them with a machine, defects are created, such as scratches (see Figure 2). Even if they are shallow, they impact the quality of the epitaxial layer by inducing other types of defects to form, such as step bunching and continuous carrots (See Figures 3 and 4). Those defects that are subsequently formed adversely impact device performance. What's more, during device manufacturing, the activation annealing and thermal oxidation processes lead to growth of step bunching near scratches.

Consequently, it is clearly desirable to eliminate as many scratches as possible during the chemical mechanical polishing (CMP) process. One way to do this is to employ our SICA range of tools in this process, because they can detect shallow surface scratches. With SICA, it is possible to review the results of polishing processes under different conditions, simplifying efforts to determine the optimum polishing process for SiC wafers. The improvements that result will be highly valued, because SiC is a very hard material – it takes a lot of time and cost to polish it and make it flat.

Another form of surface deficiency in SiC substrates, small pits, has been found to shorten the time-dependant dielectric breakdown of MOSFETs.

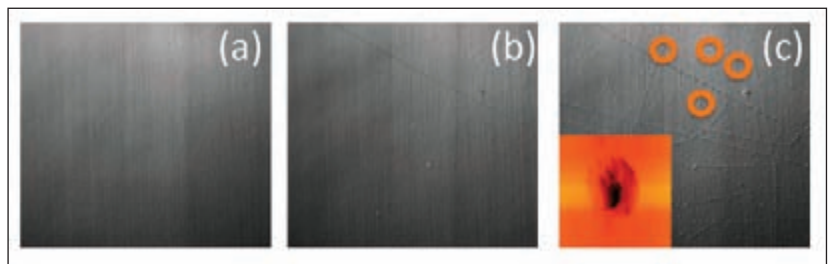
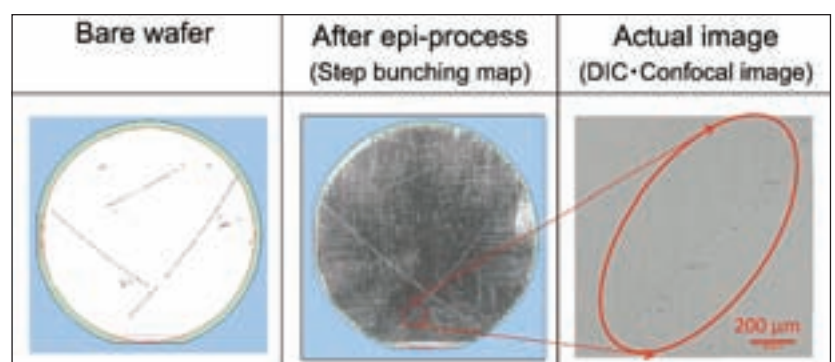


Figure 3. It is possible to observe step-bunching growth during the annealing process. Images of a rapid change in surface morphology have been observed by Tadaaki Kaneko and his team from Kwansai Gakuin University, Japan. Images (a), (b) and (c) reveal the changes in the wafer when the temperature exceeded 1500 °C. The inset in (c) is an atomic force microscopy image that confirms that the defects in the orange circles are pits

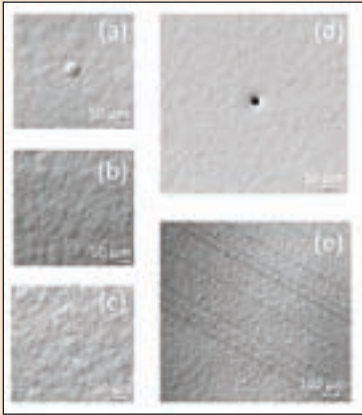
However, this effect can be mitigated by planarization of step bunching over the surface of epitaxial wafers using CMP. This implies that one route to increasing the long-term reliability of SiC devices begins by capturing detailed information of the surface conditions of the epiwafers. Our SICA tools are ideal for this task, because they can generate a plot of the distribution of step bunching over the entire surface of a wafer. In addition, they have sufficient sensitivity to reveal very small pits without interference from step bunching.

An additional attractive feature of our tool is that it has an alignment trace function for accurately locating positions of defects in different processes. This allows the user to track the impact of an individual defect in a substrate on the quality of the epitaxial

Figure 4. Scratches on substrates can spawn yield-killing defects, such as carrots, in the epitaxial film.



## Inspecting and reviewing wide bandgap semiconductors



The SICA inspection tool can identify many forms of defect, including: (a) a pit in the centre of a big bump (b) a V-shaped pit (c) a bump (d) a hole (e) cracks around the wafer edge

In addition to its tools dedicated to the inspection of SiC substrates and epiwafers, Lasertec offers an inspection and review system for transparent wafers called “TROIS series”. Designed to detect and analyse defects on wide bandgap semiconductors, the TROIS series features the same optics as the SICA tools, and allows the user to carry out inspections without interference from the hetero-epitaxial film. One of the strengths of the TROIS series is that the wavelength of its light source can be varied, ensuring optimal performance for various wafers. To meet requirements for production of large-size wafers, the latest model of the series, TROIS33, is capable of inspecting wafers up to 8 inches in diameter. Maximum throughput is six wafers per hour (for 6-inch wafers).

film grown close to it.

Specifically, the alignment trace function is capable of performing three insightful tasks: Identifying what types of defect have a large impact on electrical characteristics of a device, and how many of them are acceptable; determining what types of defects can be the root cause of yield-killing defects; and enabling the formation of a grading structure for detecting and describing defects in substrates, epiwafers and devices.

The unique capabilities of our tool are already creating something of a stir within the SiC industry. Device manufacturers are starting to consider using our tool for incoming inspections, and the SICA series is already playing a role in the SiC supply chain. Its deployment is sure to rise over the coming decade, enabling it to play a key role in improving the bang-per-buck of SiC power electronics.

• The author thanks Hirokazu Seki, Takeshi Higuchi and Genichiro Kamiyama for their help in compiling this article.

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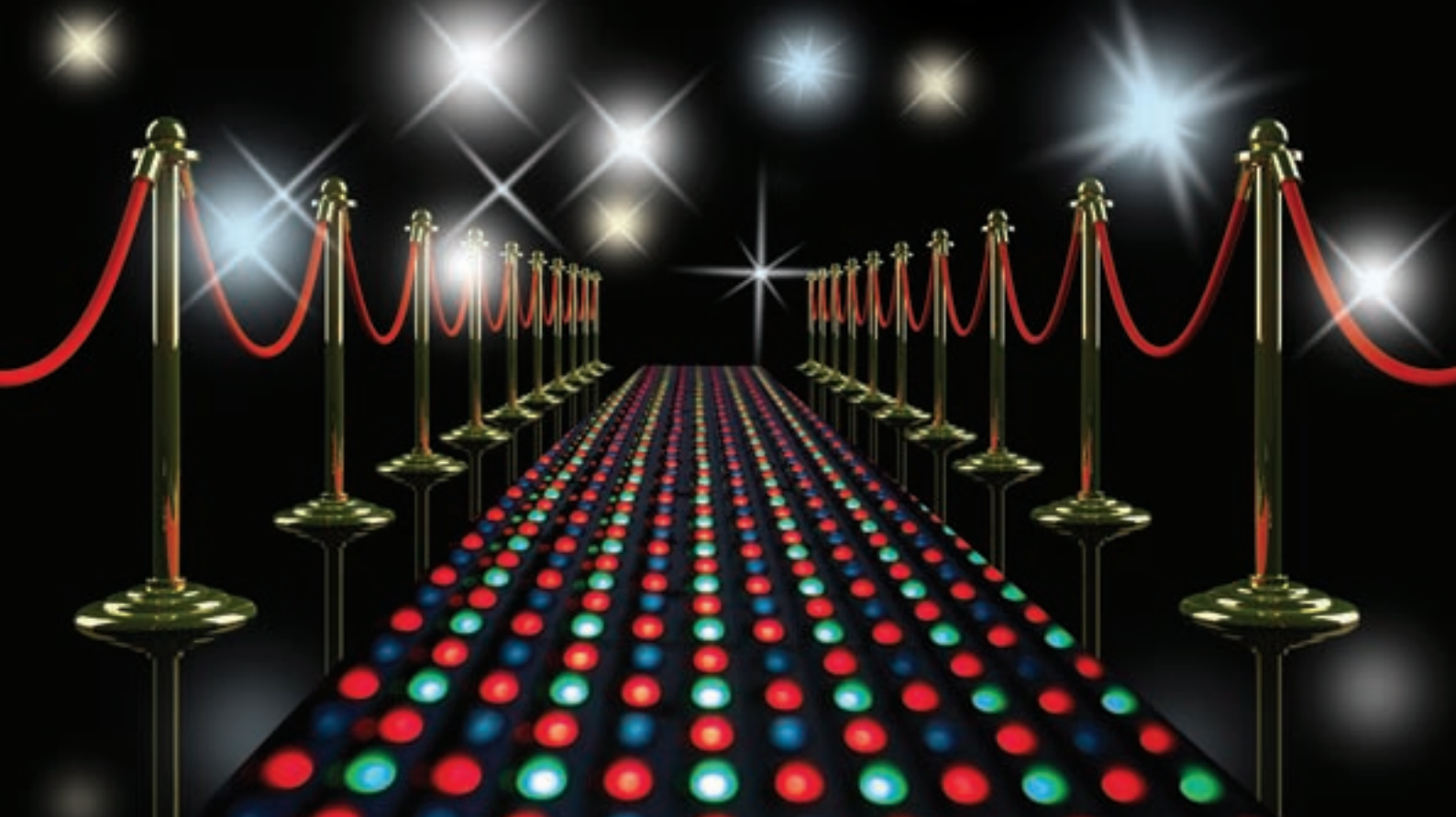
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# Slashing the cost of GaN HEMTs

Although silicon power transistors are inferior to their GaN rivals in many regards, they win hands-down in the metric that matters most: Cost. However, affordable GaN HEMTs are within reach, when production moves to 200 mm GaN-on-silicon epiwafers processed on standard CMOS lines, argues imec's Brice De Jaeger, Marleen Van Hove and Stefaan Decoutere.



**G**aN HEMTs are very promising devices for power electronics. Their combination of a high breakdown voltage, an ability to withstand high temperatures and a higher switching speed than comparable technologies gives them the potential to deliver cost reductions at the system level. For example, switching power electronics from silicon to GaN can trim the size and cost of a solar inverter by cutting the size and cost of passives – resistors, inductors and capacitors.

However, the benefit of trimming the bill for passives has to be weighed against the higher prices that GaN HEMTs sell for compared to silicon, the incumbent material for making power electronics. Today's fabrication costs for manufacturing GaN HEMTs are much higher than those for silicon transistors, due to production on dedicated processing lines using small diameter substrates, often made from sapphire or SiC.

One obvious way to slash the manufacturing costs of GaN HEMTs is to move production to a high-productivity 200 mm CMOS fab, a step that must include the transfer of the epitaxial process to a silicon platform. To reap this reward, engineers must overcome three tough technical challenges: The deposition of defect-free, crack-free GaN epilayer stacks on 200 mm silicon; the processing of AlGaIn/GaN HEMTs on 200 mm silicon wafers with a standard CMOS toolset, a requirement that prohibits the use of some materials that are often used in GaN transistor fabrication; and the development of a process flow that produces good-quality, high-performance, high-yielding devices.

At imec, an internationally renowned research centre based in Leuven, Belgium, we have been working with leading device manufacturers to solve all these challenges. This three-year effort has been hugely successful, and it has led to the demonstration of GaN-on-silicon power devices operating at high currents.

### Scaling to 200 mm silicon

Fortunately, we did not have to develop our growth technology for depositing GaN layers on 200 mm silicon from scratch. Instead, we could build on the success of our processes for forming GaN-based epitaxial stacks on 4-inch and 6-inch silicon wafers. Thanks to this in-house expertise, we were able to make good progress during our development of MOCVD process for the growth of crack-free AlGaIn/GaN/AlGaIn double heterostructures on 200 mm silicon (111) substrates.

*Wide bandgap power devices can be manufactured far more cheaply when processing is performed on 200 mm GaN-on-silicon with a CMOS-compatible process flow*



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The double heterostructure that we form consists of a 200 nm AlN nucleation layer; a buffer stack comprising 400 nm Al<sub>0.75</sub>Ga<sub>0.25</sub>N, 400 nm Al<sub>0.50</sub>Ga<sub>0.50</sub>N and 1800 nm Al<sub>0.25</sub>Ga<sub>0.75</sub>N; a 150 nm GaN channel and a 10 nm Al<sub>0.25</sub>Ga<sub>0.75</sub>N barrier layer. A 2 nm-thick GaN capping layer is deposited on top of the Al<sub>0.25</sub>Ga<sub>0.75</sub>N barrier to prevent it from cracking during post-growth cool down. On that cap, we deposit a 120 nm Si<sub>3</sub>N<sub>4</sub> passivation layer by low-pressure CVD (LPCVD) at 750 °C.

This structure yields reproducible, uniform two-dimensional electron gas (2DEG) characteristics across the wafer. According to measurements on Van-der-Pauw structures, the average 2DEG sheet resistance on 18 wafers with an identical epilayer stack is 360 Ω /□, and the standard deviation is 5 percent (see Figure 1). Hall measurements reveal that the 2DEG carrier density is 8.9 x 10<sup>12</sup> cm<sup>-2</sup> and carrier mobility is 1950 cm<sup>2</sup>V<sup>-1</sup>s<sup>-1</sup>.

The AlGaIn/GaN/AlGaIn epilayer stacks that we deposit are about 3 μm thick, and they are formed on 1.15 mm-thick silicon substrates. These are thicker than standard substrates (which are 0.725 mm thick), because a greater rigidity is needed to obtain acceptable wafer bow and wafer brittleness. Processing at imec’s 200 mm CMOS silicon line demands a wafer bow of 50 μm or less.

Our epiwafers that are formed on 1.15 mm-thick silicon wafers are, in general, suitable for processing on production tools that have not been subjected to significant hardware or process modifications. Occasionally, however, we had to make adjustments to the tools, such as slowing down the robot speed of the wafer transport systems so that they can accommodate the larger inertia of thicker silicon substrates. We also avoided direct loading of the wafers on the electrostatic

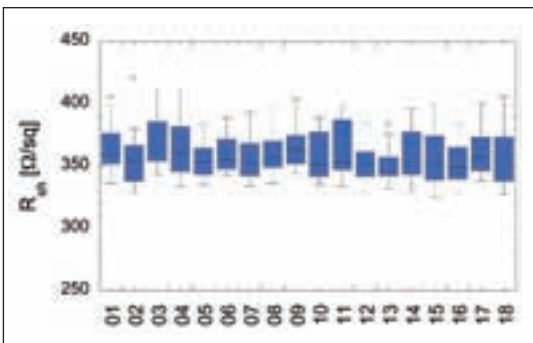


Figure 1. imec’s engineers can produce structures with a reproducible, uniform AlGaIn/GaN 2DEG sheet resistance. Data is for 18 epilayers grown on 200 mm silicon substrates

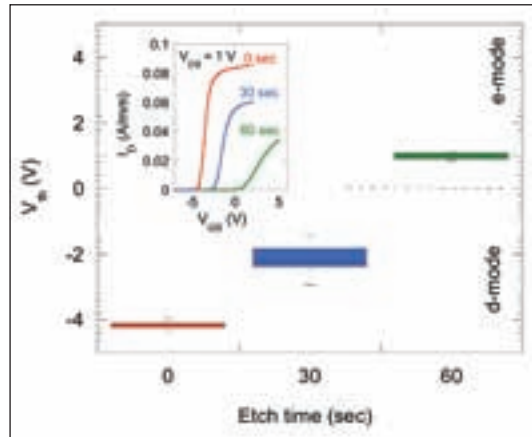


Figure 2. The threshold voltage of the MISHEMT is influenced by the barrier recess etch time. Enhancement mode devices are obtained for 60 s barrier recess. The inset figure shows the corresponding Id-Vds characteristics

chuck of our implantation system – instead, we mounted them on carrier wafers to prevent them from breaking.

Variations in wafer bow were tracked during device processing. Scrutinizing the data failed to uncover any significant addition to wafer bow during gate, ohmic, and aluminium interconnect processing. Adding thick copper interconnects introduces a tensile wafer bow, but this was limited to 40 μm or less. When modifications to the tools and bow monitoring were put in place, we experienced zero wafer loss during processing, according to standard fab operation procedures.

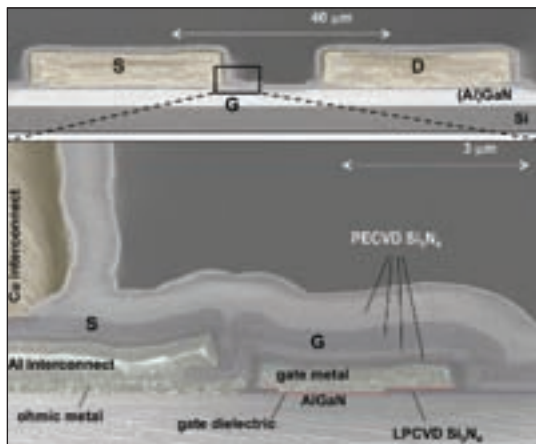
### Preventing gallium contamination

Processing wafers with compound semiconductor stacks on 200 mm silicon lines requires careful planning. Owners of these foundries may have concerns, such as the fear that gallium can contaminate the processing tools – it is a p-type dopant in silicon.

To determine whether there is genuine cause for concern, we adopted existing procedures for contamination control, while monitoring and controlling the spread of gallium from the GaN wafers to the tools. On most tools, gallium levels on the front and backside of silicon wafers are always below 1 x 10<sup>11</sup> atoms/cm<sup>2</sup>. One notable exception is the tools that etch the GaN layers, which are used for processes such as the AlGaIn barrier recess etch. In this case, gallium levels can exceed 10 x 10<sup>11</sup> atoms/cm<sup>2</sup>. However, contamination can be held below 1 x 10<sup>11</sup> atoms/cm<sup>2</sup> with an optimized chlorine-based cleaning procedure at 200 °C that involves the formation of volatile GaCl<sub>3</sub>.

In the labs and fabs used to make GaN devices today, processing tends to involve lift-off metallization schemes for defining ohmic and gate contacts. These contacts are built from either the

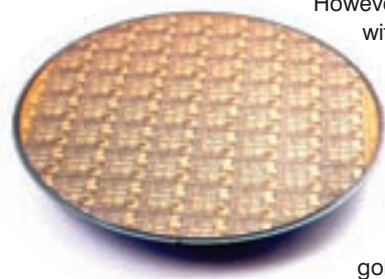
Figure 3. Cross-section scanning electron microscopy images of the power device. The top figure shows the source-gate-drain finger configuration, which has 8 µm-thick source and drain copper interconnect layer encapsulated by Si<sub>3</sub>N<sub>4</sub>. The bottom picture details the source-gate area: The T-shaped metal gate electrode with the field plate, the gate dielectric, and the metallization stack in the ohmic source area



pairing of nickel then gold or the combination of molybdenum then gold. In stark contrast, standard high-productivity CMOS fabs use gold-free metallization schemes, and dry etch patterning instead of lift-off.

It is a challenge to fabricate gold-free ohmic contacts with a contact resistance below 1.0 Ω mm.

However, it is possible to get closer to this target with an AlGaN barrier recess in the ohmic areas, which is formed with a BCl<sub>3</sub>/SF<sub>6</sub> plasma at low bias power. This yields a contact resistance of 1.25 ± 0.15 Ω mm when a 5 nm-thick AlGaN barrier remains. In comparison, contact resistances exceed 4 Ω mm when a barrier recess is not employed. Our gold-free Ohmic contact stack consists of 20 nm of titanium, followed by 100 nm of aluminium, another 20 nm of titanium and 60 nm of TiN. This is alloyed at 550 °C for 90 s in a nitrogen gas atmosphere.



A fully processed 200 mm GaN-on-silicon MISHEMT device wafer

### Device demonstrations

To showcase the feasibility of processing AlGaN/GaN HEMTs on 200 mm GaN-on-silicon wafers, we have fabricated fully functional power devices with a 60 mm total gate width.

There are a wide variety of device architectures available to us, which could realise either depletion-mode (d-mode) or enhancement-mode (e-mode) power devices. We decided to focus on the latter class of device because this is a promising candidate for making reliable, high-performance, high-breakdown GaN power devices with normally off characteristics. Specifically, we fabricated an e-mode AlGaN/GaN metal-insulator-semiconductor HEMT (MISHEMT) with barrier recess and gate dielectric.

E-mode operation results from sufficiently recessing the AlGaN barrier in the gate areas, a step that

reduces local polarization charge. To recess the Al<sub>0.25</sub>Ga<sub>0.75</sub>N barrier, we used a BCl<sub>3</sub> plasma at low bias power. Etching for 0 s, 30 s, and 60 s led to barrier recess depths of approximately 0 nm, 5 nm and 0 nm respectively. A barrier recess etch time of 60 s produced positive threshold voltages of 1.0 V ± 0.2 V over the full 200 mm wafer (see Figure 2).

The gate leakage current of power devices can be suppressed by creating a MISHEMT structure in which a gate dielectric is inserted between the metal gate electrode and the AlGaN barrier to avoid the creation of a Schottky gate contact. However, we want to obtain devices with both a low gate leakage current and a high breakdown voltage, so the gate dielectric has to be carefully chosen.

Starting with a single layer of 15 nm atomic layer deposition (ALD) Al<sub>2</sub>O<sub>3</sub>, we measured breakdown values below the 600 V target. But with a bilayer of 5 nm 650 °C LPCVD Si<sub>3</sub>N<sub>4</sub> and 10 nm ALD Al<sub>2</sub>O<sub>3</sub>, we measured breakdown values above 600 V, close to the buffer breakdown values. This improved breakdown is most probably related to the higher-quality of the semiconductor/dielectric interface obtained with the Si<sub>3</sub>N<sub>4</sub>/Al<sub>2</sub>O<sub>3</sub> bilayer (see Figure 3).

Power devices that we have produced as described above have a total gate width of 60 mm and consist of 60 gate fingers of 1 mm each. Gate length is 1.5 µm, gate-source distance is 0.75 µm and gate-drain distance is 10 µm. By extending the gate metallization by 1 µm to the drain side, we formed a gate-connected field plate. The devices delivered a maximum output current of 6 A at V<sub>GS</sub> = 8 V and V<sub>DS</sub> = 10 V. These results demonstrate the feasibility of AlGaN/GaN HEMT processing on 200 mm silicon substrates.

Our next step is to improve the characteristics of these transistors. At present, their performance lags that of our HEMTs made on 150 mm silicon wafers, which have a maximum output current of 8 A, a breakdown voltage of 750 V, a specific on-resistance of 2.9 mΩ cm<sup>2</sup> and an off-state drain leakage at 600 V of 7 µA.

There are no obvious barriers to replicating these results on 200 mm silicon wafers, and when we do that it will strengthen our claim that GaN-on-silicon wafers can combine affordability with a great set of characteristics. Silicon may be in the ascendancy in the market today, but it is going to face an ever increasing threat to its supremacy place from GaN-on-silicon power electronics.

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#### Further reading

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## Turbocharging VCSELs

How can we accelerate VCSELs to the speeds needed in chip-to-chip optical interconnects? Add a little strain to the quantum wells, tune the photon lifetime and trim cavity size and oxide capacitance, suggest Chuan Xie, Neinyi Li, Phillip Brow and Kenneth Jackson from Sumitomo Electric Device Innovations.

The VCSEL has many great attributes for providing the light source in fibre-optic data communication. It has a beam profile that is relatively easy to couple into a fibre; it can be cheap to produce; it enables on-wafer testing; it consumes very little power; and it can now be switched on and off at very high speeds, enabling rapid data transfer.

Since making its debut more than 30 years' ago, the maximum modulation speed of the VCSEL has crept up and up from a starting point of about a gigahertz. A couple of years' ago a 25 Gbit/s represented state-of-the-art performance in a research lab and VCSELs operating at these speeds will soon be launched onto the market. Initially these products will conform to standards such as Fibre Channel 32GFC and Infiniband EDR, and they will be employed in short data links, such as those used to link up scores of PCs and servers in offices. However, this should be followed by more interesting, technologically disruptive applications such as the long awaited chip-to-chip optical interconnects and optical back planes. Operating at such high data rates, photons will emerge as the indisputable winners of the 'photon-versus-electron race'.

VCSELs can cover a wide range of wavelengths. However, the most common, commercially successful designs use mirrors built from the pairing of AlGaAs of different aluminium mole fractions and they feature GaAs quantum wells emitting at 850 nm to match one of optical fibre's transmission windows. This type of VCSEL has been a workhorse in data-communications for more than 15 years.

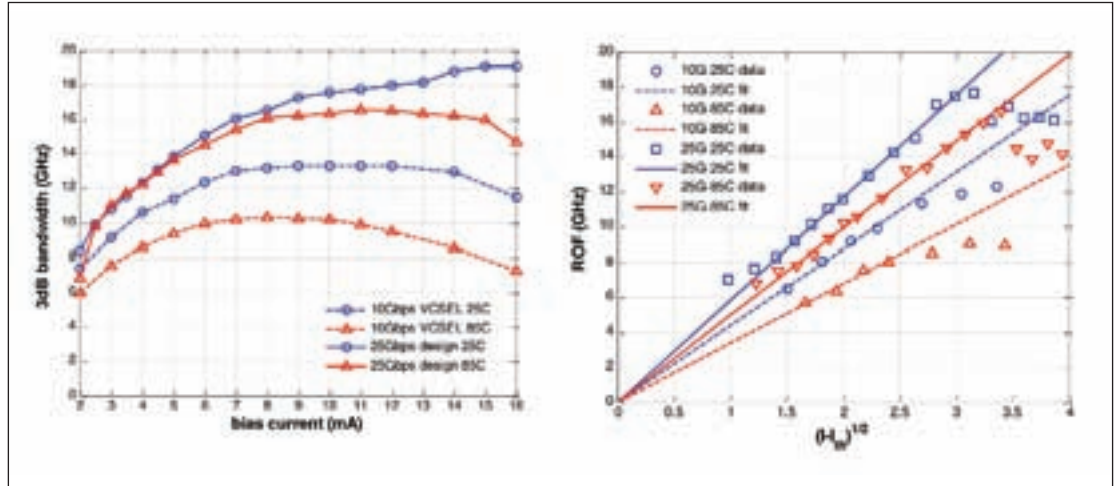
Rewind the clock to the 1990s, a time when the required data rates for short-reach communications were below 5 Gbit/s, and the 850 nm VCSEL was 'naturally' fast. However, when data rate rose to 10 Gbit/s, this device started running into difficulties. For nearly a decade, the data rate of commercial VCSELs lingered at around 10 Gbit/s, and it was difficult to foresee how this could be doubled. But it has. Although it's not been easy to do this, several VCSEL manufacturers have developed devices that can go this fast.

One of them is our team at Sumitomo Electric Device Innovations USA in Albuquerque, New Mexico. Our group has a strong track record in manufacturing high-quality VCSELs for data communications. For example, thanks to recent performance and



*One of the strengths of VCSELs is they allow on-wafer chip testing*

Fig. 1. Sumitomo's successor to its 10 Gbit/s VCSEL is designed to operate at 25 Gbit/s and has a superior 3 dB bandwidth at 25°C and 85°C (a). The slope of curves of relaxation oscillation frequency (ROF) as a function of bias indicate how fast bandwidth ramps with bias (b)



reliability improvements to our 10 Gbit/s VCSEL, the Ultralase, we have been the leading provider for several standards of active optical cables.

Our efforts at developing 25 Gbit/s VCSELs started just over 18 months ago, and our design is now in the advanced stage, with prototypes producing respectable performance. To reach these very high speeds we have had to develop devices with a very high bandwidth. In designs such as the Ultralase, bandwidth saturates at around 10 to 11 GHz at high temperature, which is more than enough for operation at 10 Gbit/s, and sufficient for even 14 Gbit/s (see Fig. 1(a)). But to operate at 25 Gbit/s, we need a minimum bandwidth of 16-18 GHz – drastically higher than the current device capability. Bridging this gap is the biggest challenge to making really high speed VCSELs.

### Back to basics

To understand the limits to reaching higher speeds, you have to understand some of the basic operating principles of a VCSEL. Like every class of semiconductor laser, this device reaches its threshold – the point at which it starts to emit laser light – when the carrier density in the gain medium

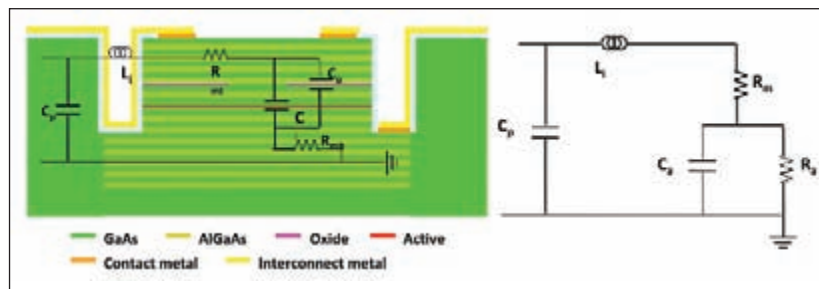


Fig. 2. A circuit diagram for the VCSEL's parasitic equivalent circuit.  $C_p$  is pad capacitance;  $L_i$  is inductance of interconnect metal;  $R_m$  is resistance from mirror stack;  $C_a$  is aperture capacitance;  $R_a$  is aperture resistance

hits a level where gain fully compensates for cavity loss. Increasing the drive current further causes light output to rise linearly with injection current for relatively low bias current.

Crank up the current to higher values and the device enters a new regime: Light output increases with current in a sub-linear manner, and eventually rolls over at increased bias. This rollover results from a rise in junction temperature due to self-heating – that's why it is often referred to as 'thermal rollover'.

At a higher junction temperature, maintaining the same gain requires more carriers, so an increasing fraction of the injection current is consumed to balance the loss, lowering the light emission efficiency. When the increase in current can no longer make up for the increase in threshold, the laser power starts to drop.

Self-heating severely limits the performance of VCSELs, due to their intrinsic high-current density and large thermal impedance, which stems from a far smaller size compared with edge-emitting cousins. This heating not only hampers the device's efficiency to produce light – it lowers its speed. In a directly modulated laser, gain governs the modulation of light. If the laser is to respond rapidly to the modulating current, gain must change sharply in response to adjustments in carrier density.

The rate that gain changes with carrier density is called the differential gain, and it must be high to ensure high-speed operation. Unfortunately, gain rises sub-linearly with carrier density and it decreases with rising temperature, so a high junction temperature lowers differential gain. The upshot is that bandwidth, like output power, is a victim of thermal rollover.

A significant downside of the VCSEL is that its



thermal impedance cannot be made arbitrarily low to overcome the thermal limitation. Techniques that are well known for trimming thermal impedance, such as using binary material rather than ternary and quaternary alloys wherever possible, have already been incorporated in most 10 Gbit/s designs. Any further improvements in this area are limited, and may not be easy to implement.

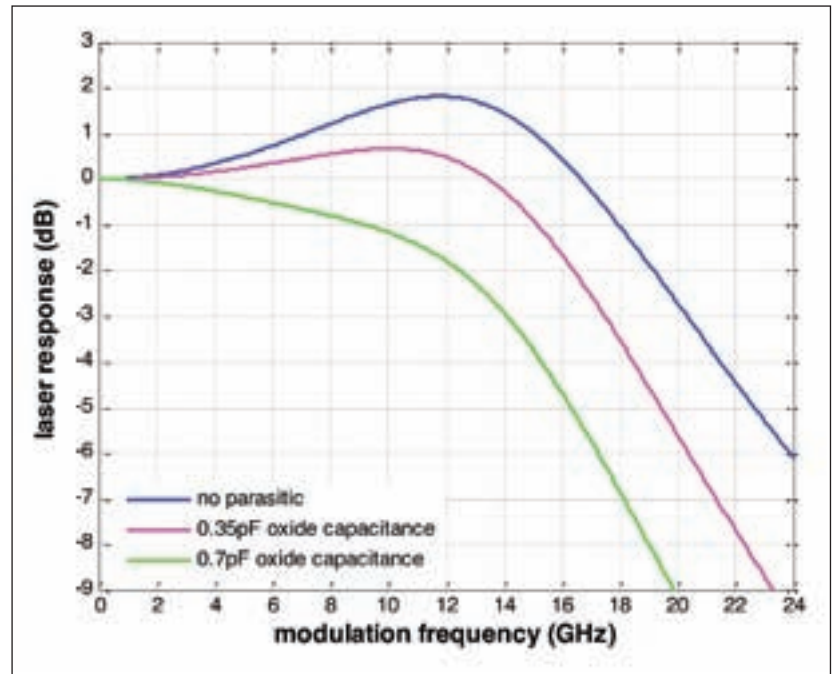
Given that it is very difficult to push out the onset of thermal rollover, increases in bandwidth must come below the thermal limit. Such a design will be welcomed by many, because a faster device that consumes no more power than existing products will be highly valued in many applications. But how is it possible to make a VCSEL with a bandwidth that ramps up faster with bias current?

One approach is to reduce the optical mode volume, because this increases the photon density. An obvious way to realise this is to trim the aperture size, but this is not a great idea because smaller apertures increase current density and aggravate thermal bottleneck. Another option is to cut the cavity length, but there isn't much headroom here, because the cavity in 10 Gbit/s designs is only one wavelength long. Further shortening is possible, but the gain is not sufficient in itself to spur VCSEL speeds to 25 Gbit/s.

### New active regions

Far greater gains are promised by selecting a better gain medium. Until now, active layers of commercial VCSELs have sandwiched GaAs quantum wells (QWs) with AlGaAs barriers. This design is easy to manufacture and has proven reliability, but to make the leap to 25 Gbit/s and beyond, the industry will have to abandon this traditional approach.

Our new design employs compressively strained QWs for higher differential gain, while maintaining an emission wavelength of 850 nm. Materials for both the QWs and the barriers have been carefully



chosen to produce an ideal level of strain, and the growth conditions optimized for performance and reliability. The number of quantum wells are chosen to maximise differential gain, and this judicious selection, plus the composition of the active region, promises to double differential gain.

When one roadblock to higher speeds is removed to any class of device, there is always the threat that another takes its place. With VCSELs, the danger is that parasitic elements become the new bandwidth bottleneck, but it is possible to prevent this from happening by minimizing pad capacitance (see Figure 2 for the VCSEL's parasitic equivalent circuit). This has already been reduced to negligible levels in our 10 Gbit/s design and it has now become necessary to lower the oxide capacitance,

*Fig. 3. Reducing device parasitic elements, such as oxide capacitance, enables VCSELs to realise higher modulation speeds*

Our new design employs compressively strained QWs for higher differential gain while maintaining an emission wavelength of 850 nm. Materials for both the QWs and the barriers have been carefully chosen to produce an ideal level of strain, and the growth conditions optimized for performance and reliability. The number of quantum wells are chosen to maximise differential gain, and this judicious selection, plus the composition of the active region, promises to double differential gain

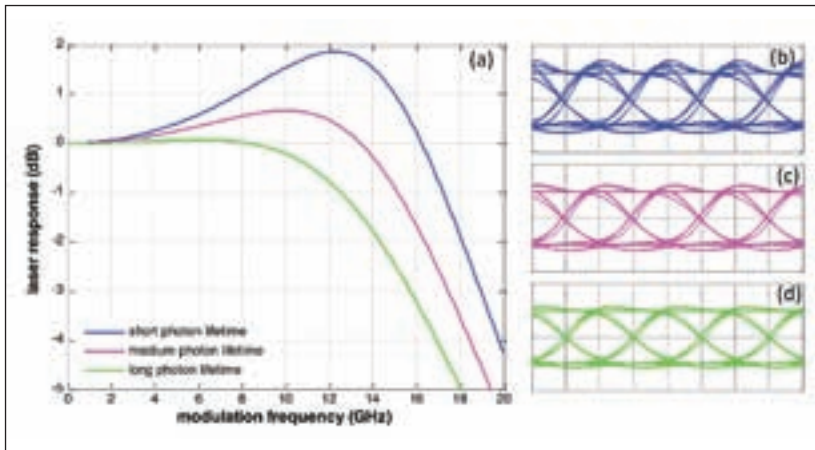


Fig. 4. Simulations show that changes to photon lifetime impact the laser's frequency response. The bandwidth decreases with increasing photon lifetime, and so does the amount of peaking. Eye diagram simulations (Fig. 4. (b) to (d)) reveal that when peaking is high (low damping), overshoot and jitter are more severe. However, when photon life is too long, rise and fall times begin to increase and the eye starts to close vertically

so that less high-frequency modulation is shunted by it. Reducing parasitic elements, in particular the oxide capacitance, has a significant impact on the frequency response of the laser (see Figure 3). Cutting oxide capacitance in half is one of the goals for our 25 Gbit/s design.

### More than a bandwidth game

If you read through the theory section of textbooks detailing laser behaviour, somewhere you'll likely to find a prediction for where the maximum bandwidth occurs – at the point where the relaxation oscillation is critically damped. According to theory, our current 10 Gbit/s VCSEL should reach an ultimate bandwidth of 22 to 27 GHz. In reality, however, it is less than half of this, due to thermal rollover.

A major term that defines the maximum bandwidth is inversely proportional to photon lifetime. This has led many engineers within the optoelectronic industry to believe that one of the best handles for increasing the bandwidth is cutting photon lifetime. But this is a misconception, at least for the VCSEL.

Cut photon lifetime and you get an unwanted side effect – reduced damping of the relaxation oscillation under the actual operation bias. This is limited by the thermal effect and requirements for either power consumption or reliability, or both of them. The key point to note is that insufficient damping degrades signal integrity, which can be

seen as overshoot and jitter in the optical eye diagram. Making matters worse, a shorter photon lifetime increases cavity loss, leading to a higher threshold. In turn, this lowers the differential gain that we have tried so hard to maximize.

In our view, the correct approach is to select a photon lifetime that is sufficiently short to not unduly penalize the bandwidth, but long enough to offer low threshold and ample damping. The good news for us is that our simulations show that the photon lifetime of our 10 Gbit/s design is also a good choice for 25 Gbit/s (see Figure 4 for details).

### Putting theory to the test

Based on the design strategy just detailed, we have carried out extensive simulations to narrow the range of design parameters. Since there is some uncertainty in many material characteristics, there is some trial-and-error associated with the process of designing, building, evaluating and modifying our lasers. However, we have found that after a few iterations, our device's performance is now close to its target. The improved bandwidth characteristics compared to our 10 Gbit/s design are shown in

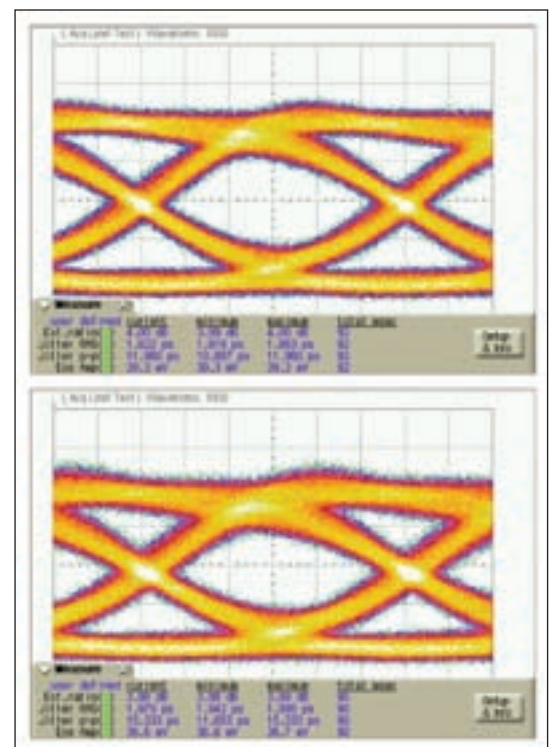


Fig. 5. Increasing the 25 Gbit/s operating temperature from 25°C (a) to 85°C (b) leads to a slightly inferior optical eye diagram

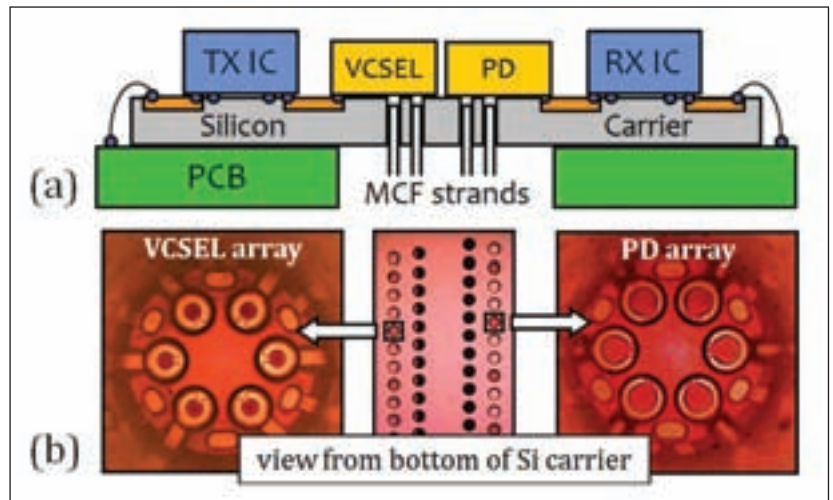
Figure 1, and eye diagrams for the 25 Gbit/s laser are shown in Figure 5. The focus has been on the laser's intrinsic parameters; there is still room to increase the parasitic bandwidth of our device, so better performance is expected in the final design.

Our lasers could have a big role to play in the growth of deployment of optical interconnects, which have been touted for many years as the next technological breakthrough. Many believe that there will come a time when various electrical interconnects are replaced by those operating in the optical domain because data rates will become too high for copper to handle effectively. It may be that the optical interconnects within an integrated circuit will have to wait for 'silicon photonics' to yield an efficient, more mature light source that is readily implemented on silicon.

However, for optical interconnects between ICs and among line cards, nothing can surpass the VCSEL as the premier light source. It wins thanks to its small size, its high efficiency that translates into low power consumption, its low manufacturing cost, and because it is readily made into one- or two-dimensional arrays flip-chip mountable on silicon, IC carriers, and PCBs alike. Now that the VCSEL has finally approached the critical data rate for optics to dislodge copper, the 'flood gate' is opening.

To our delight, even before we can put the finishing touches to our new device, many researchers have been getting in touch and asking us if they can try this VCSEL in their new interconnect transceivers. We have fulfilled some of these wishes, and our VCSELs, plus corresponding photodetectors, have been grouped together to provide data transmission down novel multicore fibres (see Figure 6) and used to build a four-channel receiver (see Figure 7).

Have we now reached the limit of what is possible? Or can data rates go even higher, to 35 Gbit/s, 40 Gbit/s, or even 50 Gbit/s? In our view they can, but it will be about revolution, rather than evolution. It will require some help from the driver, such as pre-emphasis, and the introduction of new modulation schemes with higher bandwidth efficiency.



Implementing these technologies may be tricky, but there doesn't seem to be an insurmountable barrier to ultra-fast optical interconnects. That's good news, because their electrical equivalents are clearly running out of steam.

Fig. 6. (a) Transceiver schematic and (b) selected images showing the VCSEL and photodiode arrays viewed through the silicon carrier's optical vias from the underside of the package

● The authors would like to thank Fuad Doany, Dan Kuchta, Ben Lee, and Clint Schow from IBM Thomas J. Watson Research Center for their collaboration and feedback. Our gratitude also goes to Chun Lei from Emcore Corp. for her instrumental contributions to our VCSEL program in the past few years. Many thanks go to the excellent team of the Albuquerque VCSEL FAB who made everything happen.

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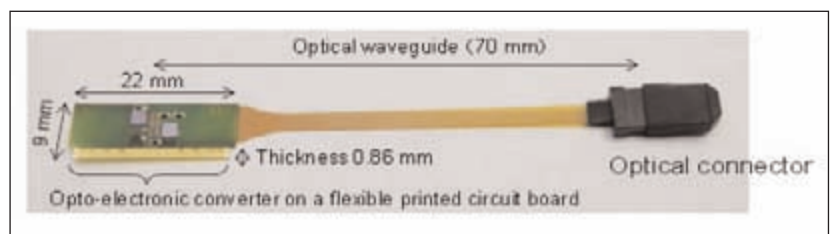


Fig. 7. A 4 x 25 Gbit/s transceiver made with precursory version of 25 Gbit/s VCSELs (see [www.fujitsu.com/global/news/pr/archives/month/2012/20120531-01.html](http://www.fujitsu.com/global/news/pr/archives/month/2012/20120531-01.html) for more details)

**Further reading**

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# Refined BiHEMT targets the latest wireless standards

Makers of smartphones and tablets place great importance on the efficiency of amplifiers because this governs battery life. WIN Semiconductors' latest H2W process has been developed to address that need: It unites on a single die pHEMT featuring a very low insertion loss and a highly linear HBT, says the company's Andy Tsai.



**G**o back a few years and you would have start up your computer to access the Internet. Today, however, you probably have other options at your disposal. If you just want to catch up on the latest sports results or find out whether it's going to rain tomorrow, you can put your hand in your pocket and get out your smartphone. But if you want to watch a clip on YouTube or take a close look at your friend's latest photos, you may well turn to your tablet.

These latest mobile devices, which offer the user mobile Internet and other multimedia services on the move, draw on far more data than previous generations of mobile phones. And in order for the owners of these laptops and smartphones to enjoy using this technology, downloading all this data must be fast. However, the electronics in the mobile devices must not only be capable of handling these fast data rates – it must also be efficient enough to allow them to operate for several hours between charges.

Faster download requirements have been enabled by the owners of wireless infrastructure, who have constructed networks with greater bandwidth and higher data transfer rates, while makers of power amplifier MMICs have helped to reduce demands on battery life.

Most of time PAs operate at a fairly low power level, so the power added efficiency (PAE) can be relatively low. To combat this, in the last few years the makers of these amplifiers have unveiled two-state PAs, which increase efficiency when the device is operating at low and medium output powers. The technology to do this tends to be referred to as either a BiHEMT or BiFET process, and it involves the monolithic integration of HBTs and pHEMTs on a single die. The result is the combination of a PA and a switch.

With this technology it is possible to operate at high efficiencies far more often (see Figure 1). The input signal can be routed through the high-power path to deliver high efficiency at high power levels; and it can be directed through the low-power path to realize good efficiency at low powers.

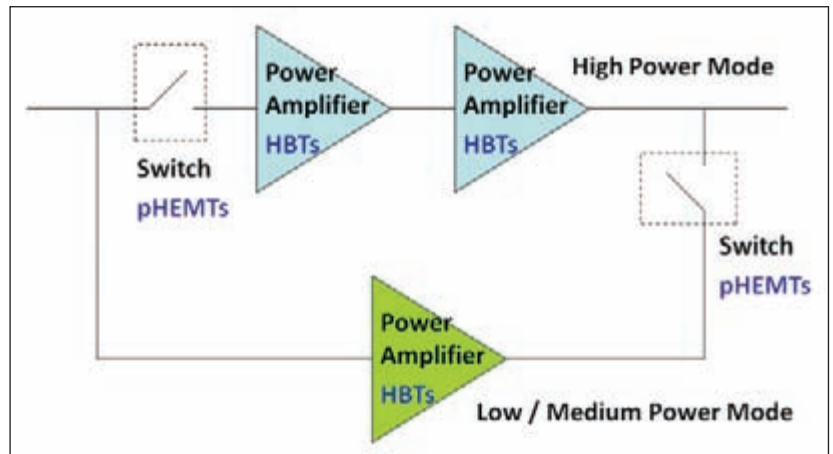
At WIN Semiconductors Corporation of Taiwan we have been developing and refining our own BiHEMT process for uniting a HBT and a pHEMT on a single die. Specifically, our first-generation technology, which we unveiled at the CS Mantech conference held in 2007, involves the monolithic integration of InGaP/GaAs HBTs and E/D pHEMTs and uses a double-recess architecture and a bi-layer T-shape gate.

More recently, we have simplified our process, which in its latest guise incorporates just D-mode pHEMTs with HBTs. This makes good sense from a commercial perspective, because most BiHEMT applications for DC bias circuits and either RF or power-mode switches can be achieved with the pairing of D-mode pHEMTs and HBTs.

One of the strengths of our latest H2W process is that it trims the on-resistance of the pHEMT. In turn, this can lead to lower insertion loss and smaller layout area when the pHEMT performs as a power mode switch (as shown in Figure 1). The new generation H2W process is also very simple, requiring just 17 mask layers – five less than the previous H2W process, and just one more than we use for our stand-alone HBT technology. This means that our latest H2W process combines superior pHEMT characteristics for better RF switch performance with a simpler, better BiHEMT process for making products for producers of handsets and tablets.

### Fabrication processes

MOCVD growth is employed for forming our epiwafers. They feature an InGaP layer to



completely separate the pHEMTs from the HBTs, which form the upper section of the epitaxial stack. This isolation holds the key to independent optimization of both types of transistor. For example, by increasing the indium composition in the channel we have enhanced channel mobility, leading to a 40 percent reduction in on-resistance with the new generation H2W (PH50-20) process.

Figure 1. Amplification is more efficient over a wider range of conditions when two amplifiers are used for high power mode and just one for low and medium power modes

A cross-section of devices formed with this latest process is shown in Figure 2. Fabrication yields 2µm InGaP/GaAs HBTs and 0.5µm D-mode pHEMTs combined with epitaxial mesa resistors, thin film resistors, metal-insulator-metal (MIM) capacitors and through wafer vias. These BiHEMTs draw on our fourth generation HBT process, which includes two interconnection metal layers - Metal1 and Metal2 - and a thicker SiN dielectric sandwiched between them, which delivers improved mechanical and moisture protection.

The Metal 1 layer is a 1 µm-thick film of evaporated gold, and plating of this metal creates a 4 µm-thick layer for Metal 2. MMIC designs that can be

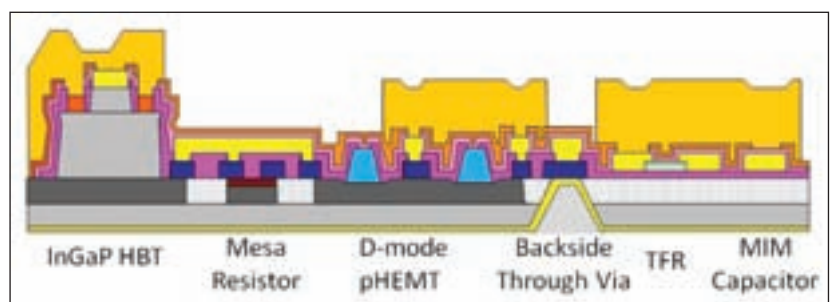


Figure 2. The new generation H2W process requires just 17 mask layers, five less than the previous generation process

The biggest challenge that we have faced when developing our latest H2W technology is forming uniform 0.5  $\mu\text{m}$  single and multiple gates for pHEMT devices around the HBT mesa. That's because the HBT mesa has a height of over 1.5  $\mu\text{m}$ . After fine-tuning gate photoresist thickness and the lithography process, the success that we have had in addressing this challenge is seen in the quality of a 0.5  $\mu\text{m}$  full-periphery gate

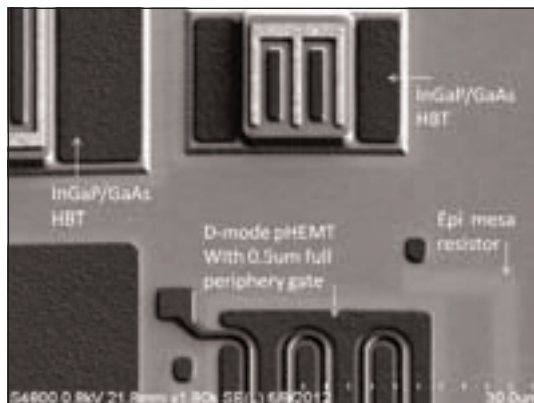


Figure 3. Scanning electron microscopy photos for new generation H2W show that pHEMT with 0.5  $\mu\text{m}$  full-periphery gate can be realized near the HBT transistors with high topology

produced by us can also feature MIM capacitors with a capacitance of 570 pF/mm<sup>2</sup>, stacked MIM capacitors with a capacitance of 870 pF/mm<sup>2</sup>, thin-film resistors with sheet resistance of 50 Ohm/ $\square$  and an epitaxial mesa resistor with sheet resistance 175 Ohm/ $\square$ .

We define the dimensions of our 0.5  $\mu\text{m}$  gate with an i-line stepper and use a single layer photo resist. A single recess, followed by metal evaporation, forms the gate.

The biggest challenge that we have faced when developing our latest H2W technology is forming uniform 0.5  $\mu\text{m}$  single and multiple gates for pHEMT devices around the HBT mesa. That's because the HBT mesa has a height of over 1.5  $\mu\text{m}$ . After fine-tuning gate photoresist thickness and the lithography process, the success that we have had in addressing this challenge is seen in the quality of a 0.5  $\mu\text{m}$  full-periphery gate realized near the HBT transistors with high topology – there is no reduction in quality compared to our stand-alone pHEMT technology (see figure 3).

### Device characteristics

HBTs produced with our PH50-20 process have a great set of characteristics. For example, the typical turn-on voltage is 1.265 V and DC current gain is 130 (see table 1 for more details). The cut-off frequency of this transistor is well above 30 GHz, so it can be widely used for constructing power amplifiers for Wireless LAN, UMTS and LTE standards.

The performance of the pHEMT is just as impressive as that of the HBT. Device characteristics of a 0.5  $\mu\text{m}$  D-mode pHEMT produced with the PH50-20 process include a pinch-off voltage of -1V ( $I_{ds} = 1\text{mA/mm}$ ) and on-resistance of 1 Ohm.mm (see table 1 for details). Compared to the previous H2W technology, the latest version produces pHEMTs with a higher channel mobility, lower on-resistance, and a similar gate-drain breakdown voltage of about 18 V. The lower on-resistance stems from the move

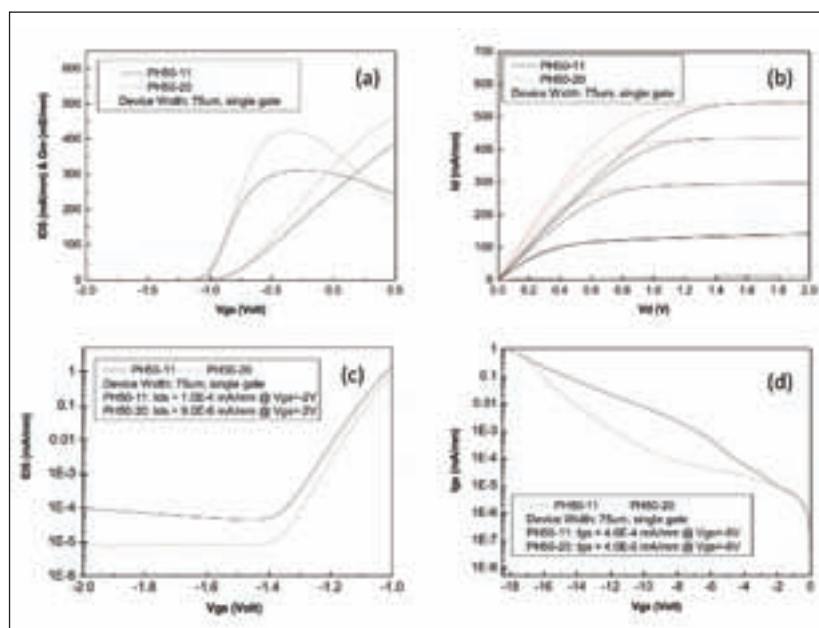


Figure 4. pHEMTs produced by the new H2W process produce superior characteristics to those fabricated with the earlier H2W process. Comparisons of: (a) transfer curves, (b) I-V curves, (c) channel leakage currents, and (d) gate leakage currents



from a double recess process to a single one. The set of characteristics associated with the latest D-mode pHEMT fulfil the power handling requirements for RF switches.

Improvements in the pHEMT wrought with the new H2W process include a higher drive current; superior transconductance and on-resistance; and lower leakage currents in the channel and gate regions (see Figure 4).

We characterised our RF switch using a single 9 x 125 µm device, 20 kΩ gate isolation resistors and a source-drain balance resistor. This revealed that the new H2W process reduced insertion loss compared to its predecessor, with losses falling from 0.15 dB to 0.1 dB.

Testing of switch linearity showed excellent rejection of higher harmonics (see Figure 5), and the switching speed for pHEMTs produced with the PH50-20 process was just 1.5 µs. The results demonstrate that the pHEMT made with the PH50-20 process is suitable for low loss, high power and high linearity switch applications.

The great performance of these pHEMTs, and the HBTs that accompany them, demonstrate the high-quality of BiHEMTs produced by our new H2W process. The die that result are smaller than before, can be produced more quickly with a foundry process yield exceeding 95 percent, and they are very attractive candidates for making UMTS and LTE power amplifiers with excellent linearity and efficiency figures, which are needed for the latest smartphones and tablets.

● The author thanks WIN's team members who supported the measurements and process development.

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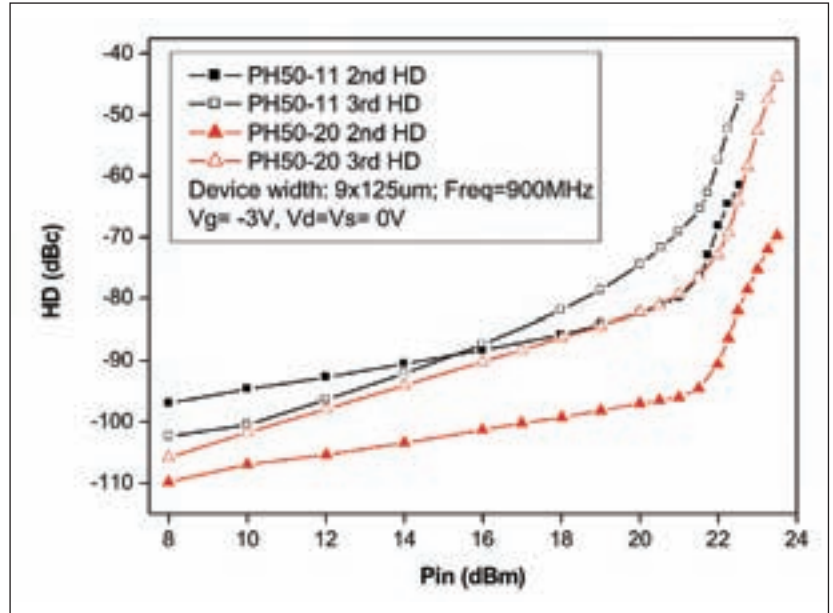


Figure 5. 80 dBc of second-harmonic and third-harmonic rejection ratios were obtained when device was biased at -3V



HBT			pHEMT			
Parameters	Unit	New H2W PH50-20	Parameters	Unit	1st Generation H2W (PH50-11)	New H2W (PH50-20)
Current Gain @ 1.25kA/cm2	N/A	130	Gm peak @ Vd=1.5V	mS/mm	340	450
BE Turn-on @ 1.25kA/cm2	V	1.265	Idss @ Vg=0V	mA/mm	265	335
BVceo @ 0.05kA/cm2	V	14	Channel On-resistance	Ohm-mm	1.7	1
BVcbo @ 0.05kA/cm2	V	28	Vdg breakdown	V	20	18
BVebo @ 0.05kA/cm2	V	9.5	Threshold voltage @ 1mA/mm	V	-1	-1
HBT Ft @ 3.6V, 25kA/cm2	GHz	37	pHEMT Ft @ Vds=3.6V	GHz	33	34

Table 1. WIN's latest H2W process produces HBTs and pHEMTs with a strong set of characteristics

# Inserting InGaN slashes LED droop

Reductions in external quantum efficiency at high current densities diminish when *p*-doped InGaN is inserted after the electron-blocking layer

A TAIWANESE COLLABORATION has unveiled a novel LED architecture for combatting droop, the decline in device efficiency as current is cranked up.

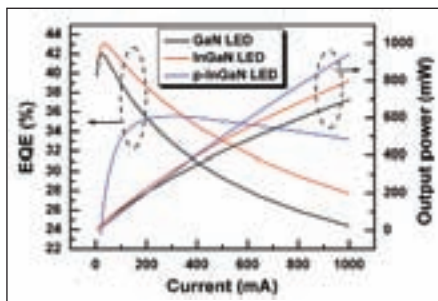
The team's modification to the standard LED structure is the insertion of a *p*-type InGaN layer after the *p*-AlGaIn electron-blocking layer. Thanks to this refinement, the drive current associated with optimum external quantum efficiency (EQE) is increased by an order of magnitude to 316 mA. Meanwhile droop – evaluated as the percentage fall from the peak value of EQE to its value at 1 A – plummets from 42 percent for a conventional control sample to just 7 percent.

These improvements in high-current LED performance are thought to result from mitigating the asymmetric carrier distribution in the device, thanks to enhanced hole injection and suppression of electron overflow.

When a conventional electron-blocking layer is used in an LED, the results are not ideal because this barrier to electrons impedes the flow of holes into the active region. Making matters worse, at high current densities a significant proportion of electrons overflow into the *p*-type region, where they recombine with holes. This may be a non-radiative process, but even if it is radiative, it will be at a significantly different emission wavelength from that produced by the active region.

One approach to combatting droop, which has been shown to work by researchers at Philips Lumileds, is to use a very thick InGaN quantum well in the active region. The Taiwanese team has also built and studied these so-called double heterostructure LEDs. According to Sheng-Fu Yu from National Cheng Kung University, their performance is not particularly good, due to poor carrier transport and the strong quantum-confined Stark effect.

The team believes that it has uncovered a superior structure for addressing droop via a study that compares a conventional LED with those featuring additional undoped and *p*-doped InGaN layers inserted after the AlGaIn electron-blocking layer. All the



Although the LED with the *p*-doped InGaN layer before the AlGaIn electron-blocking layer produces an inferior external quantum efficiency at lower currents, it is the most efficient at high drive currents

structures, which were grown with a Taiyo Nippon Sanso SR2000 MOCVD reactor on sapphire, featured a strain relaxation region comprising two pairs of 3 nm-thick InGaN and 12 nm-thick GaN.

This strain relaxation section preceded the multiple quantum well – four pairs of 3 nm-thick  $\text{In}_{0.16}\text{Ga}_{0.84}\text{N}$  sandwiched between 12 nm-thick GaN barriers, followed by another 3 nm-thick  $\text{In}_{0.16}\text{Ga}_{0.84}\text{N}$  well and a 3 nm-thick GaN barrier.

The control had an additional 5 nm-thick layer of GaN, while in the other two devices the final GaN layer was followed with 5 nm of  $\text{In}_{0.07}\text{Ga}_{0.93}\text{N}$ , either undoped or *p*-type with a magnesium concentration of  $5 \times 10^{19} \text{ cm}^{-3}$ . Onto all of these structures the team added a 20 nm-thick, *p*-type  $\text{Al}_{0.2}\text{Ga}_{0.8}\text{N}$  layer with a doping level of  $1 \times 10^{20} \text{ cm}^{-3}$  and a 100 nm-thick *p*-type GaN layer with a doping level of  $5 \times 10^{19} \text{ cm}^{-3}$ .

Simulations with SiLENSe software made and sold by the STR Group suggest that InGaN insertion benefits the distributions of electrons and holes. With the standard LED design, at a drive current of 1 A for a 1 mm x 1 mm chip, the leakage current in the *p*-side is  $7 \times 10^8 \text{ cm}^{-3}$  and the hole concentration in the well nearest to the *p*-side is  $9 \times 10^{17} \text{ cm}^{-3}$ . In comparison, inserting undoped and doped InGaN before the electron-blocking layer slashes electron leakage in the *p*-side to  $1.5 \times 10^6 \text{ cm}^{-3}$  and  $9 \times 10^5 \text{ cm}^{-3}$ , respectively, and increases hole concentration in the

wells to  $1.1 \times 10^{19} \text{ cm}^{-3}$  and  $2.5 \times 10^{19} \text{ cm}^{-3}$ , respectively. Real measurements prove that the addition of an InGaN layer, particularly if it is *p*-doped, is highly beneficial (see Figure). The conventional LED and that with an undoped InGaN layer produce a peak EQE of more than 40 percent at a drive current below 100 mA.

In comparison, although the device with the *p*-InGaN layer produces a significantly lower EQE in this regime, it overtakes the other two devices in the efficiency stakes at a few hundred milliamps, and at a 1 A drive current its output power can hit 950 mW, compared to about 800 mW and 700 mW for LEDs with an undoped InGaN layer and the control design, respectively.

One interesting feature of the LED with the *p*-doped InGaN layer is its low forward voltage. "This is a high-power chip, so I think its forward voltage should be judged at 350 mA," says Yu. On that basis, the forward voltage is just 3.32 V, 0.3 V lower than the conventional design.

The team suspects that the decrease in operating voltage stems from a change in the location of the *p*-*n* junction that makes it more favourable for holes to be transported into the active layer. However, these engineers admit that they will have to carry out more experiments to confirm this hypothesis. Efforts to date have been directed at understanding the relatively low EQE of the best device at lower current densities. Three weaknesses have been uncovered: Reversed current-voltage plots have unveiled a hike in the current of this type of LED compared to the others, indicating far greater defect-assisted tunnelling; analysis of current at low positive voltages shows severe tunnelling leakage, implying insufficient radiative recombination; and secondary ion mass spectrometry has revealed that the magnesium dopant atoms in the *p*-type InGaN layer have diffused into the active region.

Yu says that they will now try to improve the growth process to prevent magnesium atoms from diffusing into the active region.

R – M. Lin et al. *Appl. Phys. Lett.* **101** 081120 (2012)

# Coalescence promises perfect GaN boules

*Dislocation-free crystals can be made by forming GaN point seeds by the sodium-flux method and joining them together via coalescence*

MAKERS of nitride LEDs, lasers and transistors all want to build their devices on large, dislocation-free substrates. Unfortunately, they don't exist today, but they soon could thanks to the work of researchers at Osaka University, Japan.

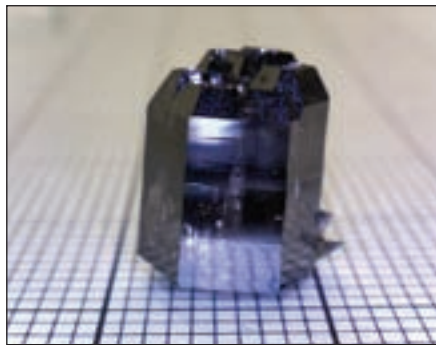
Earlier this year, this team reported how they could make dislocation-free GaN crystals using a GaN point seed. Now they reveal how to join a pair of them together in a stainless steel tube that combines a melt of gallium, sodium and carbon with nitrogen gas held at a pressure of 3.6 MPa. After 200 hours of growth at 870 °C, crystals with dimensions of several millimetres form that are free from dislocations associated with coalescence.

"We are now aiming to fabricate 8-inch GaN substrates by our newly developed coalescence process," says corresponding author Mamoru Imade.

There are no reports of any GaN crystals of that size today. The incumbent method for producing boules of this wide bandgap material, HVPE, has enabled the fabrication of 4-inch substrates with a dislocation density of about  $10^6 \text{ cm}^{-2}$ . Lower values are possible with techniques such as ammonothermal growth and a sodium-flux approach, but they yield smaller crystals.

Polish GaN crystal developer Ammono has reported that its ammonothermal growth can yield 1-inch GaN crystals with a dislocation density of  $5 \times 10^3 \text{ cm}^{-2}$ . However, according to Imade, this technique suffers from a low growth rate and high levels of impurity in the crystals. In comparison, in the last few years he and his co-workers have used the sodium-flux technique to produce 2-inch crystals with a dislocation density of  $10^4 \text{ cm}^{-2}$  on seeds with a dislocation density of  $10^8 \text{ cm}^{-2}$ .

However, in their most recent work, the Osaka university researchers begin by producing a pair of GaN point seeds. To do this, they mount a sapphire plate with two 1.2 mm holes, separated by 0.5 mm,



*The sodium-flux method can yield GaN crystals grown on the point seed. 600 hours of growth results in the formation of this crystal, which is positioned against a backdrop of graph paper with a scale of 1 mm per division*

on a 8  $\mu\text{m}$ -thick *c*-plane GaN seed layer grown on sapphire. On this structure they deposit GaN by the sodium flux method.

Point seeds form through the apertures, and when a pair of them is arranged along the *a*-direction, they coalesce without generating dislocations at this interface. In comparison, arranging the point seeds along the *m*-direction produced inferior results, with voids appearing at the coalescence boundary.

To search for dislocations in the coalesced material, the team performed room-temperature cathodoluminescence imaging on cut and polished crystals with

a Horiba Imaging-CL DF-100. Any dark spots found in the images would result from non-radiative carrier recombination at dislocations.

For both types of crystal formed by coalescence, imaging revealed the absence of dark spots in the large areas apart from the coalescence boundary.

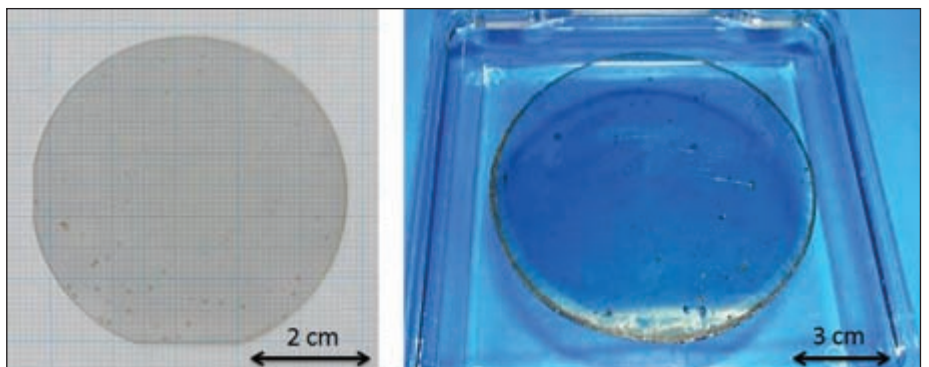
However, near to this interface, dark spots were seen in material formed from seeds aligned along the *m*-direction. In contrast, no spots were visible in the crystal created from seeds in the *a*-direction.

Meanwhile, X-ray diffraction measurements of the full-width half maximum for GaN (0002) suggest that the crystalline quality of the material resulting from *a*-direction coalescence is as good as that distant from the coalescence boundary. This was not the case for *m*-direction coalescence.

Many researchers believe that substrates made from high quality crystals that are free from dislocations should lead to improved device performance, but this conjecture is yet to be fully tested.

"This is one of our current research topics," says Imade. "We are now investigating device performance on these substrates."

N. Dharmarasu et al. *Appl. Phys. Express* 5 091003 (2012)



*The sodium-flux method that has been pioneered by researchers at Osaka University, Japan, has produced material with a diameter of up to 4 inches*



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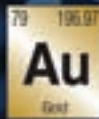
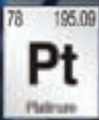
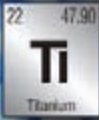
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# LEDs

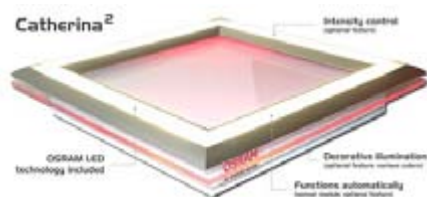
## Osram LEDs enlighten Catherina2 lighting fixtures

FuturoLighting's latest fixtures developed for planar lighting incorporate Duris E 5 LEDs from Osram Opto Semiconductors

With its Catherina square ceiling fixture, FuturoLighting is presenting a new solution for widespread use in interior lighting.

The firm's latest LED products are suited to architectural, retail and residential lighting applications.

The luminaire is optionally available with motion sensor and emergency module and has a long operational lifetime.



Osram Opto Semiconductors' Duris E 5 LEDs are mid-power LEDs which were specially developed for applications requiring high-output, homogenous planar light and will be installed in the luminaire.

A smart sensor module detects movement and distinguishes between day and night. This functionality was developed for hotel corridors and rooms where light activation is only required when customers are present in order to decrease facility power consumption.

Based on customer requirements, Catherina2 can be equipped with new emergency module based on Li-ion battery technology, this module is currently under development. The Catherina2 offers high efficiency with minimal power requirements, a life expectancy of over 50,000 hours and requires no maintenance other than normal dusting/cleaning during the whole product life.

"We are proud to include Osram LED technology in our products, with their high quality, reliability and

excellent support," says Valentin Kulikov, CEO at FuturoLighting.

The ideal LED for planar lighting The Duris E 5 has a homogenous distribution of light in panel lights. With a colour temperature of 4,000 Kelvin and a colour-rendering index of 85, the LEDs generate a light colour which is similar to daylight – an aspect which is particularly important in office and retail lighting.

The Duris E 5s are claimed to be among the most efficient LEDs on the market in their performance class (mid-power), achieving 110 lm/W (at 4,000 K and 120 mA). Since their product launch in October 2011, their output has already been increased by 25 percent.

Osram maintains they are now also achieving very good lumen maintenance figures in accordance with the IESNA LM-80-08 standard. These results are an important factor in the Energy Star certification of LED lamps and luminaires in the USA and also are increasingly being demanded worldwide as a standardised test method for lumen maintenance.

Andreas Vogler, Product Manager at Osram Opto Semiconductors comments, "Duris E 5 is the ideal LED component for high-output, homogenous planar light applications such as in Catherina2. The excellent price/performance ratio of this LED is prompting more and more manufacturers to convert their product designs to LED technology from Osram Opto Semiconductors."

Catherina2 has dimensions of 300 x 300 x 55 mm, power consumption of around 25 VA and gives out around 1,600 lm in near Lambertian light distribution.

## Shuji Nakamura wins Inventor of the Year award

The Silicon Valley Intellectual Property Law Association (SVIPLA) honoured Sora co-founder Nakamura for his pioneering work in the gallium nitride based LED industry

Sora has announced that co-founder Shuji Nakamura received the Inventor of the Year Award from The Silicon Valley Intellectual Property Law

Association (SVIPLA).

Each year the SVIPLA recognises an individual who has made an exceptional contribution in the technical arts and this year has chosen to honour Nakamura for his technological innovations, including the development of Soraa's GaN on GaN technology.



*Shuji Nakamura, Co-founder of Soraa*

"Shuji's pioneering work has enabled Soraa to produce the most advanced LED lamps on the market," says Eric Kim, CEO of Soraa. "As we continue to innovate, we are pleased to see our co-founder honoured for the work that started it all. For those who have followed his contributions to the industry and to LED technology, this award has special meaning."

Nakamura, known by some in the lighting industry as the "inventor of high-brightness blue and white LEDs," has filed more than 700 patent applications, and can claim at least 360 authorised invention patents.

His development of nitride-based semiconductors, which eventually led to Soraa's "simply perfect" LED lamps is cited by the SVIPLA as "one of the most important achievements in the materials science of semiconductors in the last 30 years."

"I am proud to be recognised by the property law association and I thank them for this. My focus is to create efficient lighting products that do not compromise on performance, offer the highest quality available and greatly reduce energy waste," says Nakamura.

Using the GaN on GaN technology developed by Nakamura, Soraa produces LEDs that perform much better than LEDs from other manufacturers that typically deposit GaN on non-native substrates like silicon or sapphire.

Soraa says GaN on GaN allows a much smaller, brighter LED brighter diode and makes it possible to use one LED light emitter per lamp-manufacturers using other substrates must use three, four and even more diodes to achieve equivalent brightness.

Multiple sources of light within a lamp mean fuzzy shadows and not the crisp light required of an MR-16 for best use in commercial, museum or high-end consumer applications. MR-16 lamps, or bulbs, are Soraa's first commercially available products.

## LED demand triggers AkzoNobel's multimillion dollar expansion

The firm is expanding its Tri-Methyl-Aluminium and Tri-Methyl-Gallium production facilities in Texas

AkzoNobel is to boost capacity at one of its US sites in order to meet increasing demand from the semiconductor industry, particularly for the production of LEDs. Financial details were not disclosed.

The investment, at the company's Battleground facility in Texas, involves extending the Tri-Methyl-Aluminium (TMAL) unit and building a new Tri-Methyl-Gallium (TMG) plant, consolidating the plant's status as the largest of its kind in the world. TMAL is a feedstock for TMG, a high purity metal organic (HPMO) used in products such as LED wafer manufacturing.

"The LED industry has been experiencing strong growth, well in excess of 20 percent per annum," explains Werner Fuhrmann, AkzoNobel's Executive Committee Member responsible for Specialty Chemicals. "This investment will make production more cost-efficient and ensure that we continue supplying our customers with a highly specialised product which is playing an increasingly important role in 21st century technology."

The global LED industry is projected to grow significantly over the next decade, driven by applications in displays such as PCs, laptops and tablet screens. The massive increase in the use of LEDs for general lighting is also expected to contribute strongly as they become the preferred



source of light over incandescent bulbs and compact fluorescent lamps, due to their low energy consumption and extended lifetime.

The expanded TMAL unit is expected to be completed in the third quarter of 2013, while the new TMG plant will be ready in August 2014.

---

## Red nitride LED phosphor patent granted to Intematix

The firm's chemical formulation lowers the concentration of oxygen impurities in the material structure. This leads to improved reliability under high temperature and humidity conditions and increases light output efficiency

Intematix Corporation has been issued its patent covering red nitride phosphor compositions used in LEDs by the United States Patent and Trademark Office (USPTO).

The patent was allowed in August and officially issued on September 25th 2012.

Intematix's U.S. Patent No. 8,274,215, entitled "Nitride-based Red Phosphors" is the 18th U.S. patent issued to Intematix in the area of LED phosphors and the 71st U.S Patent overall.

LED manufacturers worldwide have implemented Intematix's red nitride product portfolio in order to produce high performance and quality lighting products.

"Our novel chemical formulation lowers the concentration of oxygen impurities in the material structure, leading to improved reliability under high temperature and humidity conditions," explains Yi-Qun Li, Chief Technology Officer at Intematix, "This design increases light output efficiency and produces longer emission wavelengths when powered by the blue light from the LED chip."

Red phosphor technology plays a fundamental role enabling high quality LED lighting with high colour rendering index (CRI). Due to the high thermal stability of nitride technology in particular, LEDs may operate at higher temperature, power and light output per unit, lowering the costs of lighting.

## New UK homes to benefit from PhotonStar LED lighting

The British designer and manufacturer of smart LED lighting solutions will supply many new homes in the UK in order to meet new regulations to reduce CO2 emissions

PhotonStar LED has announced a rolling one year exclusive supply agreement with a major UK house builder to supply LED lighting fixtures for all of the developer's new homes.

The products will be supplied through UK wholesalers.

In the last year, the house builder completed 1500 homes, and is forecasting continued growth. All new properties will be subject to new legislation requiring improvement in energy efficiency including lighting.

The new legislation, "Code for Sustainable Homes," is an environmental impact rating system for housing in England and Wales. The first level (3) of the code has recently become mandatory on all new properties, with increasing targets for CO2 emission reduction over the next four years.

Developers have a number of choices on how they will achieve these reductions.

Following extensive testing over a one year trial, PhotonStar was able to successfully demonstrate cost effective (on a cost per plot basis) CO2 emission reduction in multiple property types through a lighting upgrade.

The financial terms of this contract have not been disclosed, but are expected to have an increasing impact as the House Builder moves to the new property designs.

James Mckenzie, CEO of PhotonStar LED Group PLC, comments, "We are delighted that they have now received the endorsement of a major UK house builder. It also serves as a credible introduction into new wholesale stockists"

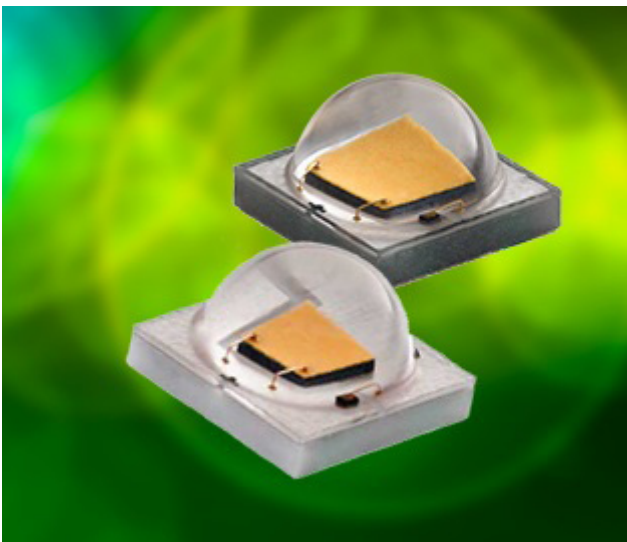
PhotonStar LED Group PLC, based in Romsey, Hampshire with manufacturing in Wales, is a designer and manufacturer of smart LED lighting solutions. The group's proprietary technology

seamlessly integrates LEDs, sensors and controls to provide intelligent lighting for commercial and architectural applications.

## Cree introduces brighter XLamp LEDs

Using silicon carbide technology, the devices double the lumens-per-dollar and delivers up to 20 percent more lumens per Watt over the original XP-E LED

Cree is introducing the new XLamp XP-E2 LED, delivering higher lumens per watt and lumens-per-dollar to lower system costs for existing XP-E and XP-G designs.



*Cree XP-E2 LEDs*

The new XP-E2 LEDs can increase the lumen output of XP-E designs for the same cost and power or lower system cost with fewer LEDs – enabling lighting manufacturers to deliver a better lighting system with minimal redesign.

“The price to performance ratio is an important consideration for our design process,” says Erik Milz, vice president of marketing, Terralux. “Since many of our products are based on Cree XP-E LEDs, the new XP-E2 LED is a significant upgrade in performance, helping to keep design costs down and speeding time-to-market for our solutions.”

The XP-E2 LEDs use the same XP footprint

(3.45mm x 3.45mm) and are optically compatible with all XP LED designs, including the popular XP-E and XP-G LEDs. The XP-E2 LEDs also enable a broad range of high-lumen applications, from indoor and outdoor lighting to portable and lamp retrofits.

Utilising the firm’s SC3 technology next generation LED platform, the XP-E2 LEDs deliver up to 128 lumens per watt at 350 mA, 85°C or 143 lumens per watt at 350mA, 25°C in cool white (6000K).

The SC3 technology platform is built with Cree’s latest SiC technology, features advancements in LED chip architecture and phosphor and showcases a new package design to deliver what the firm says is one of the most advanced lighting-class LED components in the industry.

Luminaire makers seeking ENERGY STAR qualification will have access to specification and performance data, including LM-80 reports, which can speed time-to-market. XP-E2 LEDs are a “successor” product to the original XP-E LED for LM-80 data – accelerating qualification of luminaires using just 3000 hours of LM-80 data, instead of the normal 6000 hours.

Cree XLamp XP-E2 LED samples are available now and production quantities are available with standard lead times. XP-E2 LEDs are available in 2700K to 7000K colour temperatures with minimum CRI options of 70, 80, 85 and 90.

## System which tells you when to change an LED light

The laser-guided device allows measurements to be taken from the roadside at night

In many of the nation’s traffic lights, LEDs with their brighter light and longer life have replaced standard bulbs.

But knowing when to replace the signal heads has remained a guessing game, says Suzanna Long, assistant professor of engineering management and systems engineering at Missouri University of Science and Technology. That’s because LED traffic lights don’t burn out - they just lose brightness over time.

So Long and other researchers at Missouri S&T, in partnership with the Missouri Department of Transportation, have developed an instrument to measure LED intensity. The laser-guided device allows measurements to be taken from the roadside at night, instead of requiring technicians to physically check traffic lights by using a bucket truck.

Long's team created the measurement tool while working to provide MoDOT with a data-driven replacement schedule for LEDs, which have been widely adopted for use in sustainable traffic signal management.

"The majority of agencies replace LED signals on a spot basis when they receive a complaint," she says. "The maintenance costs associated with sending a crew out to replace a single LED are very high. Our methodology provides a more cost-effective mechanism for determining replacement and allows agencies to meet goals of being good stewards of public money."

Long says in addition to addressing individual complaints about brightness, transportation officials have used a generic replacement schedule based on the manufacturers' warranties, usually six years. But since life expectancy of LEDs varies by intersection and the basic science of LED components, that's not the most cost-effective schedule.

Results of this study, named one of the 2012 "Sweet 16" High Value Research Projects by the American Association of State Highway and Transportation Officials, appears in the Engineering Management Journal's special issue on transportation management this month.

The team plans to extend the previous data and collect data from the same LED traffic indicators in the coming years to improve the reliability and accuracy of their results.

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## Optogan LEDs light up sports field in Malta

Dynamically use of the III-nitride LED DSF lighting will reduce electricity cost enormously and the expected return on investment is around 5 years

On Friday 14th September 2012 the renovated Luxol Sport field in Pembroke Malta was officially opened by Norman Darmanin Demajo, President of the Malta Football Association ( MFA ).

Also present were Pieter Bregman, official Optogan's distributor in Malta and Ove Sørensen, Director of Sales & Business Development at Optogan.

The opening took place during the evening match between 2nd division teams Gharghur and San Gwann, where everybody could enjoy the game with the new DSF (Dynamic Sport Field) LED lighting of Optogan.



"It's finally here! An outdoor field where we can provide activities for all levels in football, from 3rd Division to Premier League and all Youth games," said the President of MFA, Norman Darmanin Demajo during the inauguration ceremony. Now the sports field is equipped with an excellent Optogan DSF light, teams can play also in the evening with the advantage of great light, good uniformity of the light and quality lighting for the viewers.

With its high intensity of 280 lux, Optogan DSF offers a great performance and improvement, comparing to the old traditional lighting that provided only 96 lux. Thanks to the dynamic use of light, the light can be controlled and dynamically changed from orientation (10 percent), to training (50-70 percent) to game play (100 percent), and also only one half of the pitch can be illuminated.

With all these lighting options, the Optogan LED DSF Lighting is an energy saving system, which, in the case of LUXOL, is saving energy from 35.2KWh to 27.2KWh. And it can be even more, if used dynamically. Since the light is purely on the



pitch, neighbours don't complain about late evening matches anymore.

The system has no "light spill" and only shows the light there where it is needed. Another advantage is, that, instead of the traditional MHD ( Metal Halide ) lighting, the LED lights can be switched ON and OFF and ON again, without having to wait for them to cool down first.

Ove Sørensen, Director of Sales & Business Development at Optogan addressed the potential of the DSF system. He said, "I am proud to present our great product here in Malta. Optogan Dynamic Sport Field Lighting in fact puts the sport into the spotlight. DSF doesn't have to be only used for football fields, but is also excellent for many other purposes, like tennis, hockey, smaller play fields, as well as hotel chains having playing fields to control the spill of light and moreover, reducing the electricity bill! In other words, the DSF lighting is a very multifunctional product for lighting up areas, big or small".

Pieter Bregman also highlighted the multi functionality of DSF and said, "Although the LED DSF lighting has been installed on a football pitch, it can be used in many ways! You can think of all kind of sports facilities big and small, car parking lots, local play grounds and ... well, you name it".

Expected return on investment is around 5 years, dependable on the amount of evening matches or training sessions being played or held. "We have calculated for Luxol Sports Club, that the lighting will be used, at random, 3 hours per day and 5 days per week. Dynamically using the LED DSF Lighting will reduce electricity cost enormously. As the electricity prices are on the rise in Malta, savings made with this lighting system per year at Luxol Sports Club, will pay back the new LED DSF lighting system in approximately 5 years time," added Pieter Bregman, Project Manager of The LightShop in B'Kara, Malta.

## Can GTAT revolutionise mobile & LED market with sapphire?

Perhaps. A Chinese firm has invested \$29 million in

the firm's ASF furnaces

GT Advanced Technologies has received a \$29 million follow-on order for ASF units from an existing ASF customer in China.



*GTAT ASF furnace*

The order is scheduled for delivery by the end of 2012 and the expected revenues included in the company's 2012 range is \$925 million to \$975 million.

GTAT believes the units will be used to produce sapphire for the mobile device market.

The company has said that tolerance requirements for mobile device sapphire screens are significantly lower than epi-ready surfaces in HB LED manufacturing and should reduce cycle times and consumable costs.

The firm has also indicated that it and several of its ASF customers have entered into evaluation agreements or are, in conjunction with fabrication partners, actively sampling ASF-grown sapphire screens for use in mobile and point of sale (POS) devices.

GTAT thinks the sapphire mobile device opportunity will contribute to a significant inflow of ASF orders in

the second half of 2013.

The company also points out that several factors have driven the recent interest in ASF-grown sapphire as a viable alternative to materials currently used in mobile and POS devices.

These include sapphire's strength, ruggedness and scratch-resistance as well as its ability to improving user experience.

GTAT says its ASF platform is well positioned to meet the quality and high-volume production requirements for crystal growth for these applications.

The cost of sapphire is expected to be within an acceptable range given its compelling value proposition. GTAT expects that the cost for growing and fabricating sapphire for mobile devices will be considerably lower than for LED applications for a number of reasons.

These include the ASF crystal growth process which GTAT says can be optimised to deliver higher yields of useable material resulting in lower costs when harvested for bricks, screens or cores and wafers.

For a start, fabrication costs have the potential to come down driven by equipment that can slice boules into bricks rather than cores.

Other activities include GTAT working with consumable suppliers and cost reductions from a growing Asian supply chain.

Several fabrication steps may be eliminated when fabricating sapphire for mobile devices including CMP (chemical mechanical polishing) as well as rough and fine lapping, with the latter being replaced by faster grinding processes.

What's more, mobile screen fabrication may allow for the use of existing polishing and grinding equipment capacity at existing large volume subcontractors in Asia, removing the requirement for new fabrication equipment.

As a result, the company believes that sapphire screens for mobile devices, once commercialised, will have a cost of ownership that will be competitive with current solutions.

More specifically, GTAT estimates that a fully fabricated sapphire smartphone screen will be \$10 to \$20 higher than the price OEMs pay for current screen solutions, with the differential dependent on the level of vertical integration by the OEMs or their manufacturing partners.

Given the compelling overall value proposition of ASF sapphire screens, GTAT says that initial feedback from industry leaders suggests this cost for a superior product will be acceptable.

Factors affecting this may be a lower rate of cracked or broken screens, providing a better overall user experience.

The company also points out that the expected price differential between ASF-grown sapphire and the "current solutions" is less than what consumers typically pay to replace a single cracked screen as well as being less than the cost of screen protectors and protective cases.

GTAT also expects that there will be significant potential to reduce the cost of producing sapphire smartphone screens over time as the industry matures, increases scale, vertically integrates and continues to advance technology innovations at both the crystal growth and fabrication stages.

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## Osram Black Flat LED lights up roads

With a virtually constant light output even at high application temperatures, the III-nitride LED is suited to vehicle headlight applications

Osram Opto is marketing the Oslon Black Flat LED for automotive front lighting systems.

Equipped with state-of-the-art chip and packaging technology and a ceramic converter, this new LED product in the Oslon Black series is a high performance light source for automotive applications.



*Osron Black Flat LED*

Osram says its latest product offers high light output even at high currents, uniform distribution of light, thermal stability and particularly good contrast for seeing and being seen.

The Osron Black Flat LED had its premier as a prototype at ISAL 2011 and is available now.

Light sources for front lighting have to be multitasking. Not only do they have to illuminate the road ahead reliably in rain and fog and at night, they have to perform various functions as low beam, cornering lights and fog lights for example.

They also have to withstand high temperatures in the headlights. For these reasons more and more automobile manufacturers are opting for flexible, efficient and powerful LED technology.

With a high luminous flux even at high temperatures, the new LED contains a UX:3 chip that delivers high light output at high currents.

Osram says thermal management is much simpler with this new LED. This is thanks to the greater thermal stability of the luminous flux even under "hot" application conditions and also to a new temperature-optimised packaging process. This has meant that the typical thermal resistance has been reduced to 4 K/W.

The thermal coefficient of expansion of the black QFN package (Quad Flat No Leads) of the Osron Black Flat LED is matched to the coefficient of expansion of the metal core board.

The Osron Black Flat was developed in Regensburg and having been designed to function without a lens, its light can be injected very close to light guides or lenses. Osram says that its luminance, in other words what the human eye perceives as the brightness of a particular surface, is 2 to 5 times

higher than comparable LEDs in its class at 70 -100 Mcd/m<sup>2</sup> (million candelas per square metre).

"This is particularly important in automotive frontlighting solutions based on projection systems", points out Peter Knittl, Director Automotive LED at Osram Opto Semiconductors. "The greater the luminance of the LED, the smaller the external lens and the smaller the space needed. Headlights can therefore be made much more compact, giving designers much more freedom."

Encapsulation of the chips directly in the package produces a defined light/dark boundary in the light pattern and, in conjunction with advanced package technology and the ceramic converter, a uniform distribution of light and particularly good contrast ratio on the road.

The benefits of Osron Black Flat, above all its low thermal resistance and impressive performance under extreme conditions, have really struck a chord in the industry. Before the end of 2012 we will be seeing automobiles and motorcycles on the roads in which these small black LEDs will be performing the most important frontlighting functions", adds Knittl.

The LED measures 3.75 x 3.75 mm<sup>2</sup> and has a luminous flux of typically 200 lm at 700 mA at a T<sub>j</sub> of 25°C and 270 lm at 1.2 A at a T<sub>j</sub> of 100°C.

The luminous efficacy is 87 lm/W and the luminance is 70 - 100 Mcd/m<sup>2</sup> (millions candelas per square metre). Electrical thermal resistance is 4 K/W.

Lifetime as a function of the solder point temperature (T<sub>s</sub>) of the L70B50 is 100,000 hours at 700 mA, at a T<sub>s</sub> of 60° C and 10,000 hours at 1.2 A and a T<sub>s</sub> of 120° C.

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## Oxford sells 400th plasma tool for HBLEDs

The firm says it has a multi-tool order from China's largest HBLED manufacturer

Oxford Instruments has sold its 400th plasma system to a Chinese HBLED supplier.



“It gives me a great sense of achievement to say that we have helped to enable the HBLED revolution,” says Dan Ayres, Managing Director of Oxford Instruments Plasma Technology. “Our systems play a vital role in manufacturing HBLEDs, and we have served the industry as it has developed from its R&D roots into the global industry it is today.”



Ayres continues, “We have been able to offer systems for high performance every step of the way, developing our tools to match customer demands as the market has evolved. Our PlasmaPro range of systems offers both batch and single wafer solutions to manufacturers, using the latest technologies available, developed by our expert technology and applications teams.”

Oxford Instruments produces plasma equipment for etching of sapphire and GaN and also PECVD tools for depositing the dielectric layers essential for the finished HBLED devices.

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## **IQE recruits GEC veteran**

David Grant is excited to be joining IQE at such an interesting time in its development

IQE has appointed David Grant as a non-executive director and as senior independent director of the group.



*David Grant*

Grant, 65, gained his PhD in Engineering Science from Durham University in 1974.

Following a period with Reyrolle Parsons Automation designing power station control and instrumentation systems, Grant was appointed Technical Director of a European subsidiary of United Technologies Corporation.

In 1984, David Grant worked as Managing Director of Dowty Electronics and in 1988 he became Technical Director of the Dowty Group.

His last industrial appointment started in 1991, as Technical Director of GEC, with responsibility for engineering, research and technology development in an £11 billion turnover international company employing 25,000 engineers and spending £1.2 billion per annum on product development and technology.

He was appointed Vice-Chancellor of Cardiff University in October 2001 and retired from the post in August this year.

Grant is also a non-executive director of Renishaw plc., and holds directorships with Welsh Networking Limited and The Russell Group of Universities.

He is also actively involved in engineering professional development and has been a Council member and Vice President of the Institution of Electrical Engineers (IEE, now IET).

Grant was awarded the IEE’s Mensforth Gold Medal in 1996.

He was elected as a Fellow of the Royal Academy of Engineering in 1997, and in the same year was made a CBE for his contribution to the UK’s Foresight Programme.

David Grant was a Council member of the Engineering and Physical Sciences Research Council, EPSRC, from 2000 until 2006. In 2007 he was appointed a governing board member of the Technology Strategy Board. In 2012 he was appointed a non-executive director of Dstl, the UK’s Defence Science and Technology Laboratory.

He was a Vice-President of the Royal Academy of Engineering from 2007 to 2012. In 2011 he was appointed Chairman of the Science Engineering

Technology Mathematics Network, a UK-wide organisation that promotes Science, Engineering, Technology and Mathematics in schools.

David Grant has, in the last five years, held directorships with Rhwydweithio Cymru Cyf, The Leadership Foundation for Higher Education, Cardiff & Co Limited and Cardiff Partnership Fund Limited.

Godfrey Ainsworth, IQE's Chairman, comments, "David has performed leadership roles in a number of international businesses and I look forward to working with him and my other board colleagues in continuing to build the Group. David's appointment will bring both large company experience and a broad technology background, which can meld with an existing non-executive team that has considerable history and knowledge of IQE's business. A great combination."

Grant, says, "I am excited to be joining IQE at such an interesting time in its development. IQE is a world leader in its sector and I have been impressed with the quality of the team and their future plans. I believe that I can help them build on their existing achievements, at the same time as adding further weight to the non-executive responsibilities of the Board."

Drew Nelson, IQE's Chief Executive, concludes, "The appointment of David to the IQE Board as Senior Independent Director will strengthen the non-executive team and our ability to comply with best corporate governance practice. With his technology background and considerable industry experience, he will undoubtedly add significant value to our strategic thinking. I am delighted that we have been able to secure the services of an individual of such high calibre and reputation."

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## Aixtron presents innovations in MOCVD LED production

At a seminar in China, the firm explained how to improve LED quality, increase productivity and yield, and achieve more cost-efficient and brighter LEDs

More than 200 participants, mostly manufacturing customers, attended Aixtron's MOCVD seminar

for LED production held at the Aixtron China Ltd. Training Centre & Lab in Suzhou, China.

The seminar was co-organised by the China Solid State Lighting Alliance (CSA) and was the first of a series within the framework of Aixtron's cooperation with SINANO, the Suzhou Institute for Nanotechnology and Nanobionics.

At the seminar, a focused overview was given into the field of LED and solid-state lighting (SSL) applications, from basic principles of MOCVD to the latest break-through technologies and solutions.

Michael Heuken, Vice President Corporate Research and Development at Aixtron, comments, "It is a real pleasure to welcome so many of our prestigious customers and business partners in Suzhou today and to continue the dialogue with China's leading LED manufacturers. Our common goal remains to intensify efforts, e.g. how to improve LED quality, increase productivity and yield, and thus achieve more cost-efficient and brighter LEDs."

Along with presentations from Aixtron specialists, SINANO reported its latest results to the high-end LED industry and research professionals. Nicolas Muesgens, Director Demo & Training Centre, Aixtron China Ltd., adds. "The seminar was a further step in helping us to better meet the needs of China's rapidly expanding SSL industry. We also received positive feedbacks on Aixtron's scientifically founded training concept and particularly on the fact that our Demo & Training Centre in Suzhou can provide our customers with the experience of working on MOCVD systems under real process conditions."

Most of the speeches at the seminar were given in Chinese and were presented by Aixtron's Chinese trainers. Some of them were derived from Aixtron's training package for customers, so the seminar was a good opportunity to experience Aixtron's trainers and training methods. At the Suzhou Industrial Park in the Yangtze River Delta future Chinese MOCVD experts are regularly trained in the latest semiconductor technology and manufacturing processes by Aixtron's engineers.

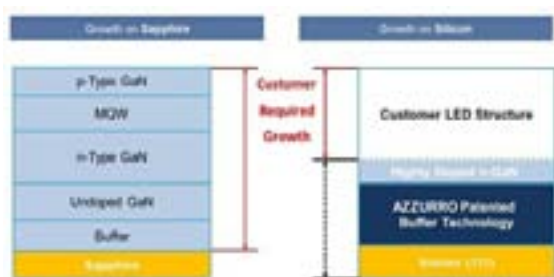
## Azzurro simplifies GaN-on-Si LED growth

The Dresden based firm is marketing 150 mm GaN-on-Silicon templates to LED manufacturers

Azzurro has released a white paper describing the easy migration of LED manufacturing to GaN-on-Silicon.

The company says its 150 mm GaN-on-Silicon templates will lead to very short design-in times.

The schematic below shows a comparison between a sapphire based LED structure and the silicon based template as shown in the firm's white paper.



[Image Courtesy of Azzurro]

The white paper outlines how to overcome the technical hurdles associated with migrating to GaN-on-Silicon. It also covers key achievements possible when using the right technology, details the advantages for the move to GaN-on-Silicon obtainable with templates and shows development solutions to the LED epitaxy engineer.

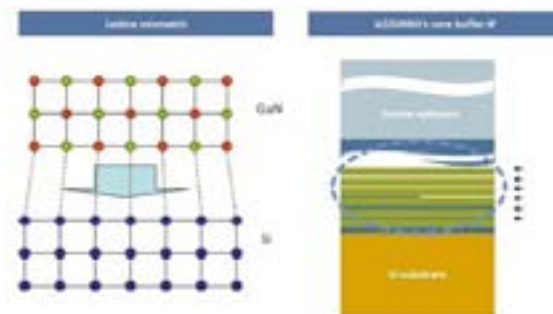
The detailed data of GaN-on-Silicon products is also revealed regarding high crystalline quality. The described EPD of the described devices is  $2 \times 10^8 \text{ cm}^{-2}$ , with a wavelength of less than 4 nm and bow values of less than  $20 \mu\text{m}$ .

Enabled by Azzurro's thick GaN-buffer as well as its patented and proprietary strain-engineering technology, these achievements permit the full utilisation of the advantages of GaN-on-Silicon. These include reduced binning due to superior homogeneities among other things.

What's more the large wafer diameter and low bow values allow the use of standard silicon processing lines which are offering cost breakthroughs for

wafer processing and back-end manufacturing.

The diagram below shows the typical lattice mismatch and Azzurro buffer technology which compensates for the induced stress.



[Image Courtesy of Azzurro]

Commenting on the huge cost saving opportunities, Markus Sickmoeller, VP Operations at Azzurro Semiconductors says, "Our plug-and-play approach, supported by our application note and engineering support assures a smooth migration from the legacy materials towards GaN-on-Silicon with easy to process, larger wafer sizes in standard silicon processing lines at much lower costs."

As part of easing the move to GaN-on-Silicon, Azzurro is delivering standard migration packages to customers which include dedicated engineering support from its team of experts.

There are a number of players in the GaN-on-Silicon market.

Toshiba together with Bridgelux's technology is launching a 200mm (or ~ 8") pilot line in north Japan in October. UK based Plessey is another new contender, and is developing a 150mm GaN-on-Silicon process with the help of Cambridge University spin-off CamGaN. With its massive Aixtron CRIUS II-XL reactor which is capable of growing  $7 \times 150\text{mm}$  (or ~ 6") wafers, which has only recently been installed, Plessey is aiming at volume manufacturing in the next few months.

EpiGaN, based in Belgium and set up by former imec researchers, is another spin-off working on 8 inch GaN-on-Silicon. Imec itself is involved in growing 8" GaN-on-Silicon for both power devices and LEDs with investments from major industrial partners such as Samsung.

Also in the last week, Veeco announced that



Nantong Tongfang Semiconductor has received one of its TurboDisc K465i MOCVD systems for research of GaN-on-silicon high brightness LEDs. The system was delivered to Tongfang's new LED Technology Centre in Nantong, China and is capable of growing up to 8 inch wafers. These are just a handful of companies who are investing in the GaN-on-Silicon market.

Azzurro's white paper's aim is to support the LED industry's move to GaN-on-Silicon.

The publication is available for download on Azzurro's website via the link: [http://www.azzurro-semiconductors.com/images/pdf/120910\\_White%20Paper%20Templates%20V09\\_RELEASED.pdf](http://www.azzurro-semiconductors.com/images/pdf/120910_White%20Paper%20Templates%20V09_RELEASED.pdf)

## Seoul Semi AC LED module reaches new heights

The firm's latest Acrich2 module saves energy by up to 50 percent and improves compatibility with Triac dimmers

Seoul Semiconductor has announced that its latest Acrich2, AC LED module, which performs at 100 lm/watt is now available for volume production.

Acrich2 provides lighting designers with a high efficacy light source which also has a high power factor, and improved Total Harmonic Distortion (THD) performance.



*220V Acrich2 16W module 120V Acrich2 16W module*

In traditional solid state lighting solutions, additional components and costs are required to provide an offline driver solution with acceptable dimming performance. Seoul Semi says its Acrich2 solution can save about \$2 over these traditional solutions.

The new AC module also provides a DC dimming interface that allows the designer to easily integrate

new dimming functions such as touch sensor and WIFI control dimming.

The Power Factor improvement which is up to 0.99, will also save costs in electricity. Conventional LED lighting products have lower Power Factors starting at 0.5 but mostly in the 0.7 to 0.8 range.

Seoul Semi says this Acrich2 AC LED module will help the performance of the power grid.

Seoul Semi's Acrich operates effectively due to its 'Integrated Multi-cell' technology, which has been developed by the firm for over 10 years. As a result of this research, Acrich operates on both alternating current and direct current. What's more, it tolerates a wide range of voltages.

4W to 16W Acrich2 AC module are available now and the firm's production line is ready to manufacture large quantity orders. Customised Acrich2 solutions are also available.

According to the LED market reports issued by Strategies Unlimited in the U.S., Seoul Semiconductor is the world's fifth largest LED supplier, holding more than 10,000 patents.

## PhotonStar LED nets a new finance director

The former CFO of SPI Lasers, a manufacturer of fibre lasers, David Holloway assisted in developing the business, including raising additional capital to support growth and also, ultimately, facilitating the sale of the company to the German engineering multinational Trumpf GmbH

PhotonStar LED Group, a British designer and manufacturer of smart LED lighting solutions, has appointed David Holloway as Group Finance Director. The appointment came into effect on 3rd September 2012.

Holloway is a chartered accountant with over 30 years commercial experience of senior finance roles, covering public companies and technology & engineering businesses, including SPI Lasers plc, IMI plc and Williams Holdings plc.

James McKenzie, Group Chief Executive, comments, "I am delighted that David is joining us. He has considerable commercial experience and expertise in a wide range of relevant operational areas including manufacturing, IT, HR, company secretariat and legal in addition to finance. We continue to grow rapidly, and thus David will help us achieve that growth in a controlled manner. We welcome him on board."

Disclosures required pursuant to paragraph (g) of Schedule 2 of the AIM Rules:

David John Holloway, 62, currently holds, and has during the last five years immediately preceding the date of this announcement held, the following directorships or partnerships:

Holloway was a director of Datrontech Group plc from 1999 until it was placed into receivership in 2001. There are no further matters to be disclosed pursuant to paragraph (g) of Schedule 2 of the AIM Rules.

PhotonStar LED Group's proprietary technology seamlessly integrates LEDs, sensors and controls to provide intelligent lighting for commercial and architectural applications which benefit from greater CO2 reduction, lower cost of ownership & improved functionality compared to other available light sources. PhotonStar says its lighting products have 90 percent less embodied CO2 than equivalent products providing the same levels of illumination.

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## BluGlass proposes to buy out SPTS EpiBlu shares

Australia's BluGlass intends to use 5 percent of its enlarged share capital to buy out the U.K.'s SPTS shares in EpiBlu. This is a joint venture between the two companies and is focused on LED growth using RPCVD

BluGlass has made a proposal (the "Capital Restructure") regarding reorganisation of capital within the company.

BluGlass is an innovator in Remote Plasma Chemical Vapour Deposition (RPCVD) which it uses in the growth of LEDs and solar cells. The company is based in Sydney, Australia.

The first proposal involves the sale of all of the

shares in its LED joint venture, EpiBlu, held by SPTS Technologies UK Limited (SPTS), to BluGlass.

The second is the issue of 15,973,678 fully paid ordinary shares in the capital of BluGlass to SPTS, which equates to 5 percent of BluGlass' enlarged share capital.

Shareholders have been asked to vote as to whether they accept the Capital Restructure.

BluGlass stresses that an independent expert has concluded that the capital restructure is fair and reasonable to shareholders not associated with SPTS.

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## U.S. gives BluGlass RPCVD LED patent the green light

The Sydney based innovator of LED and solar cell growth using Remote Plasma Chemical Vapour Deposition can now grow in the U.S., Europe, Japan, Korea and China

Australian clean-tech innovator BluGlass has announced that its patent US2008272463, "Method and apparatus for growing a group (III) metal nitride film" has now been allowed in the U.S.

This patent, once granted in the coming weeks, brings the company's international patent portfolio up to 16 granted patents in key semiconductor markets including the U.S., Europe, Japan, Korea and China.

These patents help to provide the company with broad protection of its Remote Plasma Chemical Vapour Deposition (RPCVD) technology and underpin the commercial opportunities for BluGlass in the production of high efficiency semiconductor devices such as LEDs and solar cells.

BluGlass says its RPCVD technology has many advantages over conventional manufacturing technologies such as MOCVD. It is a lower temperature process which leads to potential performance and cost advantages in the production of LEDs and solar cells.

*RPCVD vs MOCVD*



*Potential RPCVD Advantages*

- Low temperature
- Increased device performance
- Cost Competitive
- Versatile
- Scalable
- More environmentally sustainable and sensitive

Following further technical advancements made by the company, BluGlass has recently lodged two additional patents through its joint venture EpiBlu.

BluGlass CEO, Giles Bourne says, "We are pleased that we had another core patent accepted in the U.S. which will further help us to protect BluGlass technology assets, enabling the company to continue to move towards commercialising the RPCVD technology."

Building upon and continuing to expand a broad based international patent portfolio is fundamental to the commercialisation of the BluGlass technology. In addition to the 16 granted patents, BluGlass now has 17 provisional patents in four patent families filed in key semiconductor manufacturing countries.

Apart from its JV, EpiBlu, the company also has

a subsidiary, BluSolar, which is now exploring the process viability of RCPVD in photovoltaic (solar) applications.

## Lextar LEDs gain LM-79 and LM-80 accreditation

makes the Taiwanese firm one of the few in the world to become accredited with LM-80 packaging testing approval and LM-79 lighting product testing simultaneously

Lextar Electronics Corp. has announced that its "Photometric Laboratory" has been given LM-79 and LM-80 accreditation.

This makes Lextar the first of any LED corporation in Taiwan to be awarded both accreditations. What's more, Lextar's 3014 and 5630 LED package have exceeded 6,000 hours of LM-80 testing.

LM-80 is the Lumen Maintenance assurance for LED packaging. LED lumens (brightness) decay over time, producing phenomena such as light fades or colorcast. The LM-80 test approach uses LED packaging at multiple temperatures for 6,000 hours to determine the quality and life of a particular LED.

Major international plants at present all use LM-80 as indicators for the quality and life of their LED packages, making it a common testing standard across the globe. This certification helps downstream lamp manufacturers determine the quality of the pros and cons of LED lighting, and can significantly shorten the verification time needed for customers' lamp products.

LM-79, on the other hand, is the industry standard procedure for photometric and electrical measurements for LED lighting products. LED lamp manufacturers can test and report through LM-79 to provide an optical measurement value of credibility, which enhances the trust between customers and their products and vendors.

Lextar claims to be the only vertically integrated LED company in Taiwan; its Photometric Laboratory has also become the only one throughout the island and is also one of the few in the world to become accredited with LM-80 packaging testing approval



and LM-79 lighting product testing at the same time.

In the future, Lextar will be able to use its own laboratory for product testing, which will simplify testing procedures, decrease time and lower costs, as well as speed up the company's ability to capture LED lighting business opportunities across the world.

In addition, Lextar's 3014 and 5630 LED packages have completed 6,000 hours of LM-80 testing over a course of nearly 9 months and are able to remain a high standard luminous output when subjected to temperatures at 550C and 850C, showing that the products have enhanced their lifespan reliability.

Lextar says its 3014 and 5630 packages have many advantages such as high degree of stability and quality, and can be used in bulbs, tubes, down lights, panel lights, advertising light boxes as well as in many other applications, making them the most popular of LED products within the company.

Lextar's CoB product series is also the process of LM-80 testing, which is expected to be accredited as of next year.

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## DAS system eliminates waste gases in LED industry

DAS Environmental Expert GmbH has developed a new product solution for environmentally friendly cleaning of process gases such as ammonia and hydrogen, which are used during LED manufacturing

DAS Environmental Expert GmbH has developed the "LARCH" system for the environmentally friendly disposal of reactive waste gases released during the production of LED wafers.



*LARCH gas disposal unit*

As the statutory provisions on waste water and waste gas disposal will be tightened in Taiwan from 2013 onwards, Taiwanese companies will soon have to start looking around for new solutions.

Taking into account that our world is becoming more ecologically aware, engineers at DAS have recognised that it is necessary to eradicate waste process gases in an eco-friendly manner.

"With LARCH we are specifically reacting to requirements from LED makers. The LED industry is known to be a growth market and in our discussions with customers we have become aware of the demands made on modern disposal technologies," says Guy Davies, Director Business Unit Gas Treatment.

"We have given a great deal of thought to this and the LARCH system is the result. It has already generated a lot of interest: enquiries from some potential customers have already come in," adds Davies.

Industry analysts predict sustained growth in demand in the LED market. After LED backlighting for the small LC displays of mobile phones and the LC displays of larger screens in the television market, the next potential growth market is the lighting industry. Sales of LEDs in this market in 2012 are almost \$3.5 billion, nearly doubling since 2010. Yole Développement is expecting a growth of more than \$7 billion in 2014 and believes that the total market for LEDs should peak at \$17.7 billion.

A mass market on this scale for LEDs also means increasing emissions. In the manufacture of products based on innovative LED technology, ammonia and hydrogen are used in large quantities as process gases.

In the new LARCH system, the initial thermal dissociation of ammonia is achieved by reaction heat. Hydrogen is then ignited and burnt off by electrical heating elements. The reaction heat is transferred to a downstream heat exchanger. This is an elegant solution for the disposal of the large quantities of process gases generated in LED production.

The gases cleaned by LARCH can be safely released into the atmosphere. Sensors and numerous redundant safety systems guarantee

stable and safe operation.

Although the process is based on a simple principle, it can still economically achieve low emission values. It is therefore able to replace the previously used wet scrubbing solutions, which create large quantities of ammonia solution. It is also much more environmentally friendly.

“We developed LARCH especially for typical applications in the LED industry and adapted it to the industry’s requirements. But we could also imagine the system finding application in other processes in which ammonia and hydrogen are generated. Therefore we are looking to continuously develop the technology,” concludes Davies.

Established in 1991, DAS Environmental Expert GmbH, headquartered in Dresden, Germany, is an environmental technology company. DAS is a technology and equipment supplier for process gas disposal solutions. The firm’s technology is employed in the semiconductor, TFT-LCD and electronics industry as well as the solar power isector. DAS also develops process and system solutions for treating industrial and communal waste water.

## SemiLEDs restructures senior management

Along with changes in senior positions within the company, the firm has appointed former Everlight executive, Ilkan Cokgor as Executive Vice President of Sales and Marketing

LED chip and component manufacturer, SemiLEDs Corporation has announced changes to its senior management team.

After serving as President, Chief Operating Officer and director of SemiLEDs, Anh Chuong Tran has moved to the role of Chief Scientist. In this position, Tran will dedicate his time to SemiLEDs’ technology and product development efforts.

The Board of Directors of SemiLEDs has appointed Trung T. Doan, currently the Chairman of the Board and Chief Executive Officer, to the additional role of President.

“Technology has always been SemiLEDs’ foundation. This transition will allow Chuong to dedicate his time and focus on technology and product development,” says Doan.

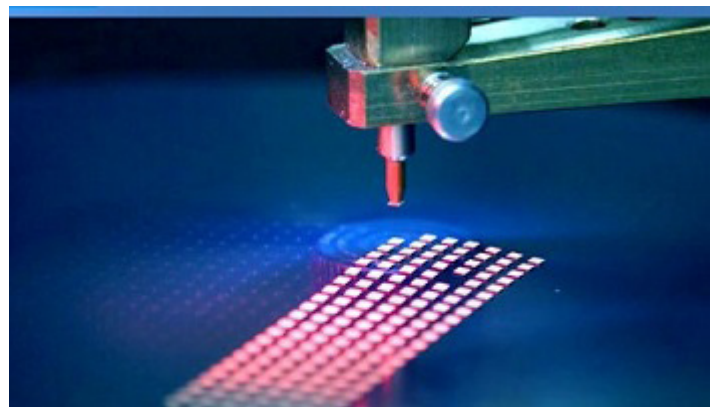
SemiLEDs has also named Ilkan Cokgor as Executive Vice President of Sales and Marketing. Cokgor brings to this position over 20 years of product development, marketing, sales, and business development experience. Cokgor is joining SemiLEDs from Everlight Electronics where he served as Vice President of Global Marketing since 2010.

“Ilkan has an impressive track-record in establishing marketing and sales channels and strong expertise in the LED industry. We are pleased to have Ilkan join our team,” adds Doan.

## SemiLEDs completes LM80 test with IST

The Taiwanese headquartered firm claims to have become one of the first to pass a third party LM-80 test in Taiwan, performed by IST, required by Energy Star

SemiLEDs, in cooperation of Integrated System Technology (IST), has announced that its S35 product line has successfully completed the requirements of the stringent 6000 hour lumen maintenance test (LM-80). The results showed an extrapolated lifetime of up to 50,000 hours.



“LED components are sensitive to heat and most failures in lighting fixtures involves thermal mistreatment. Therefore, verifying the degradation at various temperatures is very critical,” says Kevin

Tsui, VP of Reliability Engineering Department of IST.

Tsui further explains that LM-80 is required by US Energy Star and involves the collection of data based on 3 different case temperatures for over at least 6000 hours. The lumen maintenance requirement is also needed. This test will provide standardised quality assurance and quality certification for lighting fixture manufacturers and LED manufacturers respectively.

SemiLEDs CEO, Trung Doan adds that S35 and P2, warm and cool white (5700K and 3000K respectively) were our the series to go through the 6000 hour tests at both 350 and 700mA.

The test result from IST showed that the lumen maintenance is 98.75% and 97.81% for 55□ and 85□, respectively, for 3000K emitter at 700mA driving current, far above the requirements of LM-80 for domestic indoor application at 91.8% and domestic outdoor and commercial usage at 94.1%.

SemiLEDs further explains that providing high quality components to lighting fixture manufacturers is important in enabling quicker penetration of LED into the lighting market.

The S35 is SemiLEDs first series of emitters with a 35x35mm footprint utilising a silicon housing material. SemiLEDs had launched the C35 – the second generation of its 35 x 35mm emitters in June 2012. The C35 incorporates SemiLEDs EV LED chip and a ceramic base.

The thermal resistance complements SemiLEDs vertical chip on metal alloy substrate technology. Besides thermal management, SemiLEDs also implemented the latest innovation in phosphor technology, Color Precision binning, to it the C35 product family allowing customers to be in control of their CCT distribution. With the new technology, consistent colour can be produced within a single 7-step, 4step or 2-step MacAdam Ellipse centred in ANSI defined standard colour spaces.

“Working with IST for the LM-80 tests was a good choice. Being a certified test lab, IST showed its professionalism and provided all the necessary assistance for us to verify our performance. We look forward to further cooperation for new products in the pipeline,” comments Doan.

IST’s COO Jandel Lin mentions, the company’s LM-80 lab started at the end of 2011 and had already been commissioned by over 20 manufacturers to conduct the test. Lin adds that SemiLEDs’ S35 is the first case to successfully pass the test at the IST lab and the results should significantly increase SemiLEDs’ marketing competitiveness in terms of quality.

IST’s CFO and spokesperson Selina Lin also adds that at the beginning of August, IST signed a MOU with Intertek HK as the reporting body.

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## Meaglow InGaN layer breaks barriers

The Canadian firm says its indium gallium nitride technology can lower the cost of producing green LEDs and laser diodes

Meaglow has developed a low temperature Migration Enhanced Afterglow film growth technique to produce a thick InGaN layer with strong yellow emission.

This recent result bodes well to increase the efficiency and lower production costs of green LEDs and laser diodes.

The company is currently seeking collaboration opportunities to enhance the material properties required by industry for lighting, display, medical, and military applications and other uses.

Meaglow’s Chief Scientist K. Scott Butcher, says, “It’s the brightest *p-n* junction I’ve ever seen in my life, and its right in the green gap.”

The green gap (540-610nm) is a major obstacle in the development of high-efficiency solid state lighting applications. It’s well known that LEDs produced in the green region, between red and blue, have rapidly declining efficiency.

Green and yellow in the middle of the colour spectrum, known as the “green gap”, is a section of the light spectrum where devices made from either nitride or phosphide are inefficient and difficult to fabricate.



Meaglow says its reactor overcomes these difficulties by utilising its patent pending hollow cathode and low temperature growth process which is capable of growing the volatile compound of indium required to make green and yellow diodes.

Having a nitride device that emits strongly in the yellow is a monumental step forward for low temperature InGaN growth.

Meaglow also says the quality of InGaN produced by its technique is pioneering the industry. Results for this test device were presented to scientists in the nitride semiconductor research community at the recent ISSLED2012 conference held in Berlin, Germany.

The firm is now focused on commercialising its InGaN technology, and is looking for partners interested in creating next generation devices using the thick InGaN template layers.

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## Cree's 150mm n-type SiC wafers on the market

LED innovator Cree has expanded its product family and is now offering epitaxially grown silicon carbide wafers of 150mm (almost 6 inches) diameter

Cree has announced the availability of high quality, low micropipe 150mm 4H *n*-type SiC epitaxial wafers.

The firm says this latest advancement lowers device cost and enables adoption for customers with existing 150mm diameter device processing lines.



*SiC wafer*

SiC is a high-performance semiconductor material

used in the production of a broad range of lighting, power and communication components, including LEDs, power switching devices and RF power transistors for wireless communications. 150mm diameter single crystal SiC substrates enable cost reductions and increased throughput, while bolstering the continued growth of the SiC industry.

“Cree’s ability to deliver high volumes of 100mm epitaxial wafers is unrivalled in the SiC industry and our latest 150mm technology continues to raise the standards for SiC wafers,” says Vijay Balakrishna, Cree materials product manager. “Our vertically integrated approach assures customers of a complete solution for high quality 150mm SiC epitaxial wafers, providing industry leaders within the power electronics market the stable supply they demand.”

Cree’s 150mm epitaxial wafers with highly uniform epitaxial layers as thick as 100µm are available for immediate purchase.

Cree’s 150mm 4H *n*-type SiC epitaxial wafers are available for immediate purchase in limited quantities.

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## Students get free places at CS International.

CS International and European Photonics Industry Consortium (EPIC) have joined forces at the Compound Semiconductor industry’s premier international event, CS International, which will held in Frankfurt, Germany on 4th & 5th March 2013.

As part of CS International’s commitment to support and encourage students and ensure the next generation of professionals develop technologies that will benefit the compound semiconductor industry at large, ten students will be selected by EPIC to attend the conference at no cost.

This must attend event for 2013, the third in the series will be held in Frankfurt, Germany.

Professionals from around the world attending this two-day event will hear key insights and opportunities, from a range of leading analysts, and learn of the latest chip developments in LEDs, solar cells, lasers and power and RF electronics.

Delegates will also get the opportunity to network with leading industry professionals of the III-V chip making industry and interact with suppliers. Industry leaders from Intel, Cree, Epistar, RFMD, TriQuint and over 25 other leading chipmakers will be present sharing their perspective on the latest developments in device technology.

EPIC will also be hosting their AGM in conjunction with CS International on the evening of the 5th March 2013.

Registration is now open for 2013 event. Delegates who book before October 31st 2012 can take advantage of our early bird rate, saving of €57. Further information on the conference is available at: [www.cs-international.net](http://www.cs-international.net)



EPIC is the leading European Photonics Industry Consortium, a membership-led not-for-profit industry association that promotes the sustainable development of organisations working in the field of photonics. Our members encompass the entire value chain from LED lighting, PV solar energy, Silicon photonics, Optical components, Lasers, Sensors, Displays, Projectors, Optic fiber, and other photonic related technologies. We foster a vibrant photonics ecosystem by maintaining a strong network and acting as a catalyst and facilitator for technological and commercial advancement. EPIC works closely with related industries, universities, and public authorities to build a more competitive photonics industrial sector, capable of both economic and technological growth in a highly competitive world-wide marketplace. [www.epic-assoc.com](http://www.epic-assoc.com)

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## Cree`s new LED luminaires have the EDGE

The firm`s latest Innovation integrates precise optical control and exceptional colour quality for use in vehicle dealerships

Cree has unveiled THE EDGE High Output (H.O.) Area and Flood Light LED luminaires.

Capable of replacing high output sources of the past such as 1000 W metal halide and using 50 percent less energy in most applications, the new luminaire features more than 20 optical configurations.

Among them is a new FrontlineOptic technology designed specifically for auto dealerships. THE EDGE H.O. luminaire delivers brilliant and focused light to applications seeking a high output solution.

“Buying a car is a visual experience and quality lighting has an immediate positive impact on the retail shopping experience,” says Mike Lallier, president and owner, Reed Lallier Chevrolet. “Cree designed THE EDGE High Output luminaire to meet the specific needs of auto dealerships. The revolutionary solution provides superior colour quality that allows us to effectively extend our selling window after dark. The advanced optical control of THE EDGE H.O. luminaire delivers light precisely where it’s needed to always showcase our inventory in the best possible light.”

Featuring patented NanoOptic technology, THE EDGE H.O. luminaire precisely distributes light meaning customers only pay for the light required.

What’s more, exceptional thermal management enhances reliability and contributes to a system that can provide more than a decade of near maintenance-free service – eliminating expensive relamping cycles.

THE EDGE H.O. luminaire can significantly reduce energy and maintenance costs while improving illumination performance as well. The new luminaire offers better colour stability and reliability, as well as a higher CRI and a much broader spectrum colour source compared to high-wattage metal halide alternatives. THE EDGE H.O. luminaire provides unprecedented colour quality, enhanced curb appeal and increased visibility for any retail or commercial site.

“THE EDGE H.O. offered significant energy and maintenance savings compared to 1000 W metal halide without compromise,” says Allen Trench, operations manager, Irvine Home Centre, Irvine Company Retail Properties. “Improved illumination

performance, better colour quality and greater reliability allow us to provide a much more consistent and enhanced shopping experience for our customers.”

“In addition to dramatically enhancing the curb appeal for the dealership’s auto inventory, we elected to install Cree LED luminaires for the significant savings on energy costs and maintenance,” adds Mike Ward, president and owner, Mike Ward Infiniti.

“Gone are the high costs and disruptions associated with relamping our old metal halide fixtures. The Cree solution is highly reliable which means we shouldn’t need to touch them again for more than a decade. And the improved colour quality compared to metal halide really makes a difference. Now our cars always look great, day or night.”

## Telecoms

### Skyworks upgrades revenues to \$420 million for Q4 2012

The RF innovator of high performance analogue semiconductors has also updated its Non-GAAP Diluted EPS to \$0.52

Skyworks Solutions has updated its financial outlook for the fourth quarter of fiscal 2012 given strong program ramps across its analogue and mobile Internet businesses and continued operating leverage within its business model.

The Company now anticipates revenue of \$420 million for the fourth quarter of fiscal 2012, on the high end of its previous guidance range of \$415 to \$420 million, which would represent an 8 percent sequential increase.

Skyworks also expects to deliver non-GAAP diluted earnings per share of \$0.52 versus guidance of \$0.50 to \$0.51, which would represent a 16 percent sequential increase for the fourth quarter of fiscal 2012.

The company’s previous guidance was provided on July 18th, 2012 during its third quarter fiscal 2012

conference call.

### GaAs device revenue reaches new heights

Although 2011 revenues hit a record \$5.2 billion, growth is expected to slow down in the future

According to Strategy Analytics, a fast start to 2011 allowed the GaAs device market to withstand a slowdown toward the end of the year and post record revenue for 2011.

Continuing growth in demand for handset power amplifiers offset ongoing uncertainty in the global economy to propel the market to growth from last year’s value. The market research firm’s most recent report, “GaAs Industry Forecast: 2011-2016”, reports the overall GaAs device market grew by roughly 6 percent to close 2011 with slightly more than \$5.2 billion of revenue.

The report also forecasts that slowing smartphone growth and an uncertain global economy will limit future growth rates below historical averages and the market will reach slightly more than \$6.1 billion in 2016.

“The GaAs market began the year with strong growth”, notes Eric Higham, Director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs). “Toward the end of the year, slowing growth in the smartphone segment and uncertainty in the global economy became the overriding trends and the overall GaAs device market slowed substantially. The underlying trends in the GaAs market still support growth, but uncertainty in the economy is likely to limit this growth.”

Asif Anwar, Director in the Strategy Analytics Strategic Technologies Practice adds, “We remain convinced that data consumption and GaAs content in handsets will increase, but fluctuations in the global economy will put a damper on network and consumer spending.”

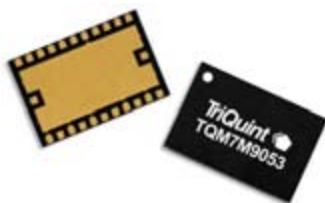


## TriQuint unveils GaAs multi-band PA for mobiles

The device employs the firm's gallium arsenide HBT technology and has a CuFlip assembly

TriQuint is marketing the TRIUMF TQM7M9053, a fully matched Multi-mode Multi-band Power Amplifier (MMPA) module.

It offers quad-band GSM/EDGE and WCDMA/LTE bands 1, 2, 5 and 8 for the 3G/4G market in North America, Europe and Asia.



*TriQuint TQM7M9053*

The firm says the versatile 5 x 7.5mm module simplifies RF design for increasingly complex next-generation global 3G and 4G smartphones and other mobile devices. It achieves high power-added efficiency, providing more browsing time for users. The compact, highly integrated module consumes less PCB space than discrete components, and the simplified routing enhances system performance and reduces manufacturing time.

The 2-Gain state WCDMA PA operates in high and medium power modes to maximise talk time over the entire range of operating conditions. It also includes a coupler and built-in regulator, ideal for today's extremely small data-enabled phones.

The TQM7M9053 is designed on TriQuint's GaAs HBT technology with CuFlip assembly - offering reliability, temperature stability and ruggedness. Its RF performance meets the stringent linearity requirements needed for demanding multi-mode operation.

## Infinera to upgrade Telefonica submarine cable network

The firm's indium phosphide based DTN-X platform expansion covers more than 20,000 KMs fibre optic network across Telefonica's international network. It will be upgraded to 100G SAM-1

Infinera's DTN-X platform has been selected by Telefonica International Wholesale Services (TIWS), to make an international upgrade to TIWS' SAM-1 submarine network.

The cable network will connect North and South America with the Infinera DTN-X platform.

The Infinera DTN-X platform is capable of delivering 500 gigabit per second (Gb/s) long haul super-channels, enabling Telefonica to address growing bandwidth demands from millions of internet users, mobile subscribers and business customers in South America.

TIWS designs and manages the international communications infrastructure of the Telefonica Group, offering an integrated voice, video and data network, with more than 100 points of presence distributed across 60 cities and 40 countries.

TIWS' network consists of more than 20,000 km of diverse SAM-1 underwater cable that guarantees its customers optimal sturdiness and reliability. SAM-1 uses Infinera's family of products to carry traffic for over 200 million customers connecting South America with the USA, including landing stations in Brazil, Argentina, Chile, Peru, Ecuador, Guatemala, Colombia, Puerto Rico and Florida.

Infinera's DTN-X enables Telefonica to deploy 500 Gb/s long-haul FlexCoherent super-channels integrated with 5 Terabits per second (Tb/s) of Optical Transport Network (OTN) switching per bay.

The firm's FlexCoherent technology enables Telefonica to optimise transmission performance using multiple software-programmable modulation formats. By deploying FlexCoherent super-channels, Telefonica can scale network capacity without scaling operations. Integrated OTN switching, coupled with an industry leading GMPLS

control plane, delivers a network with the highest wavelength flexibility and a low cost of ownership.

“Building our network with Infinera’s solutions has enabled us to seamlessly upgrade to higher data-rates and provision services quickly and easily,” says Jose Ramon Vela, CEO of Telefonica Global Solutions.

“Our positive experience with Infinera’s solutions assures us that our investment in the DTN-X will enable us to scale into the future and continue to turn up services more quickly for our customers. Infinera’s 500 Gb/s long-haul super-channels allow us to continue delivering quality and reliability of service throughout our entire network, and allows us to extend the productive life of our submarine cable,” adds Vela.

“The Infinera DTN-X platform gives Telefonica the flexibility to efficiently accommodate their network demands, allowing them to deploy 500G long-haul super-channels,” notes Tom Fallon, Infinera CEO. “The DTN-X offers integrated DWDM transport and OTN switching without compromise coupled with industry leading 500G photonic integrated circuits, together enabling Telefonica to deploy services quickly to improve their competitive position in the marketplace.”

Telefonica International Wholesale Services has been upgrading its submarine network throughout South America using the Infinera DTN platform, based on 100 Gb/s PICs and 40Gb/s coherent modulation, since 2009.

## Milmega launches GaAs telecom amplifiers

The firm’s new gallium arsenide amplifiers are suited for the wireless communications industry

Milmega, now a part of Teseq, is offering a new amplifier product range designed to meet test requirements within wireless testing frequency bands.

The AS0728 family of amplifiers has a frequency range of 700 MHz to 2.8 GHz. Available in 25 W, 50 W, 100 W and 170 W P1 dB power levels, these new amplifiers are ideal in the wireless

communications industry where high reliability, excellent linearity, power density and leading performance are required.



*Milmega amplifier*

The AS0728 broadband amplifiers feature an innovative design that utilises the latest GaAs Field Effect Transistor (GaAs FET), providing unique characteristics and benefits that differentiate them from other solid state amplifiers. This new product range includes an array of input/output and sample port options as well as cost-effective power and bandwidth upgrades.

The new amplifiers feature a rear mounted 15-pin, D-type connector that enables remote operation via TTL commands, while providing access to an output signal sample. The AS0728 has an operating temperature range of 00C to 400C and a storage temperature range of -400C to 700C.

A built-in protection system that guards against overheating is featured in all units. Should the internal temperature exceed 700C, amplifier blocks automatically switch off to avoid damage to the unit.

The amplifiers are a standard 3U high, and can be combined in rack mounted form to build higher power amplifiers. These units also offer a bench case option.

As with all of Teseq’s Milmega amplifiers, the AS0728 product range is covered by a five-year parts and labour warranty and is backed by the company’s global support network.

## Ammonia speeds MBE growth of GaN-on-silicon HEMTs

Gallium nitride transistors with good structural and electrical characteristics have been produced by ammonia MBE on a 100 mm silicon substrate

Researchers from Nanyang Technological University, Singapore, claim that they have produced the first crack-free, GaN-based HEMTs on 100 mm silicon substrates by ammonia MBE.

The substrate that they have used, silicon, is an excellent choice for producing GaN HEMTs, because it is cheap, available in large diameter formats and can produce transistors that can be processed through depreciated silicon lines.

By far the most common method for depositing the epilayers of the HEMT on silicon is MOCVD. However, according to the researchers from Singapore, this has several weaknesses compared with MBE.

In their opinion, MBE is a more flexible growth technique that delivers sharper interfaces and enables growth at lower temperatures, which aids the management of thermal mismatch between substrate and epilayers. What's more, they claim that MBE allows in-situ monitoring of the growth surface, leading to real time growth process control at the monolayer scale.

The Singapore team favours ammonia MBE over its plasma-assisted (PA) variant, because it is difficult to control the III-V ratio with the latter technique. In addition, due to the low nitrogen molecular cracking efficiency – typically 1 percent to 10 percent – growth rates are typically below 0.4  $\mu\text{m/hr}$  for PA MBE.

Using ammonia MBE, the team from Singapore have produced crack-free epilayers at growth rates of up to 0.75  $\mu\text{m/hr}$ , nearly double that typically used in PA MBE. Faster growth doesn't just save time – it also improves morphology, by accelerating the transition from three-dimensional to two-dimensional growth and suppressing defect formation.

This trimming of the defect density is revealed in cross-sectional images of the lower part of the epitaxial stack: The 50 nm-thick AlN nucleation layer, 200 nm-thick GaN and AlN stress mitigation layers, and the GaN buffer. The nucleation layer and lower GaN layer are riddled with defects, but many dislocations terminate at the interface between the second AlN layer and the GaN buffer, and a substantial proportion of those that propagate into this second buffer bend and interact within the

first few hundred nanometres.

Estimations based on X-ray diffraction analysis suggest that the density of screw-type dislocations in the GaN buffer falls from  $7.7 \times 10^9 \text{ cm}^{-2}$  to  $2.1 \times 10^9 \text{ cm}^{-2}$  when the buffer thickness is increased from 0.9  $\mu\text{m}$  to 1.7  $\mu\text{m}$ . Resistance mapping of the HEMT epiwafers, which have a 28 nm-thick Al<sub>0.25</sub>Ga<sub>0.75</sub>N barrier and a 2 nm-thick GaN cap deposited on the GaN buffer, show an average sheet resistance of 368  $\Omega$  /square.

Meanwhile, room-temperature Hall measurements reveal that the carrier density and mobility of the two-dimensional electron gas are  $1.2 \times 10^{13} \text{ cm}^{-2}$  and 1350  $\text{cm}^2/\text{Vs}$ . Cool the sample to 90K, and mobility rises to 4290  $\text{cm}^2/\text{Vs}$ .

To determine the electrical characteristics of the buffer layer, engineers formed test structures with two ohmic contacts with a gap of 5  $\mu\text{m}$ . A structure with a 1.7  $\mu\text{m}$ -thick buffer produced a buffer leakage current of  $2.6 \times 10^{-4} \text{ mA/mm}$  at 20 V and had a ratio between on-current and off-current of  $7.3 \times 10^6$ .

HEMTs with 0.3  $\mu\text{m}$  T-shaped gates were formed on high-resistivity silicon. These transistors delivered a peak drain current of 768  $\text{mA/mm}$ , produced a maximum transconductance of 190  $\text{mS/mm}$  and exhibited a threshold voltage of -4.53 V.

Further details of this work have been published in the paper, "Demonstration of AlGaIn/GaN High-Electron-Mobility Transistors on 100-mm-Diameter Si(111) by Ammonia Molecular Beam Epitaxy", by N. Dharmarasu *et al* in *Applied Physics Express* 5 091003 (2012). DOI:10.1143/APEX.5.091003

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## GigOptix lawsuit against MA/COM to go to trial

Although GigOptix was denied a motion for an "Extraordinary Remedy," the firm remains confident that it has strong evidence supporting its claim for misappropriation of trade secrets

The Superior Court of Santa Clara County, California has denied GigOptix's request to enjoin defendants M/A-COM Technology Solutions and its subsidiary Optomai from using misappropriated trade secrets.



The fabless supplier of semiconductor and optical components has also accused two of its former engineer employees of divulging information.

GigOptix addresses emerging high-growth opportunities in the communications, industrial, defence and avionics industries.

GigOptix has conducted forensic and other discovery to support its lawsuit for misappropriation of trade secrets. The firm has also brought a motion for preliminary injunction, which the Court heard on September 13th, 2012. It is not necessary that such motions be filed in trade secret misappropriation cases, and the Court's denial of the request for an injunction does not have any impact on the strength of GigOptix' case against the defendants.

The Court did not address the merits of GigOptix' claims against the defendants in denying the motion. While the Court did not provide its reasoning for denial of the motion, a spokesperson did say that, "a party seeking a preliminary injunction 'ordinarily is required to present evidence of the irreparable injury or interim harm that it will suffer if an injunction is not issued pending an adjudication of the merits.'"

GigOptix remains confident that it has strong evidence supporting its claim for misappropriation of trade secrets. The company looks forward to putting the evidence regarding the conduct and actions of the defendants before a jury and judge in "an adjudication of the merits" at trial. The Court has not yet set a trial date.

## Anadigics' InGaP technology powers Samsung Galaxy S Relay 4G

The new MMPA provides high performance quad-band GSM/EDGE and dual-band WCDMA and uses the firm's proprietary indium gallium phosphide technology

Anadigics is shipping production volumes of its ALT6181 multimode multiband power amplifier (MMPA) to Samsung Electronics for the new Samsung Galaxy S Relay 4G smartphone.



This smartphone provides a 4-inch super AMOLED display, 1.5 GHz dual-core processor, and Android 4.0 Ice Cream Sandwich operating system. In addition to a touchscreen display, the Galaxy S Relay 4G features a slide-out QWERTY keyboard.

Anadigics' MMPAs utilise the company's exclusive InGaP-Plus technology and patented design architectures to provide a high-performance single package solution for quad-band GSM/EDGE and dual-band WCDMA/LTE applications.

Anadigics says its MMPAs help to extend battery-life in applications where minimising printed circuit board (PCB) space is highly desired, such as handsets, smartphones, tablets, netbooks, and notebooks.

"The selection of our multimode multiband power amplifier for several upcoming smartphones, including the new Galaxy S Relay 4G, exemplifies the integration and performance advantages offered by this solution," says Michael Canonico, senior vice president of worldwide sales at Anadigics.

"By leveraging our innovative technologies, design techniques, and intellectual property, we are able to help manufacturers reduce RF PCB space requirements and extend battery-life in sleek, power-hungry mobile devices. We look forward to continuing our strong relationship with Samsung Electronics, as we jointly work together to raise the bar in mobile connectivity performance," he continues.

Anadigics' compact 5 mm by 7.5 mm x 0.9 mm

ALT6181 MMPA features an integrated voltage regulator, separate single-ended RF chains, and high directivity couplers. WCDMA/LTE linearity specifications for bands 1, 5, 6, 18, 19, and 26 have been enhanced, while ensuring that critical harmonic, noise and intermodulation performance results in superior mobile device performance.

Similar to the new ProEfficient family of products, the ALT6181 MMPA provides optimal WCDMA/LTE efficiency across all power levels, without the use of a DC-DC converter. This MMPA delivers high GSM/EDGE efficiency of over 40 percent in high power mode combined with more than 20 percent efficiency in low power mode. The device also has an exceptionally low quiescent current of 4 mA.

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## Charlie Roach to take Inphi sales to the next level

The sales and semiconductor veteran previously worked for Integrated Device Technologies

Inphi Corporation has appointed Charlie Roach as Vice President of Worldwide Sales.



*Charlie Roach, Vice President of Worldwide Sales*

Inphi is a provider of high-speed, mixed signal semiconductor solutions for the communications and computing markets. The firm's end-to-end data transport platform delivers high signal integrity at fast data speeds, addressing performance and bandwidth bottlenecks in networks, from fibre to memory. Inphi uses InP, GaAs, SiGe and CMOS technology in its devices.

"Charlie brings a wealth of experience in technology sales to Inphi, including a proven track record in working across computing, storage and networking markets," says Ford Tamer, president and CEO of Inphi. "He has the intellect, drive and passion to

make a difference and will be a tremendous asset to our executive team as we take Inphi to the next level."

Roach brings to Inphi more than 17 years of sales and semiconductor experience.

Prior to Inphi, he served as Vice President of Sales for Integrated Device Technologies, where he managed the Americas and South East Asia sales teams along with the worldwide EMS team. Before IDT, Roach was in charge of Worldwide Strategic Accounts at Applied Micro Circuits, the Central and Southeast U.S. Sales Manager at MMC Networks and Managing Partner and Sales Engineer at Electro Source. He holds a B.S. degree in electrical engineering from Auburn University.

"I am honoured to join the Inphi team to lead its worldwide sales organisation," says Roach. "I look forward to contributing to the company's continued success and momentum in global markets and ensuring that our customers achieve their business goals."

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## Infinera goes down under to set up PIPE submarine cable system

The firm's DTN-X platform, based on indium phosphide PIC technology, will be used for a 100G submarine network between Guam and Sydney

Infinera's DTN-X platform has been selected by PIPE Networks Pty Limited's submarine cable system, PPC-1.

PIPE is one of Australia's premier telecommunications carriers and is a wholly-owned subsidiary of TPG Telecom Limited.

PIPE is deploying FlexCoherent super-channels on PPC-1 with the Infinera DTN-X platform, offering International and Australian carriers increased speed and highly resilient services. This marks the first deployment of optical super-channels in the Asia-Pacific region.

In addition to the submarine deployment, the Infinera DTN-X platform was also selected for

the company's terrestrial network delivering 500 Gb/s FlexCoherent super-channels to multiple, strategic data centres located in Sydney. The platform supports 8 T/s on a single fibre, which will significantly increase the capacity, scalability and resiliency of PIPE's extensive metro fibre network in Sydney.

The use of the DTN-X platform on PPC-1 opens PIPE up to significantly increased capacity on PPC-1, delivering in excess of 3 Tb/s. It will also allow PIPE to deploy Infinera's 100 Gb/s coherent wavelengths using high capacity super-channel transmission for the first time in the Asia-Pacific region.

PIPE selected the Infinera DTN-X platform for the scalability, efficiency and simplicity it brings to its network. The Infinera DTN-X platform should help PIPE address the increasing demand for submarine and terrestrial bandwidth.

FlexCoherent super-channels will enable PIPE to optimise transmission performance across a range of applications using multiple software-programmable modulation formats, scaling network capacity for its customers without scaling operational expense.

One of the key factors in PIPE's selection of the platform was the attraction of a solution based on Photonic Integrated Circuits (PICs).

Infinera's DTN-X platform PICs are based on InP technology and enable high capacity Wavelength Division Multiplexing to be integrated with 5 Tb/s of Optical Transport Network (OTN) switching without performance compromise. Integrated non-blocking OTN switching allows each wavelength to be efficiently utilised, resulting in fewer wavelengths for a set of service demands.

What's more, the PIC approach is claimed to reduce capital and operating costs due to fewer fibre connections, less space and lower power consumption across the network.

PIPE further benefits from an industry leading GMPLS control plane coupled with Bandwidth Virtualisation, allowing its engineers to deploy its network in days and provision services across the submarine and terrestrial network within minutes to meet the rapidly changing demand of its customers.

"Infinera's solution for the 100G market provides our network with unique benefits which led to our decision to select the DTN-X platform," says Lee Harper, Head of Network Engineering for PIPE Networks and the TPG Group.

"The DTN-X platform's interoperability between our existing terrestrial and submarine networks, its ease of use when provisioning services along with the elimination of transponders at cable landing stations all led to our decision. We move a significant amount of data around the country, and deploying the DTN-X allows us to distribute reliable, high-capacity services with great simplicity and with industry-leading provisioning lead times," he continues.

"We are pleased to announce PIPE Networks as our first DTN-X super-channel deployment in the Asia-Pacific region," adds Tom Fallon, Infinera CEO. "Infinera's FlexCoherent super-channels simplify the deployment of 100G for both subsea and terrestrial applications while delivering scalability and efficiency."

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## GigOptix to push sales in Asia Pacific

The firm has appointed semiconductor start-up sales and engineering veteran Victor Tu to enhance sales in the APAC region

GigOptix, a fabless supplier of semiconductor and optical components that enable high speed information streaming, has appointed Victor Tu as Vice President of Sales for the Asia Pacific Region.

"The addition of Victor to the GigOptix family adds significant strength and experience to our international sales approach," states Avi Katz, Chief Executive Officer and Chairman of the Board of GigOptix. "We have continuously grown our business in the Asia Pacific Region to date but this new role will enable us to take our customer engagements to the next level."

He continues, "We are challenging Victor to help improve our market position in one of the fastest growing regions for the communications market. Going forward we are confident that this new



appointment will prove beneficial to our customers and help garner additional new business. I believe that with Victor's extensive knowledge and industry contacts, he will make an immediate impact to our bottom line and I look forward to the new business developments that he will bring to GigOptix as he builds a solid sales team in the region under his leadership."

Victor Tu has nearly 20 years of semiconductor sales and engineering experience. Prior to joining GigOptix, he served as VP of Sales (APAC) at Gennum Corporation, which was acquired by Semtech Corporation in March of 2012. Tu was responsible for growing sales revenues through direct sales and regional distribution channels in support of their analogue and mixed signal products.

Previously, Tu worked for an array of start-up optical component companies where he managed and directed worldwide sales. He started his career in product development and has worked for various semiconductor and high-tech companies.

Victor Tu received his BS degree in Electrical Engineering Technology from Old Dominion University in Norfolk Virginia.

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## **RFMD chip powers Samsung's latest GALAXY Note II**

The firm's RFMD's product portfolio supports Samsung products across all product tiers and baseband architectures

RF Micro Devices' PowerSmart power platform, claimed to be the industry's first and only converged multimode, multiband (MMMB) power amplifier, is enabling Samsung's next-generation GALAXY Note II.

Bob Bruggeworth, president and CEO of RFMD, says, "We are delighted to support Samsung's next-generation GALAXY Note II as well as numerous other flagship devices in Samsung's exciting product family. With the ramp of the GALAXY Note II, RFMD extends our coverage of Samsung's product portfolio to include all tiers and segments.

In the coming months, we look forward to the availability of additional devices and baseband architectures that expand our business with Samsung to include additional PAs, incremental switch-based content, and new high-performance WiFi front ends."

The Samsung GALAXY Note II features a 5.5" HD Super AMOLED screen, providing breathtaking visuals and crystal clear detail. Its 16:9 screen ratio ensures an immersive and enriched cinema-like video viewing experience, perfect for watching HD videos on-the-go. The GALAXY Note II also comes with a mighty 1.6GHz Quad-Core processor and HSPA Plus or 4G LTE connectivity to deliver easy multitasking, lightning-fast screen transitions, powerful browser performance, and minimal app load time.

It also has an 8 megapixel rear-facing camera and 1.9 megapixel front-facing camera with HD video recording capabilities. The Samsung GALAXY Note II is set to launch in October starting in major European, Asian, and Middle East markets.

RFMD enables Samsung with a broad range of 3G/4G front end solutions, including PowerSmart, 3G/4G power amplifiers, switches, and RFMD's advanced power management solutions. RFMD supports Samsung across all leading baseband architectures.

RFMD's PowerSmart power platforms deliver integration, design flexibility, and customisation, enabling smartphone manufacturers to rapidly deploy smartphone platforms across geographies and networks, regardless of mode or band specifications.

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## **Hittite cuts the price of GaAs pHEMT LNAs**

The less costly hermetically sealed connectorised amplifiers operate from 1 to 36 GHz and are based on gallium arsenide technology

Hittite Microwave Corporation, a supplier of complete MMIC based solutions for communication & military markets, has recently reduced the list price of several of our pHEMT Low Noise and Power Amplifier modules.

These rugged connectorised amplifiers are suited to high performance applications in microwave radio, military & space, radar systems, test instrumentation and synthesizer applications from 1 to 36 GHz.



*HMC-CO59*

The HMC-C059 and the HMC-C027 are GaAs pHEMT Low Noise Amplifier (LNA) modules which are rated from 1 to 12 GHz and 29 to 36 GHz, respectively. These high performance amplifier modules exhibit noise figures as low as 1.8 dB, with up to 20 dB of gain and up to +30 dBm output IP3.

The HMC-C059 LNA module features integrated voltage regulators and consumes 60 mA from a +6V supply, while the HMC-C027 operates directly from a single +3V supply and consumes only 80 mA.

The HMC-C020 and the HMC-C021 are GaAs pHEMT Power Amplifier modules which are rated from 17 to 24 GHz and 21 to 31 GHz, respectively. These powerful amplifier modules deliver up to +24 dBm output P1dB, up to +30 dBm output IP3, and up to 22 dB of gain.

The HMC-C026 is a Wideband High Gain GaAs pHEMT Driver Amplifier module which is rated from 2 to 20 GHz and provides up to 31 dB gain and +24 dBm output P1dB, with noise figure as low as 2.5 dB. The HMC-C020, HMC-C021 and the HMC-C026 feature integrated voltage regulators which allow for flexible biasing of both the negative and positive supply pins, while internal bias sequencing circuitry assures robust operation.

Each of these lower cost hermetically sealed modules feature internally matched and internally DC blocked RF I/Os, making them ideal for both engineering laboratory and production screening test environments.

All connectorised module products are available from stock and can be ordered via the company's e-commerce site or via direct purchase order.

# RF Electronics

## Skyworks upgrades revenues to \$420 million for Q4 2012

The RF innovator of high performance analogue semiconductors has also updated its Non-GAAP Diluted EPS to \$0.52

Skyworks Solutions has updated its financial outlook for the fourth quarter of fiscal 2012 given strong program ramps across its analogue and mobile Internet businesses and continued operating leverage within its business model.

The Company now anticipates revenue of \$420 million for the fourth quarter of fiscal 2012, on the high end of its previous guidance range of \$415 to \$420 million, which would represent an 8 percent sequential increase.

Skyworks also expects to deliver non-GAAP diluted earnings per share of \$0.52 versus guidance of \$0.50 to \$0.51, which would represent a 16 percent sequential increase for the fourth quarter of fiscal 2012.

The company's previous guidance was provided on July 18th, 2012 during its third quarter fiscal 2012 conference call.

## GaAs device revenue reaches new heights

Although 2011 revenues hit a record \$5.2 billion, growth is expected to slow down in the future

According to Strategy Analytics, a fast start to 2011 allowed the GaAs device market to withstand a slowdown toward the end of the year and post record revenue for 2011.

Continuing growth in demand for handset power amplifiers offset ongoing uncertainty in the global economy to propel the market to growth from last year's value. The market research firm's most recent report, "GaAs Industry Forecast: 2011-2016", reports the overall GaAs device market grew by

roughly 6 percent to close 2011 with slightly more than \$5.2 billion of revenue.

The report also forecasts that slowing smartphone growth and an uncertain global economy will limit future growth rates below historical averages and the market will reach slightly more than \$6.1 billion in 2016.

“The GaAs market began the year with strong growth”, notes Eric Higham, Director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs). “Toward the end of the year, slowing growth in the smartphone segment and uncertainty in the global economy became the overriding trends and the overall GaAs device market slowed substantially. The underlying trends in the GaAs market still support growth, but uncertainty in the economy is likely to limit this growth.”

Asif Anwar, Director in the Strategy Analytics Strategic Technologies Practice adds, “We remain convinced that data consumption and GaAs content in handsets will increase, but fluctuations in the global economy will put a damper on network and consumer spending.”

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# Lasers

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## Brolis wins semiconductor "Young Entrepreneur of the Year" award

The MBE specialist was awarded for its complex epitaxial structures based on arsenides and antimonides for the electronic and optoelectronic world market

Brolis Semiconductors has won the Young Entrepreneur of the Year in the Swedish Business Awards 2012.

The award was presented at a special ceremony held in Vilnius Small Theatre.



*Brolis making a speak at the awards ceremony*

Guests at the ceremony included President of Lithuania, Dalia Grybauskaitė; former president of Lithuania, Valdas Adamkus; Prime Minister of Lithuania, Andrius Kubilius; Ambassador of Sweden to Lithuania, Cecilia Ruthström-Ruin; President and CEO of Swedbank Michael Wolf and President and CEO of Ncell, Pasi Ahti Yrjänä Koistinen.

The company, headquartered in Vilnius, was established in 2011 by Augustinas, Kristijonas and Dominykas Vizbaras who are brothers who specialise in long-wavelength semiconductor lasers and MBE.

## IPG purchases JPSA Laser

The firm is boosting its integrated laser solutions to accelerate its penetration into the fine-processing markets with JPSA's lasers which operate at wavelengths from 157nm to 1064nm

IPG Photonics Corporation has acquired privately

held New Hampshire-based J.P. Sercel Associates Inc. (JPSA), a global supplier of UV excimer and diode pumped solid state (DPSS) industrial laser micromachining systems for precision processing in high-volume manufacturing.

JPSA is anticipated to add approximately \$4 million to IPG's revenues for the remainder of 2012. At current revenue levels, the acquisition is expected to be dilutive by \$0.01 to \$0.02 per share in 2012, and is expected to be accretive in 2013. Financial terms were not disclosed. The acquired business will operate under the name IPG Microsystems LLC.

The acquisition enables IPG to expand its integrated laser systems product offerings for fine-processing, precision cutting, drilling and micromachining of non-metals, including glass, semiconductors and ceramics.

JPSA's systems perform advanced laser micromachining, micro cutting, scribing and laser lift-off for semiconductors, microfluidics, LEDs, thin film solar panels, micro-electro-mechanical systems (MEMs), biomedical technology and industrial automation applications.

"This acquisition broadens our customized laser-based systems offerings and provides significant sales synergies," says Valentin Gapontsev, IPG Photonics Chief Executive Officer. "The combination of JPSA's specialized laser systems and the UV and short pulse fibre lasers that IPG is developing now should allow us to deepen our penetration of the \$800 million fine-processing market."

He continues, "At the same time, we plan to capitalise on opportunities to expand the global reach of JPSA's products through IPG's extensive sales and service network. In addition, we expect that the development expertise of the very experienced JPSA team would benefit our capabilities in other micromachining applications."

"Strong demand exists for better quality short-wavelength and short pulse width laser sources in applications addressed by JPSA's products," comments Jeff Sercel, CEO and Chief Technology Officer of JPSA.

"While we will continue to sell our UV and excimer laser systems, as well as systems which use DPSS

lasers, we strongly believe there are significant growth opportunities using advanced fibre lasers to displace traditional laser sources in high growth applications. Together, we will be able to sell into new applications, expand geographically and accelerate into markets where there are needs for advanced fibre laser technology. We look forward to being productive members of the IPG Photonics team."

JPSA is a supplier of industrial grade UV excimer, DPSS, and Pico-second laser micromachining systems and materials processing services to customers worldwide. The Company's key applications include advanced automated systems for laser scribing and lift-off (LLO) of LEDs, thin film solar scribing, semiconductor, MEMs, research, biomedical, and industrial micromachining. JPSA's laser systems operate at wavelengths from 157nm to 1064nm, and are used to grow industrial micromachining applications.

JPSA's team of scientists and engineers work together in its applications lab to develop new techniques in laser-material interaction and high productivity laser systems and automation.

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## Meaglow InGaN layer breaks barriers

The Canadian firm says its indium gallium nitride technology can lower the cost of producing green LEDs and laser diodes

Meaglow has developed a low temperature Migration Enhanced Afterglow film growth technique to produce a thick InGaN layer with strong yellow emission.

This recent result bodes well to increase the efficiency and lower production costs of green LEDs and laser diodes.

The company is currently seeking collaboration opportunities to enhance the material properties required by industry for lighting, display, medical, and military applications and other uses.

Meaglow's Chief Scientist K. Scott Butcher, says, "It's the brightest *p-n* junction I've ever seen in my life, and its right in the green gap."

The green gap (540-610nm) is a major obstacle in the development of high-efficiency solid state lighting applications. It's well known that LEDs produced in the green region, between red and blue, have rapidly declining efficiency.

Green and yellow in the middle of the colour spectrum, known as the "green gap", is a section of the light spectrum where devices made from either nitride or phosphide are inefficient and difficult to fabricate.

Meaglow says its reactor overcomes these difficulties by utilising its patent pending hollow cathode and low temperature growth process which is capable of growing the volatile compound of indium required to make green and yellow diodes.

Having a nitride device that emits strongly in the yellow is a monumental step forward for low temperature InGaN growth.

Meaglow also says the quality of InGaN produced by its technique is pioneering the industry. Results for this test device were presented to scientists in the nitride semiconductor research community at the recent ISSLED2012 conference held in Berlin, Germany.

The firm is now focused on commercialising its InGaN technology, and is looking for partners interested in creating next generation devices using the thick InGaN template layers.

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## Stuttgart University orders another Aixtron tool for laser research

The 3x2" MOCVD CCS reactor will be used for the growth of gallium arsenide solid state lasers and III-V materials on silicon

The University of Stuttgart has made a repeat order for Aixtron's CCS (Close Coupled Showerhead) system that is capable of handling three 2-inch (3x2") substrates at a time.

The system will be used by University of Stuttgart's Institute of Semiconductor Optics and Functional Interfaces (Institut für Halbleiteroptik und

Funktionelle Grenzflächen, IHFG) research group.

IHFG researchers specialise in semiconductor optics and epitaxy.

The new Aixtron system will be used to expand IHFG's work in GaAs based optoelectronics, in particular, producing material for solid state lasers.

The order was booked in the first quarter of 2012 and the reactor will be delivered in the third quarter of 2012.

Michael Jetter of IHFG comments, "We want to use the CCS 3x2" in two ways: on the one hand we want to produce our GaAs-based laser structures on GaAs, but we also want to transfer them to silicon substrates. As a specialist in semiconductor optics, the Institute's main research areas are semiconductor lasers and low dimensional structures such as quantum wells (QWs) and quantum dots (QDs)."

One focus of the work will be quantum cryptography and single photon emitters. However, the researchers also foresee opportunities arising from their efforts in automotive electronics. In particular, the researchers plan to grow III-V materials on silicon substrates using Aixtron's MOCVD technology.

Jetter adds, "We would like to give silicon electronics an optic touch, which means that we want to monolithically integrate III-V optoelectronic devices (lasers and LEDs, either QW- or QD-based) into CMOS-compatible silicon substrates. These can then be used for the optical data interconnects either on-chip, chip-to-chip or as board-to-board connectors."

The Aixtron equipment will be also used by the Stuttgart Research Centre of Photonic Engineering (SCoPE), which aims to improve interdisciplinary collaborations between scientists and engineers at the Universität Stuttgart.

IHFG and Aixtron plan to work together in the future on joint research and to co-operate on other scientific programs in the Stuttgart region, focusing on III-V growth on silicon.



# Solar

## Opel closes a further \$1.15 million in financing

The proceeds of this financing will be partly used for the development of the firm's III-V compound semiconductor POET technology

Opel Technologies Inc. has completed a further financing which resulted in proceeds of \$1,150,000 through IBK Capital Corp. as agent.

Five million units were price protected as of September 18th, 2012 in response to continued high demand for the Company's financings announced September 10th, 2012 and September 14th, 2012.

The private placement offering consisted of 5,000,000 units at a price of \$0.23. Each unit consists of one common share and one common share purchase warrant. One full warrant allows the holder to acquire one common share of Opel for a period of three years at an exercise price of \$0.35 per share. There are currently 117,106,650 common shares issued and outstanding after the financing.

The company paid a cash commission equal to \$72,500 and 500,000 broker warrants. Each broker warrant allows the holder to acquire one common share of Opel at a price of \$0.23 for 48 months. All securities issued pursuant to the private placement are subject to a hold period which expires on January 28th, 2013.

Leon M. Pierhal, CEO, comments, "The company continues to aggressively work to reduce its expenses and debt in support of our strategic decision to divest the solar division to focus on our core business which is ODIS Inc. and the POET Technology. The proceeds of this financing will be used for these initiatives and the development of POET."

## First Solar To Brighten In China With New Appointment

As MD and VP, Bruce Yung will invigorate business development in China

First Solar has taken on Bruce Yung as Managing Director and Vice President of Business Development for China.

In his new role, Yung will be based in First Solar's Beijing office and report to Jim Brown, Executive Vice President of Global Business Development.

Yung has 25 years of experience in the energy industry throughout Asia and Europe, spanning oil, gas, coal, power and renewable energy. Most recently, Yung was Managing Director of China Renewable Energy Investment Limited, a renewable energy company focused on China.

Prior to that, he held senior positions in business development, mergers and acquisitions, asset management and strategy with leading global energy companies such as British Petroleum, Entergy Power Group and British Gas.

"Bruce's extensive and diverse global experience across the energy industry will be a valuable asset to First Solar and our customers as we continue to grow and invest in the Chinese market," says Brown.

"His first-hand knowledge of the entire power life-cycle, from development to operation, will help us to expand the market for utility-scale solar PV power plants in China and to deliver value to Chinese solar power producers."

"I am excited to lead First Solar's effort to bring its leading thin-film technology and unparalleled experience in utility-scale solar to the Chinese market in order to help China reach its ambitious renewable energy goals," adds Yung.

Yung earned BS and PhD degrees in chemical engineering from the University of Birmingham and an MBA from Henley Management College in the United Kingdom. He is currently Vice Chairman of the Energy Committee at the American Chamber of Commerce in Hong Kong and Co-Chair of the Renewable Energy Chapter of the Independent

Power Producers Forum.

## Ascent Solar generates \$10 million from public offering

Like many other solar firms, the CIGS solar cell manufacturer has had to create a means of creating cash. The firm intends to use the net proceeds from the offering for working capital and for general corporate purposes

Ascent Solar Technologies has closed its previously announced underwritten public offering of 9,166,700 shares of its common stock at a price of \$1.20 per share.

Ascent received net proceeds, after deducting the underwriting discount and estimated offering expenses, of approximately \$10.1 million. The firm has also granted the underwriters a 45-day option to purchase up to an additional 1,375,005 shares of common stock to cover over-allotments, if any.

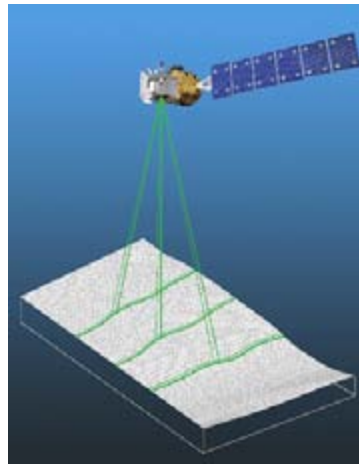
The company intends to use the net proceeds from this offering for working capital and for general corporate purposes.

Aegis Capital Corp. acted as the sole book-running manager for this offering.

## Emcore panels to take off in Orbital/NASA mission

The firm's III-V based solar panels will power one of NASA's latest missions, ICESat-2. The goal of this project is to measure the topography of the Greenland and Antarctic ice sheets and the thickness of sea ice

Emcore Corporation has been awarded a solar panel manufacturing contract by Orbital Sciences Corporation for NASA's Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) mission.



Targeted for launch in early 2016, the solar panels will be populated with Emcore's most advanced III-V based compound semiconductor ZTJ triple-junction solar cells, which will power the ICESat-2 spacecraft manufactured by Orbital.

ICESat-2 builds on measurements taken by NASA's original ICESat mission. ICESat was the benchmark Earth Observing System mission for measuring ice sheet mass balance, cloud and aerosol heights, as well as land topography and vegetation characteristics.

Data from ICESat, which was in orbit from 2003 to 2010, revealed thinning of the world's ice sheets. ICESat-2 will use precision laser-ranging techniques to measure the topography of the Greenland and Antarctic ice sheets and the thickness of sea ice.

"This award for ICESat-2 continues the strong partnership between Orbital Sciences Corporation and Emcore," says Brad Clevenger, General Manager of Emcore's Photovoltaics Group. "Our proven manufacturing capability, technology leadership and solar panel reliability make Emcore the supplier of choice for demanding spacecraft power systems."

Emcore is a manufacturer of radiation-hard solar cells for space power applications. With a Beginning-Of-Life conversion efficiency nearing 30 percent and the option for a patented, onboard monolithic bypass diode, Emcore's multi-junction solar cells provide high power to interplanetary spacecraft and earth orbiting satellites.

## Azur Space orders two Aixtron reactors for solar cells

The firm will use the reactors to manufacture gallium arsenide based cells for terrestrial applications

Aixtron SE has a repeat order for further MOCVD systems from Azur Space Solar Power GmbH of Heilbronn, Germany.

The new contract is for two MOCVD systems to be dedicated to the growth of GaAs materials for the production of concentrated photovoltaic (CPV) solar cells for terrestrial applications.

Aixtron Europe's service support team will install and commission the new reactors during the second half of 2012 in a cleanroom facility in Heilbronn.

Juergen Heizmann, Managing Director of Azur Space Solar Power GmbH, says, "Our existing Aixtron MOCVD systems have more than proved themselves, so now it is time to further expand production with two new systems. Adding more equipment from Aixtron has many advantages in terms of start-up speed, continuity and process transfer.

"It will also ensure a seamless and smooth transition to the next step in our strategic plans to move production to 6-inch wafers. This is a key step in the planned evolution towards high performance materials, but with the economic advantages of larger diameters. We therefore look forward to working with the Aixtron team," continues Heizmann.

Azur Space Solar Power GmbH is a developer and manufacturer of high efficiency solar cells for space and terrestrial applications; the latter based on the CPV concept. With over four decades of experience in space solar cell technology, its product range covers several types of silicon and III-V solar cells, including those on germanium wafers.

CPV technology uses lenses to concentrate sunlight onto a small area of photovoltaic materials in order to generate electricity. Among its advantages, and

in contrast to more conventional flat panel systems, CPV systems can be much less expensive to manufacture.

Maximising the commercial potential via the highest efficiency and lowest cost requires the ability to manufacture low-cost, light-concentrating optical systems and III-V materials. It is here that MOCVD systems such as the Aixtron platforms are bringing these objectives to commercial reality with many companies worldwide.

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## GaAs device revenue reaches new heights

Although 2011 revenues hit a record \$5.2 billion, growth is expected to slow down in the future

According to Strategy Analytics, a fast start to 2011 allowed the GaAs device market to withstand a slowdown toward the end of the year and post record revenue for 2011.

Continuing growth in demand for handset power amplifiers offset ongoing uncertainty in the global economy to propel the market to growth from last year's value. The market research firm's most recent report, "GaAs Industry Forecast: 2011-2016", reports the overall GaAs device market grew by roughly 6 percent to close 2011 with slightly more than \$5.2 billion of revenue.

The report also forecasts that slowing smartphone growth and an uncertain global economy will limit future growth rates below historical averages and the market will reach slightly more than \$6.1 billion in 2016.

"The GaAs market began the year with strong growth", notes Eric Higham, Director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs). "Toward the end of the year, slowing growth in the smartphone segment and uncertainty in the global economy became the overriding trends and the overall GaAs device market slowed substantially. The underlying trends in the GaAs market still support growth, but uncertainty in the economy is likely to limit this growth."

Asif Anwar, Director in the Strategy Analytics



Strategic Technologies Practice adds, “We remain convinced that data consumption and GaAs content in handsets will increase, but fluctuations in the global economy will put a damper on network and consumer spending.”

## First Solar to electrify rural communities in India

The pilot project in the Uttarakhand state will provide safe drinking water and irrigation using First Solar’s cadmium telluride modules

First Solar and Sir Ratan Tata Trust plan to collaborate on a pilot project to provide safe drinking water and irrigation to rural communities in India’s northern Uttarakhand state.

Many remote villages of the middle Himalayas lack basic infrastructure such as roads, health facilities, schools and electricity. In Uttarakhand, even many villages that are connected to the electrical grid receive only erratic electrical service. In the absence of electric pumps, collecting water from spring sources and carrying it to villages—a job that usually falls to women—can take three to four hours a day.

Through its charitable giving program, First Solar has joined forces with the Sir Ratan Tata Trust to develop a pilot project using First Solar’s advanced, thin-film photovoltaic (PV) CdTe modules to help off-grid villages in the region receive a reliable supply of clean energy for essential needs such as safe drinking water and irrigation. The aim of the pilot project is to develop an integrated solution that is low-maintenance and simple for the communities to install, maintain and use.

The pilot project, which will be managed under the Trust’s Central Himalayan programme (Himotthan Pariyojana) by the Himotthan Society, will consist of two solar PV power plants which will be built in the Chureddhar and Chham (Gunogi) districts, Tehri Garhwal, Uttarakhand. If successful, the pilot project could be replicated across hundreds of villages throughout India.

Ganesh Neelam, Development Manager, Sir Ratan Tata Trust, welcomed the support and contribution of First Solar. “We thank First Solar for partnering

with us for the installation of this system, which will help us meet our community development goals,” he says.

Anant Naik, First Solar’s Director of Public Affairs in India, adds, “We welcome the opportunity to join with the Sir Ratan Tata Trust and the Himotthan Society. They share our commitment to sustainable development, to harness solar energy to provide safe drinking water in order to improve the quality of life for rural households.”

The Sir Ratan Tata Trust is one of India’s oldest philanthropic organisations. For more than a century, it has provided grants and partnered with organizations that engage in innovative and sustainable initiatives and have the potential to make a visible difference.

Sir Ratan Tata Trust’s programme in Uttarakhand has focused on providing rural communities in the region with affordable, long-term solutions for livelihood enhancement and resource management. This pilot would complement on-going livelihood enhancement work by the Sir Ratan Tata Trust and field partners through community institutions.

First Solar will donate 100 modules to the pilot project, which will combine First Solar PV modules with water pumps to move water from spring sources into storage tanks in order to provide the village with a safe and convenient water supply. The project will benefit 65 households with a population of 530 individuals in the two villages.

## Plansee improves sputtering performance for CIGS production

The firm has introduced a new inner diameter coating which enables CIGS manufacturers to increase sputtering performance in monolithic molybdenum targets

Plansee’s new coating prevents direct contact between the target material and cooling water during the sputtering process.

The firm will present its “upgraded rotary target” at the EU PVSEC in Frankfurt.

Monolithic targets with inner diameter coating molybdenum sputtering targets are used to deposit the back contacts in CIGS cells by magnetron sputtering.



*Image showing the upgraded rotary target*

Monolithic rotary targets have no backing tube. They consist entirely of the thin film material.

Plansee says that thanks to these targets, CIGS manufacturers can considerably increase sputtering performance and consequently achieve greater throughput. The particularly high level of material utilisation also reduces the total cost of ownership in solar cell production.

When monolithic targets are used, the molybdenum is in direct contact with the cooling water inside the sputtering equipment. Additional particular additives (so-called inhibitors) have to be used to condition the cooling water for operation with monolithic targets. These stabilise the pH-value of the cooling water.

Plansee has now developed a protective coating for the inner diameter (ID) wall of the target, designed to make it even easier to use monolithic targets. This polymer-based layer ensures that the molybdenum no longer is exposed directly to the cooling water. The advantage is that CIGS manufacturers do not need to use the additional inhibitors and are therefore able to reduce their costs. Plansee points out that the ID coating does not noticeably impair the thermal conductivity of the rotary target.

## Roth & Rau slashes the cost of solar cell production

Achieving 50 to 70 percent savings in silver, the process is developed for front and rear side coating with nickel. A tool is now available for the production of high efficiency heterojunction cells

Meyer Burger Technology has announced that its Group member Roth & Rau AG has developed a process which uses inexpensive nickel in busbar metallisation for the electrical contacting of solar cells.

The coating process includes both the front and rear sides of the cell within a production tool. Meyer Burger says this process, which is immediately available, significantly differentiates Roth & Rau from its competitors.

Depending on the contact technology, a saving of between 50 and 70 percent in expensive silver can be achieved and therefore significantly reduce the production cost of solar cells. A further benefit from the process is the fact that nickel is a readily available material. This means that solar cell manufacturers are not tied to specific suppliers as is the case with other materials.

The HELiA system, which was developed primarily for the production of high efficiency heterojunction cells, coats the solar cells with nickel in a shortened system configuration to form the front and rear busbars. This is achieved by means of a sputtering process. In contrast to other systems, the HELiA system permits simultaneous processing not only of the rear surface but also of the front surface on which there is a significantly greater potential for savings.

A further decisive benefit of this new process is the outstanding adhesion of the cell connectors to the front and rear surfaces of the solar cell as a result of the nickel metallisation in standard soldering processes.

The metallisation of the fingers can thus take place regardless of the electrical characteristics of the busbar and be optimised to match them. In this way, the metallisation of the fingers is de-coupled from the solderability of the busbar, thereby enabling the use of new pastes and metallisation processes that do not currently achieve reliable solderability. The

performance of solar cells coated with this process is comparable with that of solar cells metallised in the conventional way by screen printing.

## Smit Ovens makes headway in CIGS “In-line” production

The company has sold a total of ten roll to roll and sheet to sheet systems

Smit Ovens has successfully installed 10 in line production systems at five CIGS customer plants.

The systems cover selenium deposition, and/or crystallisation/annealing systems for pilot and or mass production, and development of thin-film CIGS cells that are produced using the two step CIGS manufacturing process. Both roll to roll and sheet to sheet applications are served.



*Image illustrating roll to roll mass production*

“Thermal processes are a key way to achieve competitiveness in this growing market. We’re already seeing cell efficiencies of 15 percent,” says Wiro Zijlmans, CEO, Smit Ovens.

Smit Ovens says its In Line Production System design are proven to be more cost effective due to doubled output compared to existing batch and in line solutions. What’s more, the systems demonstrate high flexibility and repeatability in production that offers improved layer quality, high uptime and productivity.

Some systems are equipped with active selenium reactors which are linked to the crystallisation/anneal reactor. The balance of the systems installed are configured for annealing of glass and flexible substrates. Control of the selenium pressure at

different process steps is realised, offering overall process stability. For instance, output performance is less dependent on precursor parameters as the active selenium process is correcting for differences in pre-deposited selenium layer thicknesses.

“This milestone underscores the strong relationship we have with our customers, who aim to be leading players in the global CIGS cell market,” adds Zijlmans.

“As a machine builder, Smit Ovens has extensive experience in high-precision thermal solutions for the solar energy industry and we are eager to apply this know-how to new market areas such as CIGS. The Solliance Institute, which uses our R&D / Pilot System, is a highly valuable technology partner with a vast knowledge of CIGS materials, processes and requirements. The system at Solliance is available for Smit Ovens customers to use for verification and process development,” concludes Zijlmans.

## Ascent Solar’s EnerPlex mobile charger available in North America

The company’s CIGS powered charger debuting in this region is suited to the Apple iPhone 4 and 4S

Ascent Solar Technologies has announced the retail debut of the its CIGS powered EnerPlex solar assisted battery case for the iPhone 4 and 4S in the United States and all of North America.

The company’s distributor in this region is CommXPRTS.

The EnerPlex for iPhone 4 & 4S takes advantage of Ascent’s ultra-light, thin and flexible solar panels and enables iPhone 4 & 4S users to provide supplementary charging of their iPhones with sunlight in addition to conventional charging methods to extend the usage time of iPhones.

The EnerPlex case for iPhone is enabled by the lightweight, thin and highly customizable form factor of Ascent’s CIGS solar cells, allowing solar technology to be integrated into the thinnest and lightest solar-enabled iPhone case on the market. Paired with an ultra-thin lithium-ion battery the



EnerPlex case provides hours of additional audio, web and talk time for iPhone 4 & 4S users.

Ascent Solar's President and CEO, Victor Lee, says, "We are excited to provide consumers with the ability to experience the transformational qualities of Ascent's award-winning CIGS solar technology through a product that complements one of the most popular consumer devices in history. Moving forward we are eager to introduce a wide range of EnerPlex solutions for a variety of consumer products, including Apple's iPhone 5."

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## InnoLas installs laser scribers at 100 MW Korean CIGS plant

The current installations are a further step in the successful roll-out of the firm's laser scriber systems for CIGS thin film solar cells and other semiconductors such as cadmium telluride

German company InnoLas Systems recently installed its pioneering P1, P2 and P3 laser scribers at a 100 MW CIGS fab in Korea.



*Impala laser processing system for thin-film solar modules*

This innovative laser technology for P2 scribing of thin film solar cells is suited for use on the structures of CIGS semiconductors and has so far been delivered to four different customers. These laser patterning tools support 250 MW production volume globally. InnoLas CEO Richard Grundmüller says, "The current installations are a further step in the successful roll-out of our laser scriber systems for thin film solar cells. Not only for the processing of CIGS but also for other semiconductors, e.g. CdTe cells, the InnoLas laser systems have become

must-have production tools. Up to September this year we have already developed, built and installed P1, P2 and P3 scribing systems for a fab capacity of 300 MW."

InnoLas also offers advanced laser systems for R&D applications.

The company has received an order for a multi-functional laser tool, tailor-made for the rigorous requirements in modern photovoltaic development labs. This system can process any individual pattern either from the film side or from the glass side with multiple wavelengths.

All layers (P1, P2 and P3) can be laser scribed, and the processing side and process parameters are selected through simple menu commands. Mechanical scribing (P2, P3) is available on the same system. Highlights include integrated In-situ metrology, giving 100 percent control over scribe performance and enabling the user to optimise process parameters on the fly.

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## Ascent Solar's CIGS power unmanned aircrafts

The small solar electric-powered drone aircraft is bolstering Ascent Solar's product portfolio

Ascent Solar Technologies is collaborating with Silent Falcon UAS Technologies and Bye Aerospace to provide its lightweight, flexible CIGS photovoltaics to power the Silent Falcon unmanned aerial system (UAS).

Silent Falcon is a small tactical UAS drone designed to be easily carried and used for longer-duration intelligence, surveillance and reconnaissance (ISR) missions.



*Silent Falcon showing TFPV for energy collection on wings*

Recently unveiled at the Association for Unmanned Vehicle Systems International (AUVSI) conference in Las Vegas, Silent Falcon represents the synergy of several new technologies, including ASTI's flexible photovoltaic modules, to provide a near silent, rapidly deployed platform that has multiple military and civilian applications. With three wing configurations available for different mission profiles, each Silent Falcon system could represent up to 30 modules.

John W. Brown, CEO, Silent Falcon UAS Technologies comments, "We believe that today there is a large and growing global military and public safety agency market for small or tactical unmanned aircraft systems (UAS). In these markets alone, sales exceeding several hundred units per year are possible. As their use in these markets proves their utility and functionality, and as the FAA rules for domestic commercial, civilian use become clearer, we believe the market size and number of annual units sold could increase substantially."

Ascent Solar's President and CEO, Victor Lee, adds, "Our collaboration on Silent Falcon represents a key strength of our product, namely that its lightweight and flexible nature can address multiple markets, from consumer electronics to building integrated PV, and that our manufacturing process is sufficiently agile to support them simultaneously. We see this emerging electric drone market expanding rapidly, with applications ranging from military to disaster relief with rapid deployment and recovery with little risk to human life."

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## Opel closes final tranche in financing

The firm, will through its subsidiary Odis, use the funds to further develop its III-V compound semiconductor solar cell technology

Opel Technologies Inc. has successfully completed the final tranche of its previously announced \$3,000,000 financing through IBK Capital Corp. as agent.

The private placement offering consisted of 13,043,479 Units at a price of \$0.23 per Unit. Each unit consists of one common share and one common share purchase warrant. One full warrant

allows the holder to acquire one common share of Opel for a period of three years at an exercise price of \$0.35 per share. The securities issued pursuant to the private placement will be subject to a hold period which expires four months and one day following closing.

The final tranche amounted to the entire remaining \$1,442,580 available under the offering. A cash commission equal to 7 percent of the funds raised and 10 percent of the units sold in the form of broker warrants were paid to the agent. Each broker warrant allows the holder to acquire one common share of Opel at a price of \$0.23 for 48 months.

Opel, through its subsidiary Odis, is now concentrating on the development of III-V compound semiconductor solar cell technology

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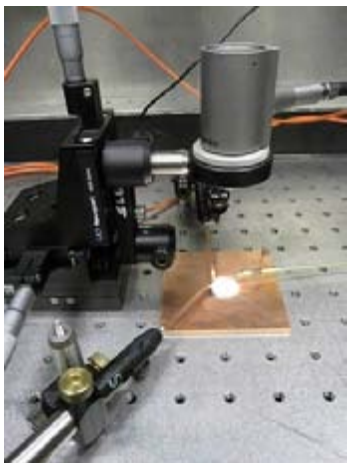
## Simulating the sun for solar research

A new laser-based solar simulator produces a spectral distribution almost identical to sunlight at wavelengths from 450 to 1750 nm. It can be used to characterise solar cells including III-V multi-junction based modules

PML researchers have devised a novel source of portable sunlight that may fill an urgent need in renewable energy research.

They have fabricated light sources that generate a near-perfect solar spectrum to be used in testing the performance and efficiency of photovoltaic (PV) materials.

The team's laser-based solar simulator produces a spectral distribution almost identical to sunlight at wavelengths from 450 to 1750 nm, and does so in a readily-focused beam that can be easily adapted to examine the latest generation of nanoscale, multi-cell, and multi-layer PV configurations. Recently the system was tested head-to-head against the best conventional sources with very promising results.



*Collimated output of the solar simulator illuminates a small solar cell. Electrical probes are used to measure cell efficiency*

“The conventional light source for testing PV materials is the xenon arc lamp,” says Tasshi Dennis of the Quantum Electronics and Photonics Division at NIST’s Boulder, CO campus. “It has plenty of energy, a decent spectral match to sunlight after some shaping, and good uniformity. But its light is spatially incoherent - it is emitted in every direction - and thus quite difficult to focus or propagate. Moreover, it’s not ideal for testing recently developed multi-junction materials in which individual sections are tuned to respond only to a particular spectral band.”

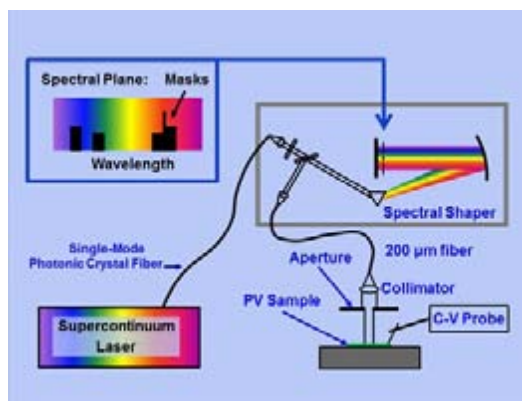
Dennis’ co-worker, John Schlager, came up with the idea of exploiting a technology that had just become commercially available; a “super-continuum” white-light laser system. Dennis and Schlager produced a design that makes controllable spectral modifications to the super-continuum light and uses the output to illuminate different PV materials.

“From the start,” says Dennis, “there was one big question to answer: Does our light really look like the sun?” The answer to that question would depend critically on two factors.

The first factor is the pulsed nature of the light from a newly available laser system that produces a super-continuum beam in a two-stage process. First, light is generated in an optical, fibre-based, mode-locked, multi-watt laser that emits pulses of several hundred femtoseconds duration at a rate that is controllable between 1 MHz and 80 MHz. That output is then amplified and sent into a photonic-crystal fibre. In the crystal medium, non-linear effects cause the spectrum to broaden out

continuously over a wavelength range of about 2000 nm. That broad range is the “super” in super-continuum.

“A key advantage of this method,” says Dennis, “is that the light from this fibre is single-mode” - that is, all the component frequencies have the same spatial distribution and form one single ray. That fibre output is then directed into a prism which splits the light into its spectral components and directs them at a mirror. Because the different wavelengths are spread out in space, inserting masks at selected points in the light before it hits the mirror will shape the spectrum to resemble sunlight by subtracting out specific wavelengths. The reflected light is then recombined into a single beam and focused onto PV samples.



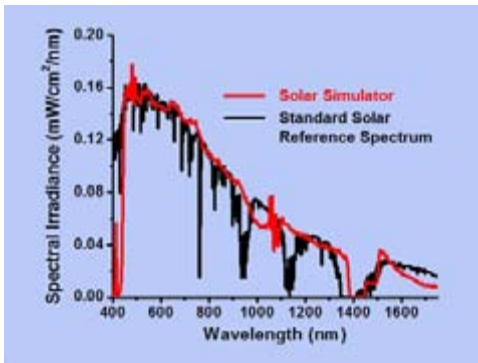
*Diagram of lab apparatus. The laser output is sent to a prism which splits the light into its constituent wavelengths. Masks are inserted into the prism beam to shape the spectrum by modulating certain wavelengths. The resulting spectrum is recombined and routed to a collimator and focused onto PV samples*

“The shaped spectrum was a very good match to sunlight over our wavelength range,” Dennis says, “but we worried that the pulsed beam might not have a quasi-continuous effect. But we found that it produces photovoltaic responses that are very close to continuous xenon light. We also wanted to see if the samples were sensitive to the pulse repetition rate, so we tested them at 20 MHz, 40 MHz and 80 MHz. As it turns out, the variation in response was only about 1 percent in PV cell efficiency. So it appears that the pulsed nature of the light doesn’t matter for PV testing purposes.”

The second factor, still an ongoing concern, is the absence of ultraviolet (UV) light in the super-



continuum system. “The fibre heavily attenuates wavelengths below 450 nanometres,” Dennis says, “so you’re not getting photons in the 300 nm to 450 nm range you see from the sun. We’re thinking of using some sort of arc-based source to fill those short wavelengths in. With that addition and a little more spectral shaping, we can get a perfect solar match,” Dennis points out.



Graph comparing the output of the solar simulator with the standard solar reference spectrum AM 1.5

But even without a UV component, the team wanted to determine how well their simulator performs compared to results with xenon-source measurements taken on exactly the same materials by colleagues at the Department of Energy’s National Renewable Energy Laboratory (NREL) in nearby Golden, Colorado, which is the federal agency responsible for certifying the efficiencies of different PV materials.

So earlier this year, Dennis and Schlager took measurements on the performance and efficiency of four different PV materials (*p*-type crystalline silicon, GaAs heterojunction, a thin film of CIGS, and amorphous silicon) illuminated by the supercontinuum light.

“We did it two different ways,” Dennis says. “First we adjusted our light to 100 mW per square centimetre, which is the average for solar radiation reaching the Earth’s surface. The match to NREL’s data was pretty good, but still off by around 10 percent, illustrating the challenge of an absolute calibration measurement. The discrepancies are likely caused by beam non-uniformity and spectral mismatch.

“In the second method, we just did whatever it took to tune the intensity until we got exactly the same current density for each sample that NREL

did. Then we measured the efficiency, and the difference went down to 5 percent. Some materials showed even better agreement with the NREL results.”

If the super-continuum system eventually joins xenon as an accepted standard solar simulator, Dennis says, it could alleviate a number of difficulties that arise in studying the newest high-tech PV materials. For one thing, its collimated beam can be tightly focused to selectively probe and excite very small features such as nanowires and carbon nanotubes.

Another advantage of the novel solar simulator may be in the testing of multi-junction solar cells. According to NREL researcher Daniel Friedman, who develops III-V multi-junction concentrator cells, “The highest-efficiency solar cells use multiple junctions, with each junction tuned to a different slice of the solar spectrum. To test these multi-junction cells, the spectrum of light from the solar simulator must be rapidly and accurately adjusted, which PML’s supercontinuum simulator provides.”

Testing will continue on additional PV materials, along with ongoing research into using a focused beam to produce spatial maps of materials.

## STMicroelectronics unveils SiC modules for solar applications

The firm’s expanding portfolio of silicon carbide power devices increases energy yield for the solar generation

STMicroelectronics is revealing innovations in SiC devices at Solar Power International (SPI) 2012.

The firm’s latest products enable systems producers to build ultra-efficient electronics for converting raw solar energy into grid-quality power.

The firm is showcasing its 1200V SiC diodes, which replace ordinary silicon diodes, in the DC-DC boost converter and DC-AC inverter. They convert the photovoltaic module’s low-voltage output into high-quality AC power at the correct line voltage.



As a base material for diodes targeting solar-power conversion applications, SiC is superior to ordinary silicon bipolar technology. SiC diodes can switch rapidly between conducting and non-conducting states without suffering the reverse recovery current that occurs when switching bipolar diodes.

Eliminating this unwanted effect saves up to 70 percent of energy normally lost, maintains high efficiency over a wide temperature range, and enhances freedom for designers to optimise the system operating frequency.

ST's trials using 1200V silicon carbide diodes have shown a 2 percent increase in overall inverter yield, even when operating at high loads and high frequencies. Over the intended lifetime of inverters used in installations such as residential photovoltaic systems and high-power solar farms, this improvement can effectively save many Megawatt-hours of valuable energy.

At SPI 2012, ST will also reveal progress in its SiC MOSFET program. These will be among the world's first commercial SiC MOSFETs; an advanced class of devices predicted to offer an alternative to high-voltage silicon IGBTs (Insulated Gate Bipolar Transistor) in solar inverters, delivering a number of advantages. In addition to saving at least 50 percent of IGBT energy losses, SiC MOSFETs require no special drive circuitry and can operate at higher frequencies. This enables designers to miniaturise other components in the power supply thereby reducing cost and size as well as enhancing energy efficiency.

Further applications for SiC MOSFETs and diodes include bulk power supplies used in energy-hungry computer rooms and data centres, and motor-drive electronics in electric vehicles.

## Manz CIGS solar power trumps fossil fuels

CIGS solar power from Manz is now at a similar cost level to electricity from fossil fuels and much cheaper than offshore wind. The firm has also set a world record of 14.6 percent total panel efficiency for thin films on a mass production line

The German firm Manz has achieved what it says is a technological breakthrough.

The company's integrated production line for CIGS thin-film solar panels, the Manz CIGSfab, can be used to manufacture solar panels that in the future will supply power costing between four euro cents (Spain) and eight euro cents (Germany) per kilowatt hour, depending on the location.

This means the cost of solar power is on a similar level to electricity from fossil fuels and much cheaper than electricity from offshore wind parks.

Taking onto account taxes and duties as well as the rapidly increasing costs of fossil fuels, the green electricity clearly trumps the competition. According to Dieter Manz, founder and CEO of Manz AG, "The new technology has the potential to revolutionise the solar industry."

The CIGS solar panel from Manz was manufactured on a mass production line and has a total panel efficiency of 14.6 percent, a world record in thin-film technology.



*Manz achieves breakthrough in the thin-film solar sector with panel that sets the world record for efficiency*

Manz believes it not only cuts the cost of solar power through a significant increase in panel

efficiency, but also through advancements in the production technology used to manufacture the panels, for example by integrating an increasing number of process steps within the process chain.

“The thin-film panels manufactured on our systems are competitive everywhere in the world,” says Dieter Manz. “And as a result, the solar market’s growth will no longer be dependent on national subsidy conditions.”

CIGS thin-film solar panels can be manufactured for significantly less than crystalline silicon panels. This is because the semiconductor layer, which absorbs the sunlight, is comprised of one half affordable copper and is less than two millimetres thick – one-hundredth of a crystalline cell.

What’s more, when manufacturing thin-film solar panels based on glass, both the complex silicon wafer production process and the need to connect the individual cells together are eliminated. The entire panel can be manufactured on a fully automated production line.

In the past, however, thin-film panels could not keep up with the efficiency rates of crystalline silicon panels – a drawback that Manz systems like the fully automated CIGSfab now make up for. The world record panel is the first time the efficiency of polycrystalline silicon solar panels has been achieved with a thin-film panel.

CIGS is considered the solar technology with the greatest potential to further cut costs and increase efficiency rates in the future. On the negative side, it contains the toxic and expensive group III elements indium and gallium.

Manz manufactured the world record CIGS panel on its own innovation line in Schwäbisch Hall, Germany. Manz acquired this line from panel manufacturer Würth Solar at the beginning of the year. As a result, the high-tech engineering firm has the ability to test and optimise new materials and production processes under mass-production conditions.

Manz claims to offer the only turnkey production line for CIGS thin-film solar panels currently available (CIGSfab). The firm has succeeded in cutting the investment costs for the line by around 40 percent since it began working with the technology back in

2010.

In doing so, the company benefited from its wide-ranging expertise in a variety of technological fields, including automation, laser processes, vacuum coating, metrology, and wet-chemical processes. In this process, the high-tech engineering firm uses synergies that result from making advancements to these technologies in its three strategic areas of business: Solar, Display, and Battery.

## First Solar secures 25MWAC project in Rajasthan

The Rajasthan Project, which will employ First Solar’s cadmium telluride solar panels, is part of the Indian Jawaharlal Nehru National Solar Mission

First Solar and Green Infra Limited have signed an agreement for the supply of First Solar’s advanced, CdTe thin-film solar modules for a 25 megawattAC (MW) project in the Indian state of Rajasthan.

The project is part of the second batch of utility-scale solar projects concluded under India’s Jawaharlal Nehru National Solar Mission, which aims to install 20,000 MW of new solar electricity generating capacity by 2022. First Solar will supply the modules for the project, which has been developed by Green Infra, which in turn has awarded the EPC contract to Juwi.

“Today, India is on the path of becoming one of the leading nations in the solar energy sector, and we are excited to be a part of this journey. Our latest project with Green Infra is a significant project under the National Solar Mission that will help India meet its energy security needs,” says Sujoy Ghosh, First Solar’s India Country Head. “Large-scale solar photovoltaic power plants are the key to achieving economies of scale and reducing the cost of solar electricity for everyone.”

“We are pleased to partner with First Solar again for this critical project,” adds Shivanand Nimbargi, Managing Director and Chief Executive Officer of Green Infra.

The project is expected to produce 46 million kilowatt hour units of clean electricity per year, equivalent to the annual electricity needs of more



than 19,000 average Indian households, and to displace more than 44,000 metric tons of CO<sub>2</sub> per year based on national averages.

Green Infra currently has 240 MW of operating assets under management in Tamil Nadu, Karnataka, Maharashtra and Gujarat.

## TSMC Solar CIGS modules hit 14.2% efficiency

The firm's current commercial TS CIGS Series which achieve 13 percent module efficiency which span 130W - 140W panels, are set to increase when the new more efficient modules go into mass production

TSMC Solar has successfully manufactured 14.2 percent efficient modules using its R&D and pilot production line at TSMC's highly-automated manufacturing facility located in Taichung, Taiwan.

These panels have entered the UL and IEC certification process with availability expected early in 2013.

TSMC has also achieved rapid improvement in its production modules, which are currently and consistently achieving 13 percent module efficiency. With this progress, the TS CIGS Series product line-up has been upgraded to span 130W - 140W panels.

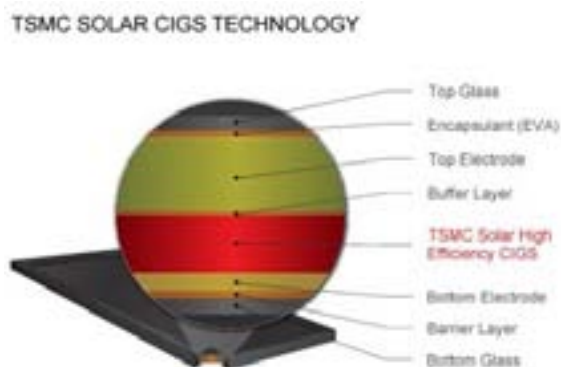
"These significant improvements achieved since entering pilot production in March of this year demonstrate our ability to make rapid technology advancements. We are confident that our focus on technology improvement will enable us to continue driving efficiencies significantly higher for the next few years," says Ying-Chen Chao, President of TSMC Solar.

Since commencing customer shipments in April this year, TSMC modules have been sold to customers in the major solar markets worldwide including Germany, Italy, USA, China and India. "Customers appreciate the TS CIGS Series all-black aesthetics, energy yield advantages in hot climates and the additional yield contributed by plus-sorting and light soaking benefits," adds Stephen McKenery, TSMC Solar Worldwide Sales Head.

The main concept common to all thin-film modules is the use of a single, very thin deposited layer of semiconductor material in order to avoid the high costs of the raw materials and energy required to produce high-purity silicon wafers. A variety of semiconductor materials are used to make thin-film modules. The ones in commercial production include amorphous silicon, micromorph silicon, CdTe and compounds made of CIGS.

Unlike typical crystalline silicon module production, producing thin-film modules involves depositing thin layers of semiconductor material on a surface made of glass, metal or plastic, typically at 250 - 500°C (according to the type of material), whereas only about a tenth of the semiconductor material used in silicon wafers is required and significantly less energy needed.

As a result, the production process only has one step, making the cells, because the cells don't have to be assembled individually, placed in an array and then interconnected for thin-film modules. Instead, they're an intrinsic part of the module's layer structure. A schematic of TSMC's CIGS module is shown below.



TSMC Solar's advanced CIGS process uses sputtering to achieve low costs and flexibility in the deposition of the complex films required to produce high-quality CIGS modules.

TSMC Solar will be exhibiting at the upcoming Solar Power International, Orlando on Sep 11th - 13th (Booth 2049) and at the European PVSEC, Frankfurt on Sep 25th- 28th in Hall 3.1, Booth F22.

## Ascent Solar debuts EnerPlex charger in Korea

The EnerPlex for iPhone 4 and 4S employs Ascent's ultra-light, thin and flexible solar CIGS panels. It enables users to provide supplementary charging of their iPhones with sunlight as well as conventional charging methods to extend usage time.

CIGS innovator Ascent Solar Technologies has announced the retail debut of the company's EnerPlex solar assisted battery case for the iPhone 4 and 4S with Korean distributor H3P Co., Ltd.

The EnerPlex cases are available at selected retail stores and online through the distributor's website at [www.h3p.co.kr](http://www.h3p.co.kr) as well as several popular online stores in Korea such as Naver's "Shop N" and E-Bay Korea's "G-Market."

The EnerPlex for iPhone 4 and 4S takes advantage of Ascent's ultra-light, thin and flexible solar panels and enables iPhone users to provide supplementary charging of their iPhones with sunlight in addition to conventional charging methods to extend the usage time of iPhones.



*Enerplex charger for Apple iPhone*

The EnerPlex case for iPhone is uniquely enabled by the lightweight, thin and highly customisable form factor of Ascent's CIGS solar cells, allowing solar technology to be integrated into the thinnest and lightest solar-enabled iPhone case on the market.

Ascent Solar's President and CEO, Victor Lee, says, "We are excited to provide consumers, for the first time, the ability to experience the transformational qualities of Ascent's award-winning

CIGS solar technology through a product that complements one of the most popular consumer devices in history, Transforming Everyday Life. Meanwhile, we will be stepping up our effort to unveil this exciting product to US consumers in time for the holiday season."

## Opel to sell solar assets to NSM

The completion of this sale should enable Opel to achieve its objective of dissociating its solar division in order to focus on the III-V compound semiconductor POET platform technology of Opel's ODIS division.

Opel and its subsidiary Opel Solar, Inc. have entered into an agreement with Northern States Metals (NSM) of West Hartford, Connecticut, involving the sale of most of the company's solar assets.

The agreement is subject to NSM completing its due diligence review and execution of definitive legal documentation.

NSM has manufacturing facilities in Youngstown, Ohio and Toronto, Ontario, with corporate offices in West Hartford, Connecticut. The firm is the developer and manufacturer Solar FlexRack, a photovoltaic mounting system which first came to market in 2009 and now has more than 350 MW worth of systems installed in North America.

The completion of a definitive agreement is conditional, among other things, upon the company being able to enter into satisfactory repayment arrangements with its solar creditors. The completion of a definitive agreement is also conditional upon the firm being able to enter into satisfactory arrangements with certain of its employees and consultants.

"We are excited about Opel's Solar Tracker," says Tom Meola, President and CEO of NSM. "It broadens our Solar FlexRack product line, and Opel's Solar Tracker is perfect for the kind of utility-scale projects that we're now targeting. The Opel Tracker technology is a proven system that is designed to increase the yield of a Photovoltaic System by up to 30 percent."

He continues, "It eliminates inter-row shadowing, allowing for larger systems to be installed in a smaller area. Solar FlexRack has been successfully marketed as the mounting system with the fastest installation time, substantially lowering labour costs. Likewise, the Opel Solar Tracker is designed for efficient installation – a complete 10 kW system can be assembled in less than four hours."

"The Opel Tracker acquisition fits well with the NSM mission to continually lower the balance of system costs for large solar projects," adds Meola. "We are working to make solar a more efficient and cost effective energy alternative."

Leon Pierhal, President and CEO of the Company states, "The completion of this sale will enable Opel to achieve its objective, announced on June 20, 2012, of divesting its Solar Division in order to focus on the POET platform technology of Opel's ODIS Division."

The POET platform is based on GaAs multijunction solar cell technology, which the company intends to focus on in the future. Opel's ODIS Inc. subsidiary designs the III-V semiconductor devices for military, industrial and commercial applications, including infrared sensor arrays and ultra-low-power random access memory; and through Opel Solar, Inc., provides PV systems for energy applications.

The Company has 37 patents issued and 13 patents pending, primarily for its semiconductor POET process, which enables the monolithic fabrication of integrated circuits containing both electronic and optical elements, with potential high-speed and power-efficient applications in devices such as servers, tablet computers and smartphones.

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## Opel extends financing for GaAs solar innovation

The firm is trying to further develop its III-V compound semiconductor POET technology by extending financing to 7th September

OPEL Technologies (Opel) has completed to date a total of \$1,557,420 of a \$3,000,000 private placement, with IBK Capital Corp., acting as agent.

On a best efforts basis, IBK is now offering up to 13,043,478 units at a price of \$0.23 per unit for proceeds of up to \$3,000.

Each unit consists of one common share and one common share purchase warrant. One full warrant allows the holder to acquire one common share of Opel for a period of three years at an exercise price of \$0.35 per share.

Only last week, the firm said it had set up two special committees to push its POET platform based on its ODIS Inc. division's III-V solar technology. To advance this platform it looks like Opel needs more financing.

The firm says securities issued pursuant to the offering are subject to a hold period which expires four months and one day following closing. Opel will pay a cash commission of 7 percent of the funds raised and 10 percent of the units sold in the form of broker warrants. Each broker warrant allows the holder to acquire one common share of Opel at a price of \$0.23 for 48 months after the closing date.

Opel has agreed with IBK, subject to acceptance by the TSX Venture Exchange, to extend the closing of the remainder of the offering to September 7th, 2012.

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## Asia Pacific to fire up PV demand

Europe has historically fuelled strong year-end PV demand but Q4'12 will represent a transition phase within the PV industry to the APAC region

PV demand from the Asia Pacific (APAC) region is forecast to grow by a whopping 80 percent year over year during the second half of 2012, driven by Q4'12 demand at the 5.3 GW level,.

This is according to new research featured in the "NPD Solarbuzz Asia Pacific Major PV Markets Quarterly" report.

While major European markets have historically fuelled strong year-end PV demand, Q4'12 will represent a transition phase within the PV industry, as demand becomes increasingly global and further diversified across new and emerging PV regions.



According to Wolfgang Schlichting, Research Director at NPD Solarbuzz, “Strong growth in APAC and other emerging PV markets is providing new impetus for companies active within downstream PV segments. However, in established PV markets, the short-term business environment will remain challenging for the remainder of 2012, with continued reductions in incentive policies and uncertainties due to the on-going trade disputes.”

There has been a shift in Q4’12 demand from major European markets to the APAC region as shown in the graph below.



Source: NPD Solarbuzz *European PV Markets Quarterly and Asia Pacific Major PV Markets Quarterly*

Growth across APAC has already provided a significant boost to overall Q2’12 demand. The region showed more than 60 percent Y/Y growth, reaching 1.4 GW and compensating for the softening in demand across established markets. In particular, PV market demand in China grew by over 300 percent in Q2’12 to reach 0.6 GW, stimulated by deadline requirements for the completion of Golden Sun PV projects.

Another APAC country providing new downstream opportunities is Japan. Combined with the year-end projects planned within China and India, the new Japanese Feed-In Tariff (FIT) program is now setting up Q4’12 as a quarter of potentially massive PV demand pull across the APAC region. Over 50 percent (or 5.3 GW) of calendar-year 2012 APAC demand is forecast to occur in Q4’12.

However, this boom at year-end in APAC provides both challenges and risks for module suppliers, balance-of-systems providers, and project developers. PV demand within many APAC regions continues to be characterized by highly-competitive pricing with low-margin returns. In addition, any

delays in project financing could lead to oversupply at year-end ahead of a seasonally-driven downturn in Q1’13, when APAC demand is forecast to decline to just 2.1 GW.

Despite the expiration of the federal cash grant in the US, the North American PV market grew 50 percent Y/Y to 1.4 GW in 1H’12. The Renewable Portfolio Standard (RPS) continues to be a key driver in North America, accelerating deployment of utility-scale projects, not only in California and Arizona, but also Illinois. Driven by RPS compliance requirements, the US market is forecast to add 1.2 GW of ground-mount PV systems in 2H’12, representing 60 percent of the second-half US demand, according to the “NPD Solarbuzz North America PV Markets Quarterly” report.

The European PV market grew 32 percent Y/Y during 1H’12 to 8.5 GW. However, incentive reductions in Germany, Italy, and other major European PV markets continue to erode the demand-share previously commanded by these former PV market leaders. Growth opportunities within Europe are forecast to shift to emerging markets during the next couple of years, including Austria, Denmark, Israel, and various countries in the east and southeast of Europe.

Over the coming quarters, the global PV market will remain highly competitive with existing PV manufacturers under extreme pressure to expand into the downstream channels as a perceived higher-margin segment. “The ability to adjust quickly to changing market conditions arising from sudden policy changes, trade action, or competitive strategies will become essential for industry participants,” concludes Schlichting.

# Power Electronics

## GaAs device revenue reaches new heights

Although 2011 revenues hit a record \$5.2 billion, growth is expected to slow down in the future

According to Strategy Analytics, a fast start to 2011 allowed the GaAs device market to withstand a slowdown toward the end of the year and post record revenue for 2011.

Continuing growth in demand for handset power amplifiers offset ongoing uncertainty in the global economy to propel the market to growth from last year's value. The market research firm's most recent report, "GaAs Industry Forecast: 2011-2016", reports the overall GaAs device market grew by roughly 6 percent to close 2011 with slightly more than \$5.2 billion of revenue.

The report also forecasts that slowing smartphone growth and an uncertain global economy will limit future growth rates below historical averages and the market will reach slightly more than \$6.1 billion in 2016.

"The GaAs market began the year with strong growth", notes Eric Higham, Director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs). "Toward the end of the year, slowing growth in the smartphone segment and uncertainty in the global economy became the overriding trends and the overall GaAs device market slowed substantially. The underlying trends in the GaAs market still support growth, but uncertainty in the economy is likely to limit this growth."

Asif Anwar, Director in the Strategy Analytics Strategic Technologies Practice adds, "We remain convinced that data consumption and GaAs content in handsets will increase, but fluctuations in the global economy will put a damper on network and consumer spending."

## Ammonia speeds MBE growth of GaN-on-silicon HEMTs

Gallium nitride transistors with good structural and electrical characteristics have been produced by ammonia MBE on a 100 mm silicon substrate

Researchers from Nanyang Technological University, Singapore, claim that they have produced the first crack-free, GaN-based HEMTs on 100 mm silicon substrates by ammonia MBE.

The substrate that they have used, silicon, is an excellent choice for producing GaN HEMTs, because it is cheap, available in large diameter formats and can produce transistors that can be processed through depreciated silicon lines.

By far the most common method for depositing the epilayers of the HEMT on silicon is MOCVD. However, according to the researchers from Singapore, this has several weaknesses compared with MBE.

In their opinion, MBE is a more flexible growth technique that delivers sharper interfaces and enables growth at lower temperatures, which aids the management of thermal mismatch between substrate and epilayers. What's more, they claim that MBE allows in-situ monitoring of the growth surface, leading to real time growth process control at the monolayer scale.

The Singapore team favours ammonia MBE over its plasma-assisted (PA) variant, because it is difficult to control the III-V ratio with the latter technique. In addition, due to the low nitrogen molecular cracking efficiency – typically 1 percent to 10 percent – growth rates are typically below 0.4  $\mu\text{m/hr}$  for PA MBE.

Using ammonia MBE, the team from Singapore have produced crack-free epilayers at growth rates of up to 0.75  $\mu\text{m/hr}$ , nearly double that typically used in PA MBE. Faster growth doesn't just save time – it also improves morphology, by accelerating the transition from three-dimensional to two-dimensional growth and suppressing defect formation.

This trimming of the defect density is revealed in cross-sectional images of the lower part of the epitaxial stack: The 50 nm-thick AlN nucleation layer, 200 nm-thick GaN and AlN stress mitigation layers, and the GaN buffer. The nucleation layer and lower GaN layer are riddled with defects, but many dislocations terminate at the interface between the second AlN layer and the GaN buffer, and a substantial proportion of those that propagate into this second buffer bend and interact within the first few hundred nanometres.

Estimations based on X-ray diffraction analysis suggest that the density of screw-type dislocations in the GaN buffer falls from  $7.7 \times 10^9 \text{ cm}^{-2}$  to  $2.1 \times 10^9 \text{ cm}^{-2}$  when the buffer thickness is increased from 0.9  $\mu\text{m}$  to 1.7  $\mu\text{m}$ . Resistance mapping of the HEMT epiwafers, which have a 28 nm-thick Al<sub>0.25</sub>Ga<sub>0.75</sub>N barrier and a 2 nm-thick GaN cap deposited on the GaN buffer, show an average sheet resistance of 368  $\Omega$  /square.

Meanwhile, room-temperature Hall measurements reveal that the carrier density and mobility of the two-dimensional electron gas are  $1.2 \times 10^{13} \text{ cm}^{-2}$  and 1350  $\text{cm}^2/\text{Vs}$ . Cool the sample to 90K, and mobility rises to 4290  $\text{cm}^2/\text{Vs}$ .

To determine the electrical characteristics of the buffer layer, engineers formed test structures with two ohmic contacts with a gap of 5  $\mu\text{m}$ . A structure with a 1.7  $\mu\text{m}$ -thick buffer produced a buffer leakage current of  $2.6 \times 10^{-4} \text{ mA/mm}$  at 20 V and had a ratio between on-current and off-current of  $7.3 \times 10^6$ .

HEMTs with 0.3  $\mu\text{m}$  T-shaped gates were formed on high-resistivity silicon. These transistors delivered a peak drain current of 768  $\text{mA/mm}$ , produced a maximum transconductance of 190  $\text{mS/mm}$  and exhibited a threshold voltage of -4.53 V.

Further details of this work have been published in the paper, " Demonstration of AlGa<sub>0.25</sub>N/GaN High-Electron-Mobility Transistors on 100-mm-Diameter Si(111) by Ammonia Molecular Beam Epitaxy", by N. Dharmarasu *et al* in *Applied Physics Express* 5 091003 (2012). DOI:10.1143/APEX.5.091003

## TriQuint wins GaN contract to triple RF PA performance

The firm will use its gallium nitride on silicon carbide experience to improve its power amplifier devices

TriQuint Semiconductor has received a \$2.7 million contract from the Defense Advanced Research Projects Agency (DARPA) to triple the power handling performance of GaN circuits.

The Near Junction Thermal Transport (NJTT) effort will build on TriQuint's advanced GaN-on-SiC technology and the reliability of its state-of-the-art RF integrated circuits.

"We are very pleased that DARPA selected TriQuint to develop this critical technology. Like other programs we have supported, NJTT will set the stage for substantial MMIC performance enhancements including reduced size, weight and power consumption while increasing reliability and output power," says TriQuint Vice President and General Manager for Infrastructure and Defence Products, James L. Klein.

The NJTT initiative is the latest in DARPA's overarching Thermal Management Technologies program. NJTT focuses on thermal resistance at the 'near junction' of the transistor die as well as the device substrate. These areas can be responsible for more than 50 percent of operational temperature increases. By combining its GaN-on-SiC process technology with diamond substrates and new thermal handling processes, TriQuint seeks to significantly reduce heat build-up to enable GaN devices that can generate much more power.

TriQuint's partners in the program include the University of Bristol in the United Kingdom, Group4 Labs and Lockheed Martin. The University of Bristol is recognised for its leadership in thermal testing, modeling and micro Raman thermography. Group4 Labs is a pioneer in the use of diamond substrates and has worked with TriQuint to demonstrate diamond's potential as a substrate material. Lockheed Martin will evaluate the results of the program for its projected impact on future defence systems.

TriQuint has pioneered GaN technology since 1999 and is currently working on multiple process and



manufacturing initiatives for DARPA as well as the U.S. Air Force, Army and Navy laboratories.

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## Entegris opens European facility to provide SUPERSiC products

The plant in France will provide silicon carbide products as well as specialised coatings used in semiconductor processing

Entegris has opened a new facility in the Techlid region of Lyon, France to provide specialised silicon and diamond-like coatings to support Europe's semiconductor, industrial, and plastics industries.

The new plant will also house the company's European office to support the sale of line of POCO graphite and SUPERSiC SiC products.

To manufacture the coatings, the facility will use a proprietary Plasma Enhanced Chemical Vapour Deposition (PECVD) process that ensures no change to the hardness of the substrate, even to those processed at low temperatures.

These coatings are ideal for a variety of high purity processes and components for applications including semiconductor processing chambers and materials handling.

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## Mitsubishi Electric to set up green facility in Japan

The manufacturer of silicon carbide based power devices has received green designation from Fukuoka Prefecture

Mitsubishi Electric Corporation has been designated as a "Green Asia Special Global Strategy Synthesis Area" company in Japan's Fukuoka Prefecture.

Under this designation, Mitsubishi Electric's Fukuoka-based Power Device Works, a base for the development and manufacture of power devices, will accelerate development of new technologies and products including SiC power devices.

Mitsubishi Electric develops and manufactures low-loss power devices. The new designation reflects the company's development of environmentally conscious, functional and cost-effective products, as well as production bases, which is a main goal of the Green Asia Special Global Strategy Synthesis Area project.

The firm plans to strengthen its power device technologies and capabilities, and accelerate product development at its Power Device Works by building a new facility where related design and development divisions will be consolidated, while also making further investments.

In addition to facilitating closer interaction between the divisions, the consolidation will free up space at the Works for new product sample evaluation, creating further operational efficiency. The company will concentrate on accelerating the development of new technologies and power device products for which demand is growing and becoming more diversified.

High-energy-performance power devices are used in products ranging from air conditioners, refrigerators and other consumer appliances to equipment for industry and railroads. The growing proliferation of hybrid and electric vehicles, solar- and wind-power generation and similar developments are expected to raise the global demand for power devices even further.

The new building is approximately 1,800 square metres and has a floor space of about 10,500 square metres. The plant is scheduled to be completed in February 2014 and is estimated to start being used the following month. The investment is approximately JPY 2.5 billion (or roughly \$0.032 billion).

Kitakyushu and Fukuoka cities in Fukuoka Prefecture have been designated as Green Asia Special Global Strategy Synthesis Areas by the Japanese government based on the Cabinet Office's "Special Zone Measure" policy. Leveraging industries, technologies, human resources, networks and others resources accumulated in the region, projects are being carried out in line with four initiatives.

The first two aims are in exporting urban environmental infrastructure packages in Asia and

developing environmentally conscious products along with their production bases. The other goals are to establish a resource recycling system and realising a borderless business environment in Asia.

## Transphorm awarded for advancing GaN power technology

The innovator of gallium nitride design and process technologies has been honoured for enabling implementation of highly-efficient power conversion systems

Transphorm has been selected by the World Economic Forum as a 2013 Technology Pioneer, citing the company's innovations in GaN technology.

The World Economic Forum selected its 2013 Technology Pioneers in the areas of information technology, telecommunications and new media, energy and environment, and life sciences and health, based on demonstrative vision and leadership in their fields, innovative ideas and approaches, and their impact on society and business.

"Transphorm is delighted and honoured to be selected as a Technology Pioneer by the World Economic Forum," says Transphorm CEO Umesh Mishra. "By redefining power conversion using our proprietary gallium nitride-based products, Transphorm is solving the immediate and urgent problem of unnecessary waste in power conversion, saving valuable resources and enabling new energy efficient systems today."

Transphorm says its efficient, compact, and easy-to-use solutions can cut total world electrical energy waste by as much as 10 percent and simplify the design and manufacturing of a wide variety of electrical systems and devices, including motor drives, power supplies and inverters for solar panels and electric vehicles.

## Transphorm unveils first JEDEC qualified 600V GaN HEMT

The 600V gallium nitride-on-silicon carbide device employs the firm's EZ-GaN technology

Transphorm has gained JEDEC qualification of its TPH2006PS, GaN HEMT (High Electron Mobility Transistor) grown on a SiC substrate.

The firm says this is the industry's first qualified 600V HEMT device.

The TPH2006PS, based on its patented, EZ-GaN technology, combines low switching and conduction losses resulting in reduced energy loss of up to 50 percent compared to conventional silicon-based power conversion designs, today. The TO-220-packaged device features RDS(on) of 150 mΩ, Qrr of 42 nC and high frequency switching capability that enables compact, lower cost systems.

"Our team has accomplished the first qualification of a 600 V GaN Transistor product, allowing our customer-partners to now introduce energy saving products, Powered-by-Transphorm", says Primit Parikh, President of Transphorm. "This development also lays to rest any doubts that high voltage GaN transistors can indeed be successfully qualified".

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

For customers looking for a low-risk roadmap to the next generation of power conversion technology, Transphorm says its proprietary EZ-GaN provides a cost-effective, customisable and easy-to-use solution ready for commercial scale.

## STMicroelectronics unveils SiC modules for solar applications

The firm's expanding portfolio of silicon carbide power devices increases energy yield for the solar generation

STMicroelectronics is revealing innovations in SiC devices at Solar Power International (SPI) 2012.

The firm's latest products enable systems producers to build ultra-efficient electronics for converting raw solar energy into grid-quality power.

The firm is showcasing its 1200V SiC diodes, which replace ordinary silicon diodes, in the DC-DC boost converter and DC-AC inverter. They convert the photovoltaic module's low-voltage output into high-quality AC power at the correct line voltage.



As a base material for diodes targeting solar-power conversion applications, SiC is superior to ordinary silicon bipolar technology. SiC diodes can switch rapidly between conducting and non-conducting states without suffering the reverse recovery current that occurs when switching bipolar diodes.

Eliminating this unwanted effect saves up to 70 percent of energy normally lost, maintains high efficiency over a wide temperature range, and enhances freedom for designers to optimise the system operating frequency.

ST's trials using 1200V silicon carbide diodes have shown a 2 percent increase in overall inverter yield, even when operating at high loads and high frequencies. Over the intended lifetime of inverters used in installations such as residential photovoltaic systems and high-power solar farms, this

improvement can effectively save many Megawatt-hours of valuable energy.

At SPI 2012, ST will also reveal progress in its SiC MOSFET program. These will be among the world's first commercial SiC MOSFETs; an advanced class of devices predicted to offer an alternative to high-voltage silicon IGBTs (Insulated Gate Bipolar Transistor) in solar inverters, delivering a number of advantages. In addition to saving at least 50 percent of IGBT energy losses, SiC MOSFETs require no special drive circuitry and can operate at higher frequencies. This enables designers to miniaturise other components in the power supply thereby reducing cost and size as well as enhancing energy efficiency.

Further applications for SiC MOSFETs and diodes include bulk power supplies used in energy-hungry computer rooms and data centres, and motor-drive electronics in electric vehicles.

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## Tianyu expands SiC power device epitaxy facilities

The firm, which grows 4", 3" and 2" silicon carbide wafers, is expanding to cope with increased demand from the power market

Tianyu Semiconductor Technology, one of the first SiC epitaxial wafer companies in China, has started to expand its SiC epitaxial wafer business globally.

The company made this move after completing three contracts prior to this in August 2012.

"The prospects of the SiC are bright," says Li Xiguang, GM of Tianyu. "SiC substrate is getting better, larger and cheaper; more attention is paid on this market. SiC device will show more competitiveness in the global market."

According to market analysts at Yole Développement, the SiC device market will be netting a billion dollars in a decade.

SiC epitaxial wafers are used in producing Schottky diodes, MOSFETs, JFETs, and BJTs over a wide voltage range and customised wafers for thyristors, GTOs and IGBTs over a wider voltage range for medium to very high voltage power conversion



system applications.

These devices are used for energy efficient power electronic devices for numerous applications, such as air-conditioning, solar and wind turbine inverters, hybrid and electric vehicles, high speed trains, smart grids and high-voltage DC power transmission. SiC-based semiconductor devices can reduce energy losses and system size, leading to overall reduced system costs and enhanced reliability.

Tianyu was founded on January 7th, 2009, and is located in China's Songshan Lake National High-tech Industrial Development Zone of Dongguan City in Guangdong province.



*Tianyu facility in Dongguan City*

The firm has six major researchers and 30 engineers working on the SiC epitaxial technology growth. The epitaxial wafers are 4", 3", and 2". Production capacity is 10000 pieces per month, which can be increased if needed, and product specifications reach the advanced level in international standards.

## EPC to update Safe Operating Area data on eGaN FETs

The firm says its enhancement mode gallium nitride FETs exhibit a positive temperature coefficient across their entire operating range, thus overcoming one of the performance limitations of the silicon MOSFET

Efficient Power Conversion Corporation (EPC) is releasing safe operating area (SOA) data for its entire product line of eGaN FETs.

The positive temperature coefficient across virtually

their entire operating range allows a square SOA limited only by average device temperature.

SOA is an indicator of the device's ability to transfer heat away from a resistive junction. The more efficient a device is at getting rid of generated heat, the lower thermal resistance and the better the SOA performance.

EPC says its eGaN FETs have many major advantages over the power MOSFET needed for today's high performance applications. The firm's eGaN FET's are claimed to offer superior device on-resistance while its positive temperature coefficients inhibit hot spot generation within the die, resulting in superior Safe Operating Area capabilities.

An application note presenting the Safe Operating Area for EPC eGaN FETs is available at: <http://epc-co.com/epc/documents/product-training/SafeOperatingArea.pdf> In addition, EPC is in the process of updating each of its product data sheets to include SOA performance curves.

EPC's enhancement mode GaN based power management FETs are power MOSFET replacements in applications such as servers, wireless power transmission, envelope tracking, RF transmission, power-over-ethernet (PoE), solar micro inverters, energy efficient lighting, and class-D audio amplifiers.

## First GaN vertical diode with 3000V breakdown

Using a new technique known as void-assisted separation, Hitachi Cable has developed gallium nitride power devices with low dislocation densities and a very high breakdown voltage

Hitachi Cable says it has succeeded in the trial manufacture of the world's first GaN vertical diode with a reverse breakdown voltage of 3,000V or higher and a low on-resistance of about 1mΩcm<sup>2</sup> in the forward direction.

The firm achieved this development through joint research with Toru Nakamura Laboratory in the Research Centre for Micro-Nano Technology of Hosei University and the Hitachi Central Research Laboratory.

In recent years, public interest in power devices as a way to conserve energy has been escalating. Power devices are semiconductors such as diodes and transistors with the ability to convert and control electricity. They are used in a wide variety of fields, including consumer electronics in houses, automobiles, railroad vehicles, and power plants.

Conventional power devices have mainly used silicon. To further reduce energy consumption, however, there has been active development of power devices using new materials which exceed the performance limits of silicon.

The latest device is a GaN vertical *p-n* diode with an electrode diameter of 400 to 800 $\mu$ m in which GaN epitaxial layers are grown on Hitachi Cable's freestanding GaN substrate using MOCVD.



*Appearance of GaN substrates for power devices*

Thanks to the VAS (void-assisted separation) method developed by Hitachi Cable, it was possible to create a stable device with a low dislocation density of 106cm<sup>-2</sup>.

The firm also confirmed that the dislocation defects in the freestanding GaN substrate were only edge dislocations and mixed dislocations ; nowhere on the entire surface of the substrate is there a "core" area where dislocation defects are densely located.

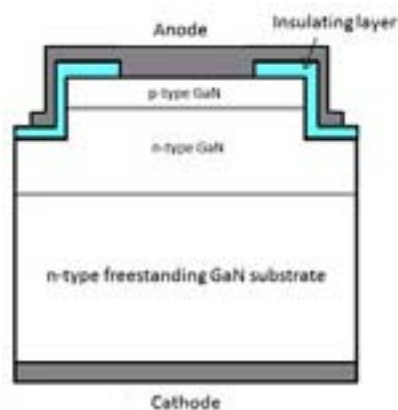
The voltage resistant test using sample diodes confirmed a high reverse breakdown voltage of 3,000V or higher, demonstrating that the dislocation defect in the freestanding GaN substrate is not a killer defect which significantly degrades the performances of power devices. This test also demonstrated that the epitaxial layers grown on the freestanding GaN substrate have a breakdown field which is close to the ideal GaN value (3.3 - 3.8MV/cm).

The test also indicated that the on-resistance of this diode in the forward direction is about 1m $\Omega$ cm<sup>2</sup>, smaller than the sum of the resistances at each layer of the diode. This means that conductivity modulation, which lowers the resistance, occurs when an electric current is injected.

Conductivity modulation is an excellent effect which can increase the performance of a device beyond its material's inherent performance limits. While it is often used in silicon power devices, it has rarely been seen in compound semiconductors, which have short carrier lifetimes.

In terms of this diode, Hitachi's theoretical analyses have suggested that the light generated at a *p-n* junction is re-absorbed by a diode, and that conductivity modulation, which increases carriers, occurs due to the absorption. This time, Hosei University experimentally demonstrated the light-emitting properties of diodes.

These findings demonstrated that the freestanding GaN substrate produced by the VAS method is capable of making possible power devices with a much higher performance index than with conventional materials such as silicon and SiC. High-efficiency power devices based on this development are expected to reduce the power consumed by equipment and facilities in the future.



*A schematic cross-section of a sample diode created in this study*

Hitachi Cable is committed to working on the sales of freestanding GaN substrates to be used in optical devices as well as to the expansion of its compound semiconductor business by putting more effort into expanding the sales of freestanding GaN substrates for power devices and GaN epitaxial wafers grown

using the MOVPE method.

## All American to distribute GeneSiC products

The distributor will sell silicon carbide products used in solar inverters, electric vehicles, wind power, medical power supplies, down hole oil drilling and motor drives

All American Semiconductor, a distributor of electronic components, has signed a distribution agreement with GeneSiC Semiconductor Inc., a provider of SiC and silicon-based high-power semiconductor products.

The company's cost-effective silicon technology is available with quick lead times and is claimed to offer the best forward voltage drop in the industry.

GeneSiC's SiC products feature a high operating temperature range, small heat sink requirements and fast switching speeds. They are also inherently radiation resistant and offer a higher voltage and current capability.

The company's products are used in a variety of industries, such as aerospace, alternative energy, commercial, industrial and military. Applications include solar inverters, electric vehicles, wind power, medical power supplies, down hole oil drilling and motor drives.

"All American is always looking to provide its customers with the most innovative semiconductor technology," says Cory Dana, Corporate Product Manager at All American. "We recognise GeneSiC as a leader in the field and are glad to begin distributing their silicon carbide products."

Founded in 2004, GeneSiC was an early pioneer in SiC technology and holds multiple patents on leading SiC devices.

All American Semiconductor is a distributor of electronic components for some of the world's largest suppliers. The company's complete product offerings include a broad range of active, passive, interconnect and electromechanical components. The company also offers design and technical expertise to meet each customer's individual needs.

GeneSiC capitalises on its core competency in device and process and provides high quality products that are specifically tuned to each customer's requirements. GeneSiC has prime/sub-contracts from major US Government agencies including ARPA-E, US Dept of Energy, Navy, DARPA, Dept of Homeland Security, Dept of Commerce and other departments within the US Dept. of Defence.

## Showa Denko moves towards 150mm SiC growth with Aixtron

Aixtron's CVD reactor will be used to grow silicon carbide power devices employed in consumer electronics, railroad power handling and the automotive markets

Japanese based firm, Showa Denko K.K (SDK) has added an Aixtron SiC CVD Warm-Wall Planetary Reactor system to its equipment collection.

The AIX 2800G4WW reactor is capable of handling either ten 100mm or six 150mm wafers. SDK has increased its four-inch SiC epitaxial wafer production capacity by 2.5 times, to 1,500 units a month, through facility expansion and improvement in production technology.



*AIX 2800G4WW*

The chemical vapour deposition (CVD) system will be used to produce homoepitaxial material on SiC substrates for a range of power electronics applications and devices, such as inverter systems for solar power modules, AC-DC converters and industrial motor controllers.



With the new system, SDK will extend its existing 100mm-diameter wafer production and also migrate production to the larger diameter 150mm SiC wafers that are now becoming available from semiconductor material suppliers. Production on larger wafers should lead to cost reductions and wider market acceptance.

“Aixtron has designed its system to push these economies of scale even further by reducing the wafer edge exclusion zone, increasing chip yields per wafer of larger diameter substrates,” Frank Wischmeyer, Vice President and Program Manager Power Electronics at Aixtron, comments. “The attraction of silicon carbide for such application derives from its unique material properties, such as high critical electrical field strength, allowing high device breakdown voltages and low turn-on resistance. Further advantages for power applications arise from SiC’s higher thermal conductivity and ruggedness at higher operation temperatures.”

A special reactor chamber was developed for the most modern Aixtron Warm-Wall reactor for SiC. It is capable of handling up to the 1650°C, which is needed for the growth of SiC. The six 150mm wafers loaded per batch in the Aixtron system have individual ‘planetary’ rotation during epitaxy, to improve uniformity and reproducibility.

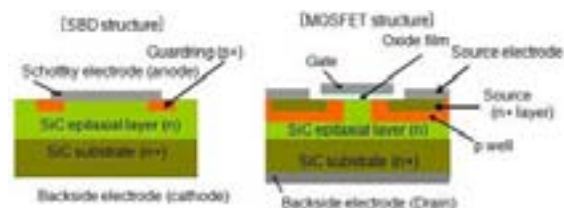
The company sees market opportunities for SiC-based products arising immediately in consumer electronics, and in the longer term in railroad power handling and automotive markets.

The epitaxial SiC business was acquired at the end of 2008 from Esicat-Japan LLP, a spin-off from Japan’s National Institute of Advanced Industrial Science and Technology (AIST), Central Research Institute of Electric Power Industry (CRIEPI) and Showa Denko.

When compared with conventional silicon-based semiconductors, SiC power devices using SiC epitaxial wafers can operate under higher voltages, heavier currents and at higher temperatures.

These features enable reductions in the number of components and miniaturisation of cooling devices, helping to make smaller and lighter power control modules. SiC power devices also reduce energy loss in the process of power control, resulting in a

substantial energy saving.



*Schematics of SBD and MOSFET, based on SiC epitaxial wafers*

SiC power devices are also expected to be used increasingly in inverters (devices for converting direct current into alternating current) to control rotation of motors. Such inverters are already commercialised in some home electric appliances and distributed power supply systems, and used in subway railcars on a trial basis.



*Outline of products related to SiC epitaxial wafers*

What’s more, an increasing number of electric vehicles and hybrid cars are expected to be equipped with inverters using SiC power devices. These inverters contain Schottky barrier diode (SBD), and metal oxide semiconductor field-effect transistors (MOSFETs), based on SiC power devices.

SDK says it can manufacture SiC-MOSFETs, incorporating a surface oxide film which is very smooth. The smooth surface is needed during device operation.

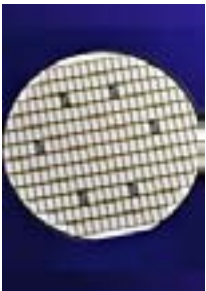
Following the capacity expansion, SDK will continue developing SiC epitaxial wafers with larger diameter, lower defect, and higher uniformity. The firm will concentrate on developing six-inch SiC epitaxial wafers for heavy-current high-voltage applications.

## Cree's 150mm n-type SiC wafers on the market

LED innovator Cree has expanded its product family and is now offering epitaxially grown silicon carbide wafers of 150mm (almost 6 inches) diameter

Cree has announced the availability of high quality, low micropipe 150mm 4H *n*-type SiC epitaxial wafers.

The firm says this latest advancement lowers device cost and enables adoption for customers with existing 150mm diameter device processing lines.



SiC wafer

SiC is a high-performance semiconductor material used in the production of a broad range of lighting, power and communication components, including LEDs, power switching devices and RF power transistors for wireless communications. 150mm diameter single crystal SiC substrates enable cost reductions and increased throughput, while bolstering the continued growth of the SiC industry.

“Cree’s ability to deliver high volumes of 100mm epitaxial wafers is unrivalled in the SiC industry and our latest 150mm technology continues to raise the standards for SiC wafers,” says Vijay Balakrishna, Cree materials product manager. “Our vertically integrated approach assures customers of a complete solution for high quality 150mm SiC epitaxial wafers, providing industry leaders within the power electronics market the stable supply they demand.”

Cree’s 150mm epitaxial wafers with highly uniform epitaxial layers as thick as 100µm are available for immediate purchase.

Cree’s 150mm 4H *n*-type SiC epitaxial wafers

are available for immediate purchase in limited quantities.

## Equipment and Materials

### SP3 Diamond granted new patents for laser applications

The patents awarded to the supplier of diamond products and deposition equipment services, relate to thermal management in packaging. The technology is ideally suited for mounting large semiconductor chips such as high-power transistors and laser diodes where CTE matching is required

sp3 Diamond Technologies, has been awarded two patents by the United States Patent and Trademark Office for its DiaMatch coefficient of thermal expansion (CTE) matched heat spreader technology.

The diamond-based multilayered structure outlined in the patents solves several technical challenges to deliver the high heat spreading and CTE matching required for reliable semiconductor and laser packaging.

“In 2007, we received Phase II SBIR funding from the Missile Defence Agency to develop a thermal management solution that enables the next generation of high power lasers and semiconductors. We had established solid IP in this area and began providing solutions with great potential that target current and future high-power semiconductor and laser applications,” says Dwain Aidala, president and COO of sp3 Diamond Technologies.

“We are currently in the process of identifying the right thermal management or specialised material partners to further develop this technology into a fully productised offering.”

U.S. Patent Nos. 8,105,693 and 8,147,927 cover a multilayered structure including at least one diamond layer and methods of making

these multilayered structures, respectively. The technology detailed in the patents is ideally suited for mounting large semiconductor chips such as high-power transistors and laser diodes where CTE matching is required.

The proliferation of diamond use in technology has seen a dramatic increase in recent years. Formed in 1993, sp<sup>3</sup> Diamond Technologies has been a driving force in that commercialisation.

“We experienced our best year ever in 2011 due in large part to two markets,” continues Aidala. “We saw our diamond heat spreaders adopted in multiple applications, most notably in wireless base stations where the thermal properties of diamond are paying huge dividends. In CMP pad conditioning we sold five times more CVD diamond deposition tools than the previous year. “

“Diamond is being adopted. While our CVD diamond equipment and our heat spreaders remain our primary focus, we see tremendous opportunity for diamond applications in the future. The potential for diamond layers in the SOI-based process alone creates fantastic growth opportunities,” adds Aidala.

Semiconductor devices require packaging with high thermal conductivity to prevent overheating and to maintain useful operation of the device. Existing materials generally deliver good thermal characteristics but poor CTE matching, or are well-matched to most semiconductor materials, but do not offer high enough thermal conductivity for today's devices.

sp<sup>3</sup> Daiamond says its DiaMatch technology bridges this gap by offering variable CTE-matching, copper-level thermal conductivity and a choice of conductive or insulating die attach surfaces. What's more, it delivers precise edges and no compositional variability from point to point in the material.

The new patents detail a multilayered structure of thin diamond layers and high thermal conductivity metal layers and the methods of making the structure. The multilayered structure has a variable CTE, which depends on the various layer thicknesses and can be different on each side. This allows the structure to safely bond to compound semiconductor materials such as SiC, GaAs, and GaN while providing the thermal management

benefits of diamond.

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## LED demand triggers AkzoNobel's multimillion dollar expansion

The firm is expanding its Tri-Methyl-Aluminium and Tri-Methyl-Gallium production facilities in Texas

AkzoNobel is to boost capacity at one of its US sites in order to meet increasing demand from the semiconductor industry, particularly for the production of LEDs. Financial details were not disclosed.

The investment, at the company's Battleground facility in Texas, involves extending the Tri-Methyl-Aluminium (TMAL) unit and building a new Tri-Methyl-Gallium (TMG) plant, consolidating the plant's status as the largest of its kind in the world. TMAL is a feedstock for TMG, a high purity metal organic (HPMO) used in products such as LED wafer manufacturing.

“The LED industry has been experiencing strong growth, well in excess of 20 percent per annum,” explains Werner Fuhrmann, AkzoNobel's Executive Committee Member responsible for Specialty Chemicals. “This investment will make production more cost-efficient and ensure that we continue supplying our customers with a highly specialised product which is playing an increasingly important role in 21st century technology.”

The global LED industry is projected to grow significantly over the next decade, driven by applications in displays such as PCs, laptops and tablet screens. The massive increase in the use of LEDs for general lighting is also expected to contribute strongly as they become the preferred source of light over incandescent bulbs and compact fluorescent lamps, due to their low energy consumption and extended lifetime.

The expanded TMAL unit is expected to be completed in the third quarter of 2013, while the new TMG plant will be ready in August 2014.



## Ocean Optics unveils 1100-1900nm InGaAs spectrometer

The firm's high-resolution NIRQuest512-1.9 utilises one of Hamamatsu's indium gallium arsenide detector

Ocean Optics has added another option to its small-footprint near-infrared spectrometer line with the NIRQuest512-1.9.

The NIRQuest512-1.9 is suited to applications ranging from monitoring changes in food production and chemical processing to characterising lasers for semiconductor assembly and medical treatment.



*NIRQuest512-1.9 system*

NIRQuest512-1.9 has a high-stability, 512-element Hamamatsu InGaAs-array detector and is available with multiple grating and optical bench options for optimising performance between 1100 and 1900 nm.

The standard NIRQuest512-1.9 comes with a 150 lines/mm grating, 25 µm entrance slit and a non-fluorescing longpass filter that transmits over 1000 nm. The filter helps to mitigate second-order effects.

NIRQuest512-1.9 has external hardware triggering functions that allow users to capture data when an external event occurs, or to trigger an event after data acquisition. Spectrometer operation is controlled using SpectraSuite software, a modular, Java-based spectroscopy platform.

The low dark noise characteristics of the NIRQuest make it possible to integrate the spectrometer (or expose the detector in the spectrometer to light) for longer durations, which is useful in low light level environments. Signal to noise ratio at full signal is over 15000:1 at 100 millisecond integration

time. High gain mode operation is available for applications where sensitivity is paramount.

Headquartered in the USA, Ocean Optics is a supplier of solutions for optical sensing - fundamental methods of measuring and interpreting the interaction of light with matter.

## EVG wins first order for ZoneBOND technology in compound semiconductor market

The firm is expanding its proprietary ZoneBOND temporary bonding/debonding process into the CS industry with its first order from a major player

EV Group (EVG) has received an order for its EVG850 temporary bonding/debonding (TB/DB) systems from a leading maker of compound semiconductor-based components.

This order marks the first implementation of ZoneBOND TB/DB technology in the manufacture of compound semiconductors, whose rapid growth is being driven by unrelenting demand for smart phones and other mobile products.

"The compound semiconductor market has always been a front runner in driving the introduction of new temporary bonding/debonding technologies – starting from solvent-assisted debonding, tape debonding, slide off debonding and now ZoneBOND," notes Thorsten Matthias, business development director for EVG.

"EVG has provided TB/DB equipment to the compound semiconductor market for over 10 years. And, the introduction of ZoneBOND is a natural evolutionary step. EVG's low-temperature debonding technology and our ZoneBOND Open Platform approach enable a standardisation of processes and equipment, which provides customers with a wide choice of bonding materials for increased flexibility during thin-wafer processing," adds Matthias.

Since its introduction in October 2011, ZoneBOND TB/DB technology has fast gained a foothold in the semiconductor industry. Companies such as Fraunhofer IZM ASSID, which has expertise in advanced semiconductor R&D, received ZoneBOND equipment for processes and materials qualification as part of a joint-development agreement with EVG.

With a strong supply chain supported by leading materials suppliers and continuing to expand, customers will only continue to have more and more flexibility to choose the material adhesive that best suits their manufacturing requirements and processes.

Initially created to drive the advancement of 3D IC commercialisation, EVG's ZoneBOND technology provides a breakthrough approach for temporary wafer bonding, thin-wafer processing, and debonding applications – overcoming the last remaining limitations associated with thin-wafer processing.

Benefits of ZoneBOND technology include: standardisation of processes and equipment, the use of silicon or glass carriers; compatibility with existing, field-proven adhesive platforms; and the ability to debond at room temperature with virtually no vertical force being applied to the device wafer.

To support grinding and backside processing at high temperatures and to allow for low-force carrier separation, ZoneBOND defines two distinctive zones on the carrier wafer surface with strong adhesion in the perimeter (edge zone) and minimal adhesion in the centre zone.

As a result, low separation force is only required for carrier separation once the polymeric edge adhesive has been removed by solvent dissolution or other means. The EZR (Edge Zone Release) and EZD (Edge Zone Debond) modules can be easily integrated in EVG's high-volume manufacturing equipment platforms such as the EVG850 TB/DB Series.

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## Azur Space orders two Aixtron reactors for solar cells

The firm will use the reactors to manufacture gallium arsenide based cells for terrestrial applications

Aixtron SE has a repeat order for further MOCVD systems from Azur Space Solar Power GmbH of Heilbronn, Germany.

The new contract is for two MOCVD systems to be dedicated to the growth of GaAs materials for the production of concentrated photovoltaic (CPV) solar cells for terrestrial applications.

Aixtron Europe's service support team will install and commission the new reactors during the second half of 2012 in a cleanroom facility in Heilbronn.

Juergen Heizmann, Managing Director of Azur Space Solar Power GmbH, says, "Our existing Aixtron MOCVD systems have more than proved themselves, so now it is time to further expand production with two new systems. Adding more equipment from Aixtron has many advantages in terms of start-up speed, continuity and process transfer.

"It will also ensure a seamless and smooth transition to the next step in our strategic plans to move production to 6-inch wafers. This is a key step in the planned evolution towards high performance materials, but with the economic advantages of larger diameters. We therefore look forward to working with the Aixtron team," continues Heizmann.

Azur Space Solar Power GmbH is a developer and manufacturer of high efficiency solar cells for space and terrestrial applications; the latter based on the CPV concept. With over four decades of experience in space solar cell technology, its product range covers several types of silicon and III-V solar cells, including those on germanium wafers.

CPV technology uses lenses to concentrate sunlight onto a small area of photovoltaic materials in order to generate electricity. Among its advantages, and in contrast to more conventional flat panel systems, CPV systems can be much less expensive to manufacture.

Maximising the commercial potential via the highest efficiency and lowest cost requires the ability to manufacture low-cost, light-concentrating optical systems and III-V materials. It is here that MOCVD systems such as the Aixtron platforms are bringing these objectives to commercial reality with many companies worldwide.

## GaAs device revenue reaches new heights

Although 2011 revenues hit a record \$5.2 billion, growth is expected to slow down in the future

According to Strategy Analytics, a fast start to 2011 allowed the GaAs device market to withstand a slowdown toward the end of the year and post record revenue for 2011.

Continuing growth in demand for handset power amplifiers offset ongoing uncertainty in the global economy to propel the market to growth from last year's value. The market research firm's most recent report, "GaAs Industry Forecast: 2011-2016", reports the overall GaAs device market grew by roughly 6 percent to close 2011 with slightly more than \$5.2 billion of revenue.

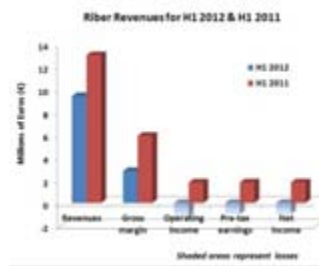
The report also forecasts that slowing smartphone growth and an uncertain global economy will limit future growth rates below historical averages and the market will reach slightly more than \$6.1 billion in 2016.

"The GaAs market began the year with strong growth", notes Eric Higham, Director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs). "Toward the end of the year, slowing growth in the smartphone segment and uncertainty in the global economy became the overriding trends and the overall GaAs device market slowed substantially. The underlying trends in the GaAs market still support growth, but uncertainty in the economy is likely to limit this growth."

Asif Anwar, Director in the Strategy Analytics Strategic Technologies Practice adds, "We remain convinced that data consumption and GaAs content in handsets will increase, but fluctuations in the global economy will put a damper on network and consumer spending."

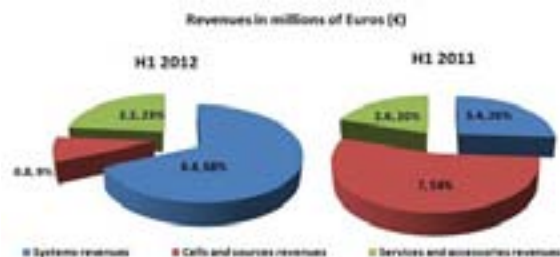
### Change in product mix slashes Riber financials

MBE equipment manufacturer, Riber has released its earnings for the first half of 2012.



In view of the level of growth in the order book at the end of August, full-year revenues for 2012 are expected to represent €26 to €28 million, enabling Riber to achieve an operating margin ratio of 7 to 9 percent of revenues.

In an uncertain economic environment for the semiconductor industry, revenues for the first half of 2012 came to €9.4 million. As expected, this performance reflects a change in the product mix in favour of MBE system sales, unrivalled since 2002.



In this way, sales of MBE systems are up 89 percent, buoyed by the consolidation of Riber's commercial positions, particularly in the research sector.

Sales of evaporation sources and cells were down compared with the previous year, which included the delivery of a major investment order for OLED production equipment in Asia.

The services and accessories business was down 15 percent, set against the slowdown in demand in Europe and the US. Riber made major efforts to build its order book back up again on this segment, with an upturn in business in the third quarter of 2012.

The half-year gross margin before changes in provisions for inventories came to €3.0 million (€5.6 million at June 30th, 2011), representing 32 percent of revenues. It reflects an unfavourable change in revenues and product mix in relation to the first half of 2011. The provisions recorded for inventories



showed a net charge of €0.2 million (compared with a €0.2 million reversal on June 30th, 2011), bringing the gross margin to € 2.8 million.

Operating income showed a loss of €1.2 million, compared with a €1.8 million profit for the first half of 2011. Consolidated net income represented a €1.0 million loss, compared with a net profit of €1.8 million on June 30th, 2011.

With around one third of revenues recorded during the first half of the year, but half of fixed costs, the earnings figures on June 30th cannot be extrapolated over the full year.

Cash totalled €6.0 million at June 30th, 2012, some €6.1 million less than December 2011, factoring in the half-year losses, the dividend paid out in June and the increase in inventories in anticipation of the production plan for the second half of the year.

#### Outlook for 2012

The order book at the end of August 2012 came to €22.3 million, 13 percent higher than the same period the previous year. The order book for MBE systems is up 40 percent over one year.

It includes one production system and 15 research systems, to be delivered between 2012 and 2013, which represents approximately one year's business for this segment. These book figures do not include an order placed in September 2012 for a research system in India.

For cells and sources, the order book (€1 million at the end of August 2012) was down following the completion of investments in OLED production lines, as well as the difficulties faced by the photovoltaic sector as a result of the general economic environment. Riber is currently preparing a range of new generation cells with a view to the next waves of investments.

In view of these elements, 2012 revenues are expected to come in at between €26 and €28 million, enabling Riber to record a profit in 2012, with operating income representing 7 percent to 9 percent of its revenues, including an OSEO refundable advance debt write-off with positive impact on the second half of the year for €579,000.

## Brolis wins semiconductor “Young Entrepreneur of the Year” award

The MBE specialist was awarded for its complex epitaxial structures based on arsenides and antimonides for the electronic and optoelectronic world market

Brolis Semiconductors has won the Young Entrepreneur of the Year in the Swedish Business Awards 2012.

The award was presented at a special ceremony held in Vilnius Small Theatre.



*Brolis making a speak at the awards ceremony*

Guests at the ceremony included President of Lithuania, Dalia Grybauskaitė; former president of Lithuania, Valdas Adamkus; Prime Minister of Lithuania, Andrius Kubilius; Ambassador of Sweden to Lithuania, Cecilia Ruthström-Ruin; President and CEO of Swedbank Michael Wolf and President and CEO of Ncell, Pasi Ahti Yrjänä Koistinen.

The company, headquartered in Vilnius, was established in 2011 by Augustinas, Kristijonas and Dominykas Vizbaras who are brothers who specialise in long-wavelength semiconductor lasers and MBE.

## Can GTAT revolutionise mobile & LED market with sapphire?

Perhaps. A Chinese firm has invested \$29 million in the firm's ASF furnaces

GT Advanced Technologies has received a \$29 million follow-on order for ASF units from an existing ASF customer in China.



*GTAT ASF furnace*

The order is scheduled for delivery by the end of 2012 and the expected revenues included in the company's 2012 range is \$925 million to \$975 million.

GTAT believes the units will be used to produce sapphire for the mobile device market.

The company has said that tolerance requirements for mobile device sapphire screens are significantly lower than epi-ready surfaces in HB LED manufacturing and should reduce cycle times and consumable costs.

The firm has also indicated that it and several of its ASF customers have entered into evaluation agreements or are, in conjunction with fabrication partners, actively sampling ASF-grown sapphire screens for use in mobile and point of sale (POS) devices.

GTAT thinks the sapphire mobile device opportunity will contribute to a significant inflow of ASF orders in the second half of 2013.

The company also points out that several factors have driven the recent interest in ASF-grown sapphire as a viable alternative to materials currently used in mobile and POS devices.

These include sapphire's strength, ruggedness and scratch-resistance as well as its ability to improving user experience.

GTAT says its ASF platform is well positioned to meet the quality and high-volume production requirements for crystal growth for these applications.

The cost of sapphire is expected to be within an acceptable range given its compelling value proposition. GTAT expects that the cost for growing and fabricating sapphire for mobile devices will be considerably lower than for LED applications for a number of reasons.

These include the ASF crystal growth process which GTAT says can be optimised to deliver higher yields of useable material resulting in lower costs when harvested for bricks, screens or cores and wafers.

For a start, fabrication costs have the potential to come down driven by equipment that can slice boules into bricks rather than cores.

Other activities include GTAT working with consumable suppliers and cost reductions from a growing Asian supply chain.

Several fabrication steps may be eliminated when fabricating sapphire for mobile devices including CMP (chemical mechanical polishing) as well as rough and fine lapping, with the latter being replaced by faster grinding processes.

What's more, mobile screen fabrication may allow for the use of existing polishing and grinding equipment capacity at existing large volume subcontractors in Asia, removing the requirement for new fabrication equipment.

As a result, the company believes that sapphire screens for mobile devices, once commercialised,

will have a cost of ownership that will be competitive with current solutions.

More specifically, GTAT estimates that a fully fabricated sapphire smartphone screen will be \$10 to \$20 higher than the price OEMs pay for current screen solutions, with the differential dependent on the level of vertical integration by the OEMs or their manufacturing partners.

Given the compelling overall value proposition of ASF sapphire screens, GTAT says that initial feedback from industry leaders suggests this cost for a superior product will be acceptable.

Factors affecting this may be a lower rate of cracked or broken screens, providing a better overall user experience.

The company also points out that the expected price differential between ASF-grown sapphire and the “current solutions” is less than what consumers typically pay to replace a single cracked screen as well as being less than the cost of screen protectors and protective cases.

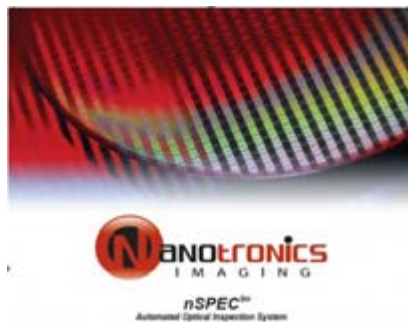
GTAT also expects that there will be significant potential to reduce the cost of producing sapphire smartphone screens over time as the industry matures, increases scale, vertically integrates and continues to advance technology innovations at both the crystal growth and fabrication stages.

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## Nanotronics defect inspection ticks all the boxes

The new system handles both blank and patterned compound semiconductor wafers including III-arsenides, phosphides and nitrides as well as silicon carbide

After gaining initial product success with nSPEC, Nanotronics Imaging has introduced new capabilities to provide a more complete semiconductor inspection system.



nSPEC now detects and categorises defects on semiconductor wafers after photolithographic patterning and other chip processing steps.

Nanotronics says its nSPEC has already proven its high effectiveness for the inspection of blank substrates and epitaxial wafers, across a full range of compound semiconductor materials such as SiC, GaN, GaAs and InP.



The firm says its patterned wafer inspection feature makes nSPEC a unique tool with unparalleled capability to track wafer quality through the whole chip manufacturing process from bare substrate all the way to fully processed devices.

Software has been developed in collaboration with Microsemi Corp. of Aliso Viejo, California and supported by funding from the US Air Force.

Bruce Odekirk, SiC Program Director at the Microsemi manufacturing facility in Bend, Oregon, comments, “We have been early adopters of nSPEC for SiC epitaxial wafer inspection, and our first Nanotronics tool has been producing highly informative data for over a year. Now we are delighted to extend its ability to monitor and improve our post-epi chip processing with equally great performance and cost-effectiveness.”

Ivan Eliashevich, VP at Nanotronics Imaging, adds, “nSPEC’s versatility in image acquisition and state-of-the-art data processing power allow us to deliver



exceptionally broad range of testing capabilities by adding new software-driven features to existing tool platforms. Instead of bearing the expense of buying multiple tools, dealing with data compatibility issues etc., customers now can have multiple functions seamlessly combined in one affordable machine.”

Commercial release of the patterned wafer inspection software for new and existing nSPEC systems is expected in Q1 2013. It is currently available for evaluation as a beta version.

## InnoLas installs laser scribers at 100 MW Korean CIGS plant

The current installations are a further step in the successful roll-out of the firm’s laser scriber systems for CIGS thin film solar cells and other semiconductors such as cadmium telluride

German company InnoLas Systems recently installed its pioneering P1, P2 and P3 laser scribers at a 100 MW CIGS fab in Korea.



*Impala laser processing system for thin-film solar modules*

This innovative laser technology for P2 scribing of thin film solar cells is suited for use on the structures of CIGS semiconductors and has so far been delivered to four different customers. These laser patterning tools support 250 MW production volume globally.

InnoLas CEO Richard Grundmüller says, “The current installations are a further step in the successful roll-out of our laser scriber systems for thin film solar cells. Not only for the processing of CIGS but also for other semiconductors, e.g. CdTe

cells, the InnoLas laser systems have become must-have production tools. Up to September this year we have already developed, built and installed P1, P2 and P3 scribing systems for a fab capacity of 300 MW.”

InnoLas also offers advanced laser systems for R&D applications.

The company has received an order for a multi-functional laser tool, tailor-made for the rigorous requirements in modern photovoltaic development labs. This system can process any individual pattern either from the film side or from the glass side with multiple wavelengths.

All layers (P1, P2 and P3) can be laser scribed, and the processing side and process parameters are selected through simple menu commands. Mechanical scribing (P2, P3) is available on the same system. Highlights include integrated In-situ metrology, giving 100 percent control over scribe performance and enabling the user to optimise process parameters on the fly.

## Two members jump off Board at 5N Plus

The producer of specialty metal and chemical products used in MOCVD growth is seeking new members

5N Plus, has announced the resignation of Laurent Raskin and Frank Fache from its Board of Directors.

As the Company had already initiated a process of adding members to its Board of Directors, it has already identified and is currently meeting with high profile potential candidates to join its Board of Directors in the near future.

“We seek to add new Board members whom will bring a wealth of technical expertise and business experience both domestically and internationally. We would like to thank Messrs. Raskin and Fache for their contribution to our company and wish them the best in their future endeavours”, says Jacques L’Ecuyer, President and Chief Executive Officer of 5N Plus.

## DAS system eliminates waste gases in LED industry

DAS Environmental Expert GmbH has developed a new product solution for environmentally friendly cleaning of process gases such as ammonia and hydrogen, which are used during LED manufacturing

DAS Environmental Expert GmbH has developed the "LARCH" system for the environmentally friendly disposal of reactive waste gases released during the production of LED wafers.



*LARCH gas disposal unit*

As the statutory provisions on waste water and waste gas disposal will be tightened in Taiwan from 2013 onwards, Taiwanese companies will soon have to start looking around for new solutions.

Taking into account that our world is becoming more ecologically aware, engineers at DAS have recognised that it is necessary to eradicate waste process gases in an eco-friendly manner.

"With LARCH we are specifically reacting to requirements from LED makers. The LED industry is known to be a growth market and in our discussions with customers we have become aware of the demands made on modern disposal technologies," says Guy Davies, Director Business Unit GasTreatment.

"We have given a great deal of thought to this and the LARCH system is the result. It has already generated a lot of interest: enquiries from some potential customers have already come in," adds

Davies.

Industry analysts predict sustained growth in demand in the LED market. After LED backlighting for the small LC displays of mobile phones and the LC displays of larger screens in the television market, the next potential growth market is the lighting industry. Sales of LEDs in this market in 2012 are almost \$3.5 billion, nearly doubling since 2010. Yole Développement is expecting a growth of more than \$7 billion in 2014 and believes that the total market for LEDs should peak at \$17.7 billion.

A mass market on this scale for LEDs also means increasing emissions. In the manufacture of products based on innovative LED technology, ammonia and hydrogen are used in large quantities as process gases.

In the new LARCH system, the initial thermal dissociation of ammonia is achieved by reaction heat. Hydrogen is then ignited and burnt off by electrical heating elements. The reaction heat is transferred to a downstream heat exchanger. This is an elegant solution for the disposal of the large quantities of process gases generated in LED production.

The gases cleaned by LARCH can be safely released into the atmosphere. Sensors and numerous redundant safety systems guarantee stable and safe operation.

Although the process is based on a simple principle, it can still economically achieve low emission values. It is therefore able to replace the previously used wet scrubbing solutions, which create large quantities of ammonia solution. It is also much more environmentally friendly.

"We developed LARCH especially for typical applications in the LED industry and adapted it to the industry's requirements. But we could also imagine the system finding application in other processes in which ammonia and hydrogen are generated. Therefore we are looking to continuously develop the technology," concludes Davies.

Established in 1991, DAS Environmental Expert GmbH, headquartered in Dresden, Germany, is an environmental technology company. DAS is a technology and equipment supplier for process gas disposal solutions. The firm's technology is

employed in the semiconductor, TFT-LCD and electronics industry as well as the solar power isector. DAS also develops process and system solutions for treating industrial and communal waste water.

## Riber receives MBE kit order from Chinese university

The MBE reactor will be used to grow new III-V compound semiconductor based structures

MBE system manufacturer, Riber, is announcing the sale of a Compact 21 MBE machine to SITP (Shanghai Institute of Technical Physics) a famous material research institute in China.



*Riber Compact 21 Integrated Reactor for up to 3" wafers*

SITP is a regular user of Riber MBE products specialised for the growth of thin film layers and quantum well structures.

This new Compact 21 system will enable the laboratory to increase its fundamental research capabilities on new III-V based structures.

With a more than 800 MBE machines installed base and its successful industrial experience, Riber is one of the leaders in the MBE-based compound semiconductor deposition market.

## EVG releases novel automated resist platform

The fully automated modular system which can accomodate 50mm to 200mm wafers, integrates spray coating processes for compound semiconductor and advanced packaging

Taiwanese firm, EV Group (EVG) has revealed its next-generation EVG150 automated resist processing system.



*EVG150 system*

The high-volume coater/developer has been completely redesigned to provide customers with a flexible, modular platform that integrates spin coating and developing with EVG's advanced, proprietary spray coating technology.

"Close collaboration with our customers made it clear that the next logical step for our coater/developer technology was to create a universal approach for high-volume processing of devices with more complicated structures and topographies," stated Markus Wimplinger, EV Group's corporate technology development and IP director.

"This latest incarnation of our EVG150 system addresses customers' production needs for back-end lithography, conformal coating and planarisation – all in one modular, fully automated platform. Leveraging EVG's 15 years of experience in resist coating and developing, and particularly our spray coating, the EVG150 is ideally suited for high-volume coater/developer applications needing increased uniformity and process flexibility."

Part of EVG's resist processing equipment family, which addresses all wafer sizes up to 300 mm, the EVG150 platform can accommodate wafers from 50 mm to 200 mm in diameter, and enables up to four wet process modules to be combined with two stacks of hot plates, chill plates and vapour prime modules.

The system performs spin coating, developing, spray coating and lift off, and its modular structure



helps minimise system downtime and improve serviceability. Throughput is optimised via EVG's latest Computer Integrated Manufacturing (CIM) Framework software platform and unmatched process control.

EVG currently has more than 100 customers implementing its proprietary OmniSpray technology, which is also integrated into the new EVG150 resist processing platform. The firm's OmniSpray technology specifically allows the conformal coating of high topography surfaces via its proprietary ultrasonic nozzle.

Spray coating technology is ideally suited for ultra-thin, fragile or perforated wafers. In addition, according to EVG, the implementation of OmniSpray coating can result in a greater than 80 percent reduction in material consumption compared to traditional spin coating.

Another available option for the EVG150 platform is EVG's NanoSpray technology, which is an enhanced, patented coating technique that can coat surfaces with vertical sidewall angles thus, for example, enabling conformal coating of through-silicon vias (TSVs) with polymer liners and photoresist.

The modular EVG150 automated resist processing platform is available immediately for demonstration and evaluation.

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## Ultra Tec reveals module for improved electronic packaging

A new hardware and software development enhances digital sample preparation system for the decapsulation, thinning and polishing of compound semiconductor packaged and wafer-level devices

Ultra Tec Manufacturing, has announced the availability of a new End-point Detection Module for the ASAP-1 IPS Selected Area Preparation System.

The End-point Detection Module is a hardware and software enhancement (patent pending) for the ASAP-1 IPS that provides the capability to quantify and act upon the capacitive and/or resistive

properties of electronic device and packaging materials, in order to enhance the sample preparation process.

The ASAP-1 IPS is suited for use in compound semiconductor and silicon sample preparation.

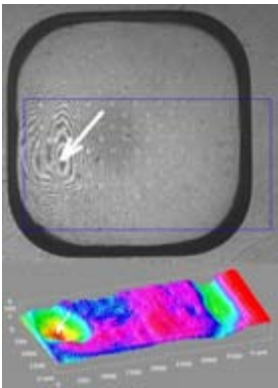


*An integrated circuit on a graphics board being prepared on the ASAP-1 IPS in End-point Detection Mode*

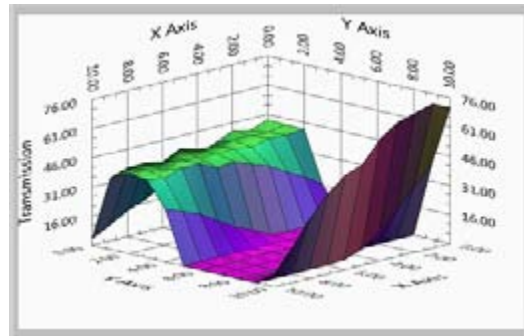
Controlled microsurgery, with interactive end-pointing, opens the door for improved resolution with SQUID Microscopy, INSB thermography (Lock-In), Thermal Laser Stimulus and similar techniques without fully exposing the die topside or by stopping a few microns before target on silicon from the backside.

ASAP-1 IPS is a digital sample preparation system for the decapsulation, thinning and polishing of packaged and wafer-level devices. Drawing on Ultra Tec's knowledge and market leadership in the selected area preparation area, ASAP-1 IPS has been designed to be specifically 'device centric' – using a combination of advanced programming and tool patterns, force feedback and live machine-vision - to help the user obtain the best results with the highest yield.

The End-point module will be available for demonstration at the upcoming ISTFA 2012 Conference in Phoenix, Arizona.



*A 4 x 4mm pocket area backside thinned into an IC on a deliberate tilt to confirm endpoint capability. The indicated spot shows the thinnest remaining silicon (2.5µm) on the left. The Upper image shows the fringes at 1064nm and the Lower image is a C-SPM image of the area of interest, also produced on the ASAP-1 IPS system*



S2M can also create maps from Raman microspectral data in conjunction with the Craic Apollo Raman microspectrometer. Craic says its microspectrometers can now create spectral maps with micron scale resolution rapidly and automatically.

“Craic Technologies has worked to develop the Spectral Surface Mapping package because of customer requests. Our customers wanted the ability to automatically survey and characterise the entire surface of samples by their spectral characteristics. They also wanted a high spatial resolution” says Paul Martin, President of Craic Technologies.

“The S2M package does just that. It allows you to collect spectral data from thousands of points with a user defined mapping pattern. And because our customers deal with so many different types of microspectroscopy, we gave S2M the ability to map UV-visible-NIR transmission, absorbance, reflectance, emission and even Raman microspectra all with the same tool,” he adds.

Spectral Surface Mapping includes a software module that is used with CraicTechnologies MINERVA microspectrometer control software. When used with Craic’s microspectrometers with programmable stages, S2M allows a user to automatically take spectral measurements with user-defined mapping patterns that reach to the limits of the stage itself.

## Craic unveils multifunctional spectral surface mapper

A new tool on the market enables automatic spectral mapping of semiconductor wafer surfaces with microscopic spatial resolution. 3D maps can generate transmission, absorbance, reflectance, polarisation, fluorescence, phosphorescence and Raman spectra

Craic Technologies has unveiled the Spectral Surface Mapping (S2M) capabilities for its Perfect Vision microspectrophotometer line.

With the ability to measure up to a million points, high definition maps of the spectral response of the surface of a sample are possible.

The firm says its S2M gives users the ability to map the spectral variation of surfaces of their samples with microscopic spatial resolution. Surface profiles can be created using UV-visible-NIR transmission, absorbance, reflectance, emission, fluorescence and polarisation microspectral data.

An example of a map of a transmission map of a LCD ColorMask is shown below.

## FEI makes TEM sample prep that much easier

Two new tools for 100mm and 300mm wafers will hopefully make TEM sample preparation not so hit and miss

Semiconductor equipment maker FEI has revealed the Helios NanoLab DualBeam system for engineers that need to make vital process improvement decisions.

The firm says its 450HP and 1200HP DualBeam systems have new capabilities that meet the critical requirements for semiconductor process development.



Transmission Electron Microscopy (TEM) is invaluable in determining dislocation density, thickness, microstructural and failure analysis and interface quality.

TEM has been extensively used in the past to look at interface quality in III-V semiconductors and is used by many research institutes and universities.

FEI says its latest additions will make TEM sample preparation a lot easier than its predecessors; in the past, TEM sample prep used to be a laborious process and even when you had a thin enough sample, it may have been in the wrong area of the wafer. This often made it very frustrating. But once you had a decent sample, it was well worth the effort as you could see things you wouldn't using any other technique.

"Developing new processes and technologies that include shrinking geometries, new materials and novel device architectures and ramping those processes to high-volume production quickly are driving unprecedented increases in the demand for

TEM analysis," says Rudy Kellner, vice president and general manager, Electronics Business Unit, FEI.

"TEM samples must be ultra-thin, of the highest quality, and generated in a routine and consistent manner across a fleet of tools. Typically, as samples get thinner, the difficulty becomes time to results, operator skill level and subtle differences among equipment. We have designed the 450HP and 1200HP systems to overcome these issues. Ultimately, the system's ability to yield more good samples at double the throughput allows for potentially significant reductions for both the time-to-answer and the cost-per-answer."

The Helios NanoLab 450HP and 1200HP DualBeam systems can prepare 15nm thick samples with less than a 2nm damage layer in 90 minutes. FEI says this is twice as fast as competitive alternatives. iFast automation software maximises ease-of-use while ensuring consistency among multiple operators and systems.

QuickFlip grid holders facilitate inverted sample preparation to improve sample quality while maintaining high throughput. Cell Navigation software allows automated navigation within non-unique memory arrays that can locate a single designated bit cell in a 50nm lateral field. Together, these features enable a robust process to prepare high quality, ultra-thin lamella across multiple tools in a consistent manner - independent of operator, a major factor.

The Helios NanoLab 450HP and 1200HP DualBeam systems are available for ordering immediately. The 450HP model can accommodate samples up to 100mm, while the 1200HP system can handle full 300mm wafers.



# Novel Devices

## Ammonia speeds MBE growth of GaN-on-silicon HEMTs

Gallium nitride transistors with good structural and electrical characteristics have been produced by ammonia MBE on a 100 mm silicon substrate

Researchers from Nanyang Technological University, Singapore, claim that they have produced the first crack-free, GaN-based HEMTs on 100 mm silicon substrates by ammonia MBE.

The substrate that they have used, silicon, is an excellent choice for producing GaN HEMTs, because it is cheap, available in large diameter formats and can produce transistors that can be processed through depreciated silicon lines.

By far the most common method for depositing the epilayers of the HEMT on silicon is MOCVD. However, according to the researchers from Singapore, this has several weaknesses compared with MBE.

In their opinion, MBE is a more flexible growth technique that delivers sharper interfaces and enables growth at lower temperatures, which aids the management of thermal mismatch between substrate and epilayers. What's more, they claim that MBE allows in-situ monitoring of the growth surface, leading to real time growth process control at the monolayer scale.

The Singapore team favours ammonia MBE over its plasma-assisted (PA) variant, because it is difficult to control the III-V ratio with the latter technique. In addition, due to the low nitrogen molecular cracking efficiency – typically 1 percent to 10 percent – growth rates are typically below 0.4  $\mu\text{m/hr}$  for PA MBE.

Using ammonia MBE, the team from Singapore have produced crack-free epilayers at growth rates of up to 0.75  $\mu\text{m/hr}$ , nearly double that typically used in PA MBE. Faster growth doesn't just save time – it also improves morphology, by accelerating the transition from three-dimensional

to two-dimensional growth and suppressing defect formation.

This trimming of the defect density is revealed in cross-sectional images of the lower part of the epitaxial stack: The 50 nm-thick AlN nucleation layer, 200 nm-thick GaN and AlN stress mitigation layers, and the GaN buffer. The nucleation layer and lower GaN layer are riddled with defects, but many dislocations terminate at the interface between the second AlN layer and the GaN buffer, and a substantial proportion of those that propagate into this second buffer bend and interact within the first few hundred nanometres.

Estimations based on X-ray diffraction analysis suggest that the density of screw-type dislocations in the GaN buffer falls from  $7.7 \times 10^9 \text{ cm}^{-2}$  to  $2.1 \times 10^9 \text{ cm}^{-2}$  when the buffer thickness is increased from 0.9  $\mu\text{m}$  to 1.7  $\mu\text{m}$ . Resistance mapping of the HEMT epiwafers, which have a 28 nm-thick Al<sub>0.25</sub>Ga<sub>0.75</sub>N barrier and a 2 nm-thick GaN cap deposited on the GaN buffer, show an average sheet resistance of 368  $\Omega$  /square.

Meanwhile, room-temperature Hall measurements reveal that the carrier density and mobility of the two-dimensional electron gas are  $1.2 \times 10^{13} \text{ cm}^{-2}$  and 1350  $\text{cm}^2/\text{Vs}$ . Cool the sample to 90K, and mobility rises to 4290  $\text{cm}^2/\text{Vs}$ .

To determine the electrical characteristics of the buffer layer, engineers formed test structures with two ohmic contacts with a gap of 5  $\mu\text{m}$ . A structure with a 1.7  $\mu\text{m}$ -thick buffer produced a buffer leakage current of  $2.6 \times 10^{-4} \text{ mA/mm}$  at 20 V and had a ratio between on-current and off-current of  $7.3 \times 10^6$ .

HEMTs with 0.3  $\mu\text{m}$  T-shaped gates were formed on high-resistivity silicon. These transistors delivered a peak drain current of 768  $\text{mA/mm}$ , produced a maximum transconductance of 190  $\text{mS/mm}$  and exhibited a threshold voltage of -4.53 V.

Further details of this work have been published in the paper, "Demonstration of AlGaN/GaN High-Electron-Mobility Transistors on 100-mm-Diameter Si(111) by Ammonia Molecular Beam Epitaxy", by N. Dharmarasu *et al* in Applied Physics Express 5 091003 (2012). DOI:10.1143/APEX.5.091003

## Gallium concentration lowers threshold in InP QDs

The concentration of gallium in the confining layers immediately above the indium phosphide self assembled quantum dots strongly influences their properties

A Cardiff University based project has produced InP self assembled quantum dots that can deliver a threshold current density of 130 A cm<sup>-2</sup> for a 2 mm broad area oxide stripe laser with uncoated facets.

Not a bad achievement. And the researchers have also managed to reduce threshold temperature sensitivity in the material.

Lower power consumption is required for today's compact and portable biophotonic applications such as OCT and lab-on-a-chip.

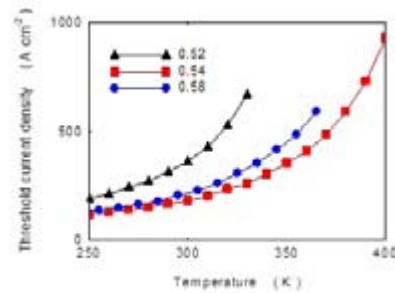
These structures, with their low threshold, reduced temperature sensitivity and broad gain spectrum have the potential to fulfill these requirements.

The scientists at Cardiff adjusted the composition of a key epitaxial layer to improve material quality, reduce the threshold and its temperature sensitivity whilst also allowing some tuning of the laser wavelength.

The properties of InP self assembled quantum dots are strongly influenced by the compositions of the confining layers immediately above and below them.

The group varied the fraction of gallium in the upper confining layer from 0.43 to 0.58 in a series of epitaxial structures. Laser threshold measurements and spectroscopy showed a range of laser wavelengths of 696 – 725 nm available. The improvements in threshold were most pronounced at a gallium fraction of 0.54.

The graph below shows the results of the scientists.



The scientists are now concentrating on optimising and tailoring these versatile materials for a variety of device applications.

Further details of this work have been published in the article, "The effect of strained confinement layers in InP self-assembled quantum dot material," by Stella N Elliott *et al* 2012 in the journal, *Semiconductor Science & Technology*. DOI :10.1088/0268-1242/27/9/094008

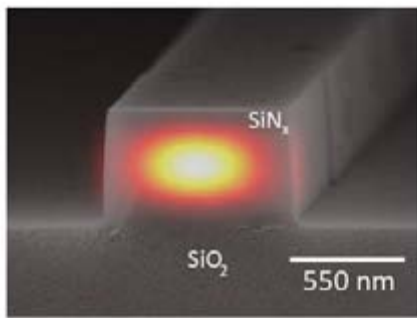
## SiN optical wavelength converter is oh so quiet

Researchers have demonstrated a noise-free wavelength conversion using silicon nitride waveguides fabricated on a silicon substrate

Researchers from the NIST Centre for Nanoscale Science and Technology have demonstrated a low-noise device for changing the wavelength of light using nanofabricated waveguides created on a silicon-based platform using standard planar fabrication technology.

Optical wavelength conversion is an important resource for applications in both classical and quantum information processing; it can connect physical systems operating at different wavelengths, and facilitate improved light detection by converting light to wavelengths for which highly sensitive detectors are available.

However, for many such applications the conversion process must not introduce additional noise. The researchers were able to demonstrate noise-free wavelength conversion using silicon nitride (SiN) waveguides fabricated on a silicon substrate.



Scanning electron micrograph of the cross-section of a silicon nitride waveguide designed for the low-noise frequency conversion with a simulation of the device's optical field profile superimposed

These waveguides were designed based on electromagnetic simulations to determine an appropriate device geometry for a process called four-wave-mixing Bragg scattering, where an input signal field is converted to an output field whose frequency is shifted from the original by an amount equal to the difference in the frequencies of two applied pump fields.

Measurements show conversion efficiencies in these devices as high as a few percent, approaching the levels needed for some applications, and with no excess noise added during the conversion process.

These new noise-free frequency converters are dramatically smaller than the nonlinear crystals and optical fibres used in previous work (by several orders of magnitude), and can be created in arrays and integrated with other on-chip devices using scalable silicon-based fabrication methods.

The scientists say that in the future, they will focus on increasing the conversion efficiency levels by optimising the waveguide geometry and incorporating the waveguides into optical resonators.