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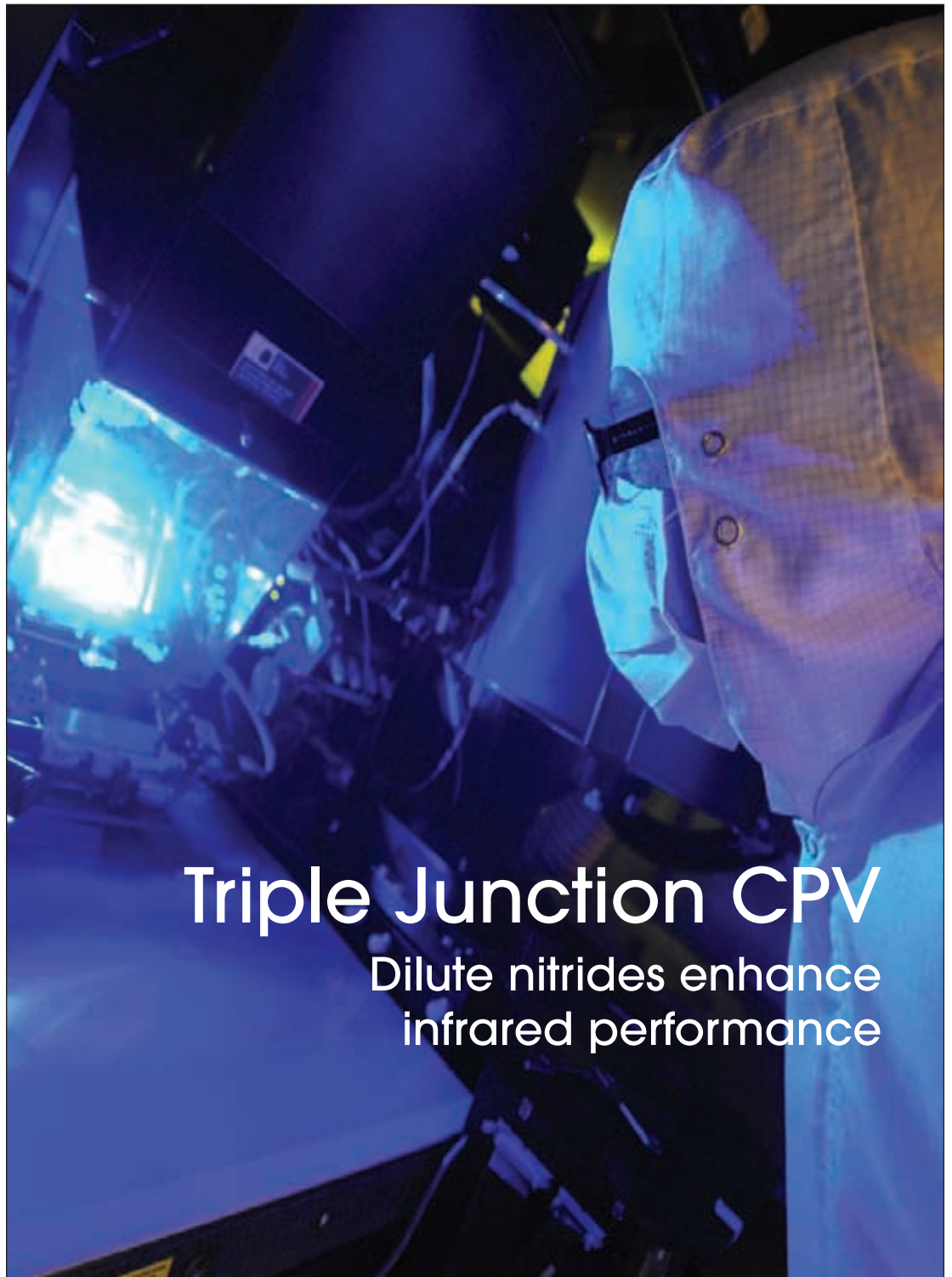
Improving thin film LED output

## HFET boost

Freestanding  $\alpha$ -plane substrate

## GaAs nanowires

Defect free manufacturing on silicon substrates



## Triple Junction CPV

Dilute nitrides enhance infrared performance

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**AIXTRON**

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## Dilute nitrides: material for making money?

Dilute nitrides are the precocious siblings in the compound semiconductor family. When grown on GaAs, they have the potential to form infrared emitters and detectors that are cheaper and better than the incumbents built on the far more brittle InP platform. In addition, this slightly esoteric material can also be used to create red, orange and yellow LEDs that are less sensitive to temperature than the AlInGaP incumbents. And when these dilute nitrides are inserted into the base layer of HBTs, they can lower the transistor's turn-on voltage.

But – and it's a big but – dilute nitrides are incredibly difficult to grow, which goes some way to accounting for their modest commercial success. This is illustrated in the histories of three long-wavelength dilute nitride laser pioneers, Infineon, Picolight and Optical Communications Products, whose technologies now rest with Alight, JDSU and Oplink, respectively. These new owners say very little about their dilute nitride devices – I'll leave you to decide what that may say about the successes that they are having.

Meanwhile, the progress of dilute nitride LEDs has suffered from the folding of its leading pioneer, Quanlight.

On the transistor front things are better - Kopin has been offering this technology for several years. However, it is not disclosing how much commercial success it is enjoying with this class of device.

In stark contrast to all these firms, West-coast start-up Solar Junction is actively engaging with the media about its dilute nitride product – a triple junction cell with a dilute nitride base layer. However, given that it is in the process of trying to raise capital to vastly expand its manufacturing capacity, its openness is to be expected.

Solar Junction turned to dilute nitrides to improve cell performance in the infrared, a move that has paid dividends on overall device efficiency. This Stanford spin-off currently holds the world record for efficiency at high concentrations of 43.5 percent, and it has a road map to get to 50 percent.

In an interview with Solar Junction (see p. 18 of this issue), the founders claimed that their higher cell efficiencies give the company a massive advantage over the incumbents, such as Spectrolab and Emcore. According to their own modelling, cells that outperform all alternatives by a few percent can deliver such a big benefit at the system level that they can price competitors out of the market.

It's certainly a bold claim from Solar Junction, and one that will not be tested until this outfit has won capital, built a bigger fab and started shipping these products in high volumes. But if it can do all this, it will certainly be a success story for the dilute nitrides that will be worth shouting about.

**Richard Stevenson PhD**  
Consultant Editor





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### Next Generation Technology Pavilion

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SEMICON Japan 2011  
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## Information

The SEMI Global Opto/LED Fab Watch database tracks investments and activity in more than 200 LED fabs worldwide.

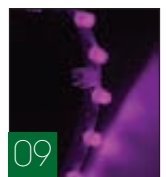
**industry & technology**

- 18 **A critical edge**  
Richard Stevenson interviews Solar Junction and discovers that its record breaking efficiencies stem from dilute nitrides
- 25 **Lighting up the world**  
euroLED 2011 highlighted the progress of LEDs for general illumination and discussed mass market adoption challenges
- 28 **Wafer bonding selection**  
LEDs with a vertical geometry show promise for solid state lighting but success can be dependent on the right tool process
- 33 **High yield desires**  
Improving yield output is vital to lowering production costs and a comprehensive inspection regime may be the key
- 37 **Droop solution**  
The droop problem is well known to LED manufacturers so news that quaternary barriers cut droop is welcome
- 38 **Thin film LEDs**  
Photochemical etching with potassium hydroxide creates LEDs with less strain
- 39 **Boosting HFET performance**  
Freestanding substrate provides needed boost to GaN HFET performance
- 40 **Intra cavity frequencies**  
QCLs with internal frequencies are doubling target gas sensing
- 42 **Defect free GaAs nanowires**  
A silicon base can improve GaAs nanowires



**news**

- 07 Mercury satellite helped by GaAs  
Aixtron celebrate 2 000th system
- 09 Joint venture to advance LED  
First Solar reach 4GW
- 10 GaN bar raised for industry  
RFMD qualifies 65V process
- 12 US DOE provide LED impetus  
Smallest GaN broadband 5W PA
- 13 GaN HEMT PA  
S-Band RF portfolio
- 15 GaN on SiC for the masses  
First GaN HEMT T/R C-Ku



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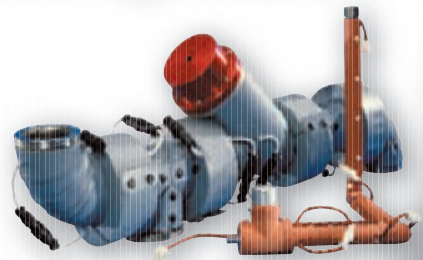
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# GaAs PV assist Mercury spacecraft

THE MESSENGER probe which incorporates gallium arsenide multi-junction solar cells is able to operate in extreme temperatures and will orbit 730 times around Mercury for a year.

Key technologies and hardware developed by Northrop Grumman Corporation gave the first spacecraft to orbit Mercury a power system that works to its maximum even in the searing heat that surrounds the planet closest to the sun.

The company also perfected a fully robotic welding process to assemble the photovoltaic cells before they were bonded to the solar array panel. The work was done under the pressure of meeting a launch window that was so tight that missing it would have meant a year-long wait until the next launch opportunity.

“When it launched in 2004, MESSENGER was the first Northrop Grumman program to use these advanced solar cells, electrical designs

and welding processes that now are the baseline for all our major programs, including the James Webb Space Telescope and the Defence Weather Satellite System,” said Tim Frei, vice president, system enhancements and product applications for Northrop Grumman Aerospace Systems. “Our depth of talent and the processes we developed enabled us to perfect the technology needed for spacecraft to perform under very harsh conditions.”

Solar array performance is critical – if it fails, so does the mission. Two single-sided solar panels are MESSENGER’s main source of electrical power. They are two-thirds mirrors and one-third solar cells. The mirrors reflect the sun’s energy and keep the panels cooler. The panels also rotate away from the sun to get the required power and maintain an operating temperature of about 300 F.

Since its launch, MESSENGER has completed one swing past Earth, two Venus flybys and three Mercury flybys. By using the gravity of each planet to



gain speed and alter its trajectory, MESSENGER was able to conserve the fuel it will need during its mission orbiting a planet that is only 29 million miles from the sun, about two thirds closer to the sun than Earth.

At Mercury’s equator, temperatures become hot enough to melt lead. The spacecraft’s fast, elliptical orbit allows it to approach Mercury, gather data and swing out far into space to cool down.

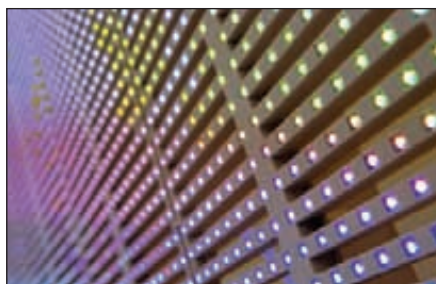
MESSENGER is a NASA Discovery program spacecraft designed and built by the Johns Hopkins University Applied Physics Laboratory, Laurel, Md. The probe completed a six-and-a-half-year journey prior to its March 17 insertion into orbit around the planet closest to our sun. MESSENGER will orbit 730 times around Mercury for a year.

## Changelight receives 2 000th Aixtron MOCVD system

AIXTRON SE has installed its 2 000th MOCVD system at LED and solar cell company Changelight in China.

Bastian Marheineke, Vice President Sales at Aixtron, took the opportunity to congratulate DianMing Deng, President Changelight, personally. “We are extremely pleased to be able to share this historic occasion with such an important customer. Changelight was the first customer to use the AIX 2800G4 in China. Their AlGaInP LED epitaxial wafers and chips are amongst the best at the domestic level in terms of scale, output and sales. In 2010, multiple Aixtron G3 and G4 systems were installed at the Xiamen facility with others at the Yangzhou site.”

“The vast majority of systems we sold in 2010, almost 95%, are used for the manufacture of LEDs. In the first quarter of 2011, around 90% of Aixtrons



revenues were generated by sales into Asia; almost 90% of systems sold are for the manufacture of LEDs. China will undoubtedly be our biggest market in 2011,” concludes Marheineke.

DianMing Deng, President Changelight, adds, “We feel deeply honoured that Aixtron supplied its 2 000th system to Changelight. Development from our initial private enterprise to the present listed company is inseparable from the great support we have enjoyed from the

Aixtron team since our foundation in February 2006. Today, our facilities are based exclusively on Aixtron MOCVD equipment which has been pivotal in our becoming the biggest supplier of high-quality AlGaInP Red Orange Yellow (ROY) HB LED chips in China.”

“The new systems form part of our expansion plans in Yangzhou. I see our strategic cooperation partnership with Aixtron will become deeper and broader. We send our best wishes for the company’s further success. Hopefully with the delivery of the 3000th and 4000th MOCVD system in China, too.”

The 2,000th system is part of a multiple tool order for 60x2-inch AIX 2800G4-R systems for advanced optoelectronics devices and will be installed and commissioned by the local Aixtron service team at the Changelight production facilities.

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# Kyma and Veeco to push LED manufacturing forward

KYMA TECHNOLOGIES has teamed with Veeco Instruments for next generation LED manufacturing equipment development project which was awarded \$4 million in funding from the US Department of Energy.

Kyma President and CEO, Keith Evans, stated, "We appreciate the opportunity to work with Veeco on this project to accelerate growth in the LED market."

Kyma's product line is designed to improve energy efficiency and overall performance of LEDs and power electronics, critical for furthering growth in solar, solid state lighting and other green technology markets. In order for materials to be accepted commercially there needs to be an appropriate process equipment infrastructure.

Veeco is receiving funding for a project targeted at lowering costs and improving brightness and efficiency of LEDs through new materials, substrates, and deposition technologies. Kyma Technologies will be supplying material and services to Veeco as part of this development project.

US Congressman David Price said, "The



Veeco and Kyma team's project is an excellent example of a research investment that ensures our future economic competitiveness. This project and others like it show that the Triangle is again leading the way investing in job creation, furthering our nation's energy independence, and moving us one step closer to a clean energy economy."

The market for nitride semiconductor devices was \$12B in 2010 and is expected to reach \$90B over the long term, including \$60B in visible lighting applications and \$30B in power electronics applications.

## First Solar reaches 4 GW manufacturing milestone

FIRST SOLAR says it has manufactured 4 GW of thin-film photovoltaic CdTe solar modules since beginning commercial production in 2002.

A 4GW generation capacity is enough solar electricity to power around two million households, displacing more than 2.5 million metric tons of CO2 emissions a year—the equivalent of taking 500,000 cars off the road. The company also announced that its second factory at Frankfurt an der Oder, Germany, has begun producing solar modules one month ahead of schedule.

The four new production lines are still expected to ramp to full production during the third quarter of 2011, bringing annual capacity at the two Frankfurt factories to more than 500 MW.

First Solar, which is one of the world's leading producers of PV solar modules, also has manufacturing sites in Perrysburg, Ohio and Kulim, Malaysia, as well as new plants under construction in Mesa, Arizona and Vietnam. It recently completed the production ramp of its two newest plants in Malaysia.

## Global smartphone market to grow 55% in 2011

THE worldwide smartphone market is forecast to grow 55% year over year in 2011 as a growing number of users turn in their feature phones for more advanced devices.

According to the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker, vendors will ship a total of 472 million smartphones in 2011 compared to roughly 305 million units shipped in 2010. That figure will nearly double to 982 million by the end of 2015.



The fast-growing smartphone market, which will grow more than four times the rate of the overall mobile phone

market this year, is being fuelled by falling average selling prices, increased phone functionality, and lower-cost data plans among other factors, which make the devices more accessible to a wider range of users.

"The smartphone floodgates are open wide," said Kevin Restivo, senior research analyst with IDC's Worldwide Quarterly Mobile Phone Tracker. "Mobile phone users around the world are turning in their 'talk-and-text' devices for smartphones as these devices allow users to perform daily tasks like shopping and banking from anywhere."

"The growth trend is particularly pronounced in emerging markets where adoption is still in its early days. As a result, the growth in regions such as Asia/Pacific and Latin America, will be dramatic over the coming years."

# RFMD raises the bar with qualified 65 V GaN1 process

RF MICRO DEVICES, a designer and manufacturer of high-performance radio frequency components and compound semiconductor technologies has qualified its GaN1 power semiconductor process technology for 65V operation.

The high reliability power semiconductor process technology supports RFMD's GaN-based power semiconductor product designs and is also available to foundry customers through RFMD's Foundry Services business unit.

Previously, RFMD's GaN1 power semiconductor process technology had been qualified for 48V operation. The increase in operating voltage from 48V to 65V enables miniature, 0.5kW power devices with high operating efficiency for L- and S-Band military and civilian radar applications.

Bob Van Buskirk, president of RFMD's Multi-Market Products Group (MPG), said, "The qualification of our 65V GaN1 power process technology enables RFMD to target multiple higher voltage market opportunities across MPG's diversified markets while helping our foundry customers to design smaller periphery die for high power applications.

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RFMD continues to optimize our game-changing GaN process technology for both foundry customers and proprietary RFMD product designs, with particular emphasis on higher peak efficiency, lower power consumption and higher linearity."

RFMD's 48V GaN1 process technology is an established performance leader in the high power semiconductor industry, and RFMD's 65V GaN1 process technology moves the performance bar even higher.

RFMD's 65V GaN1 process technology demonstrates a Mean-Time-to-Failure (MTTF) of 43 million hours with a channel temperature of 2000C at power densities of 10 W, a significant industry performance benchmark.

The high reliability power semiconductor process is ideally suited for higher voltage operations in next generation military, radar, and public/defence mobile radio applications.

# Announcement

## Compound Semiconductor Greater China Magazine

**Launch:** October 2011

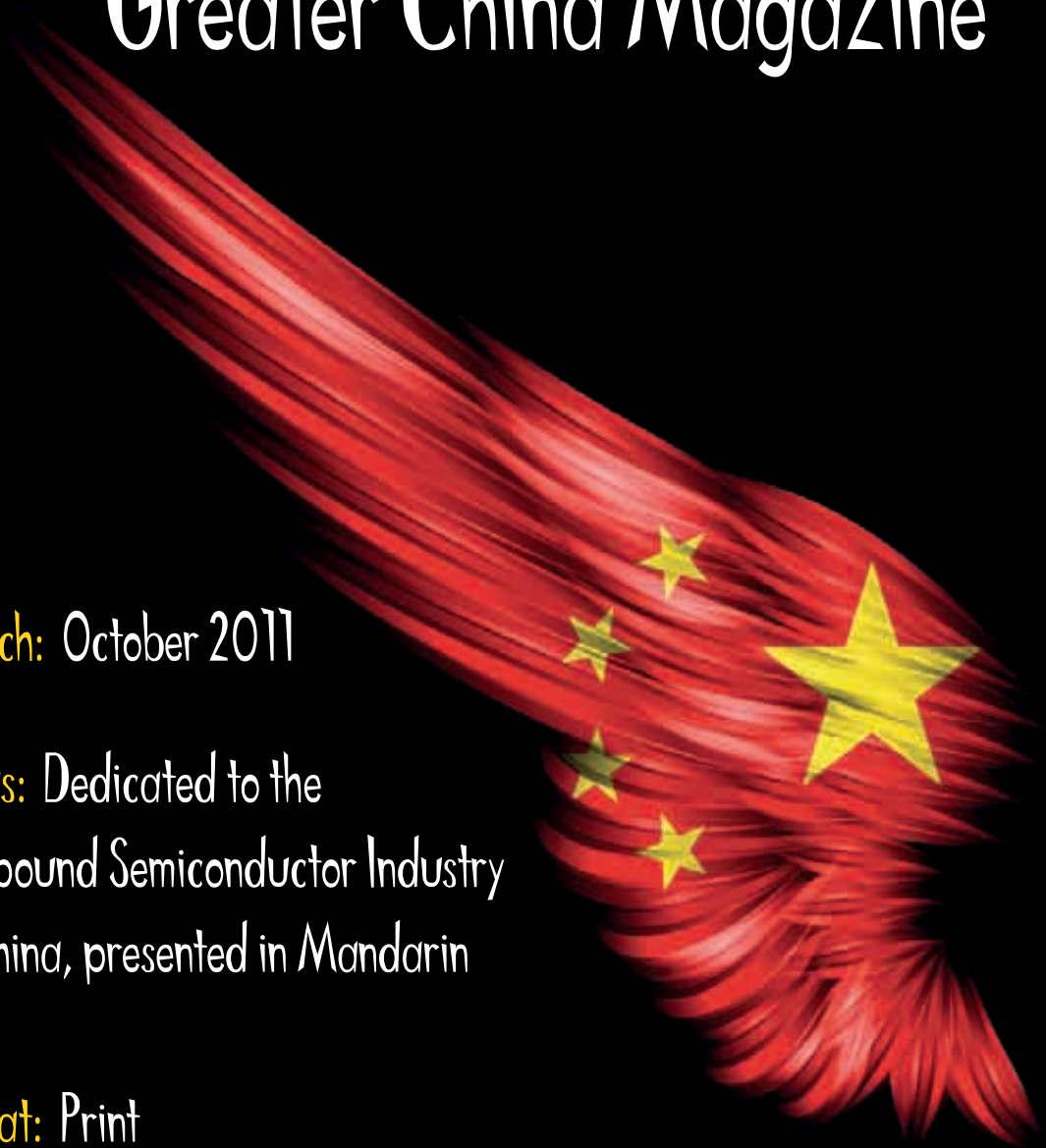
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# Veeco awarded \$4 million to boost LED manufacturing

THE US DOE has awarded a total of \$14.8 million to accelerate technologies that reduce costs and enhance product quality in SSL lighting. Other recipients include Cree, Lumileds, Sora, Moser Baer and three US universities.

US Energy Secretary Steven Chu has awarded nearly \$15 million to support eight new R&D projects that will accelerate the development and deployment of SSL technologies like LEDs and OLEDs. Both have the potential to be more energy efficient than conventional incandescent lighting and can last up to 25 times as long.

The projects selected are located in four states and are focused on advancing core R&D goals, developing new products, and expanding domestic manufacturing capacity to help the U.S. remain competitive in this growing technology market.

“These investments in cutting-edge lighting technologies will support American innovation, create new



manufacturing jobs for U.S. workers, and help ensure that the United States leads the world in this rapidly evolving industry,” said Secretary Chu.

The projects selected address the full spectrum of research, development, and deployment for SSL technologies and will leverage an additional \$4 million in private sector funding. In order to achieve significant cost reductions and

enhanced quality by improving manufacturing equipment, processes, or monitoring techniques, Veeco Instruments has been awarded \$4 million. Moser Baer Technologies has been given nearly \$3 million. To enhance product development, Cree has been awarded \$1.6 million and Philips Lumileds almost \$2 million.

Research recipients are Arizona State University, Research Triangle Institute, Sora and the University of Rochester who have been awarded a total of \$4.3 million. These projects will focus on filling key technology gaps in LED and OLED development, improving scientific knowledge, and providing performance data for these technologies.

This is the seventh round of DOE funding for SSL technology R&D, and the second time that DOE has funded SSL projects. These efforts are part of DOE’s initiative to accelerate the adoption of SSL technology through improvements that reduce costs and enhance product performance.

## Nitronex announces smallest gallium nitride broadband 5W PA

NITRONEX, a designer and manufacturer of GaN based RF solutions for high performance applications in the defence, communications, cable TV, and industrial & scientific markets, says it has developed the industry’s smallest broadband 5W PA solution.

The NPA1003 is a GaN PA MMIC and features a 4mm x 4mm thermally-enhanced QFN package with RF input and output matched to 50  $\Omega$ . The highly integrated NPA1003 GaN MMIC only requires an external resistor and inductor to provide bias. With output power over 5W from 20 to 1500MHz and typical efficiency of over 50%, the overall solution size is less than 0.25 square inches.

“The new NPA1003 has created a pull in

the market that we fully anticipated it would,” commented Gary Blackington, VP of Sales & Marketing at Nitronex. “This new device has filled a market void with the right power, gain, frequency response, compact size, and ease of use all at the right price point. We have already achieved several design-ins at top tier accounts.”

“Nitronex’s MMIC process was established under a joint development agreement with a large military contractor, resulting in a fully-qualified, production-ready process in July 2009. We have worked with multiple strategically selected customers since 2009 to develop and productize custom MMICs and have shipped more than 50,000 production devices to customers,” said Ray Crampton, VP of Engineering at Nitronex.

“Nitronex’s proprietary GaN-on-Silicon process has a significant advantage over our competitors using SiC substrates. Our superior starting substrate quality and cost structure allow us to develop high performance, large area MMICs at competitive prices which gives us the freedom to solve customer problems in ways our competitors can not.”

Nitronex’s qualified MMIC process is based on a 28V, 0.5 $\mu$ m gate length GaN HEMT and features high voltage capacitors, air bridges, through-wafer vias, nichrome and epi resistors, and two levels of metal interconnect. Furthermore, a 3.5 $\mu$ m plated gold top metallization results in low loss inductors, and a high resistivity silicon substrate is used which supports low loss transmission lines to over 20 GHz.

# Toshiba introduces GaN HEMT PA for extended Ku-Band

AT the 2011 IEEE MTT-S International Microwave Symposium, Toshiba America Electronic Components (TAEC) and its parent company, Toshiba Corporation revealed the TGI1314-25L, GaN HEMT. This is the latest addition to its power amplifier (PA) product family.

The TGI1314-25L, Toshiba's new GaN HEMT for Ku-band satellite communication application, operates in the 13.75GHz to 14.5GHz range with output power of 25W.

The device features output power of 44.0dBm (typ.) with 39dBm input power, linear gain of 8.0dB (typ.) and drain current of 2.5 Amps (typ.) and an efficiency of 29%. The product comes in a 77-AA07A package and is targeted to Satcom applications including very small aperture terminals (VSAT).

"The expansion of Toshiba's GaN power amplifier family brings higher gain and very efficient features to microwave

designers, which reduce heat sink requirements and enable smaller terminals and converters with a full GaN HEMT line-up that includes drivers," said Homayoun Ghani, business development manager, Microwave, Logic, and Small Signal Devices, TAEC Discrete Business Unit.

"Since Toshiba released its 50W Ku-band product a few years ago, many customers have requested a full line-up of GaN HEMTs, which will simplify the power supply design of Solid-State Power Amplifiers (SSPA) and block up converters (BUC). In addition, small output power applications, such as VSAT, can benefit from GaN HEMTs, making fan-less or very small equipment possible," he concluded.

In 2009, Toshiba announced the addition of the Extended Ku-band TGI1314-50L to its GaN power amplifier family, which operates in the 13.75GHz to 14.5GHz range for Satcom to support SSPA applications.

# Microsemi expands S-Band RF portfolio with GaN-on-SiC devices

MICROSEMI CORPORATION, has expanded its family of S-band RF power transistors to include devices that use advanced GaN-on-SiC process technology.

The latest high-pulsed power transistors deliver industry-leading peak power and power gain for radar systems operating in the 2.7 GHz to 3.5 GHz frequency band.

"This is a significant step in Microsemi's ongoing strategy to extend its product development and marketing initiatives to support the increasingly challenging requirements of next-generation air traffic control and other radar systems," said Charlie Leader, Microsemi vice president and general manager.

"By expanding our power transistor offering beyond traditional silicon material to use the latest compound semiconductor technologies, we take performance to the next level, create new markets for our products, and demonstrate our continuing commitment to customers in the radar systems development business."

Microsemi has leveraged its industry-leading expertise in S-band RF power transistors to create a family of GaN-on-SiC solutions that are tailored to support the requirements of next-generation systems requiring higher power, better efficiency, and wider bandwidth than is possible using conventional silicon or SiC process technologies.







# Taiyuan University selects Aixtron for GaN blue LED

AIXTRON SE has a new order for an MOCVD reactor from new customer Taiyuan University of Technology, China. The order is for one Aixtron Close Coupled Showerhead (CCS) 3x2-inch configuration deposition system which will be used for research into GaN-based materials for high-brightness (HB) blue LEDs. The system will be delivered in the second quarter of 2011. One of Aixtron's local support teams in China will commission the new reactor in a new state of the art facility at the University.

Jian Liang, Professor of Taiyuan University of Technology's Material College State Laboratory, comments, "This will be our first Aixtron epitaxial growth system though we are already very familiar with this technology and know well of the reputation of this company's equipment and service. The Close Coupled Showerhead system is an ideal choice for us because it satisfies so many criteria. We are particularly interested in its versatility as well as stand-out factors such as low material consumption. These will ensure that this system is so much superior for our University research project."

Celebrating its 100th anniversary in 2002, Taiyuan University of Technology comes under the authority of the provincial government of Shanxi, China. Historically, although it was originally part of Shanxi University it did not become an independent university until much later. Today it is listed officially as one of the 'Top 100 Universities in China' according to the Chinese government.

For applications operating in frequency bands up to 20GHz, the wide bandgap material properties of GaN-on-SiC technology enable smaller systems with improved voltage, gain, broadband performance, drain efficiency, and long-term reliability.

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## 2011 CSIC Symposium

From its beginning in 1978 as the GaAs IC symposium, CSICS has evolved to become the preeminent international forum for developments in compound semiconductor integrated circuits, embracing GaAs, InP, GaN, SiGe, and more recently, CMOS technology. Coverage includes all aspects of the technology, from materials issues and device fabrication, through IC design and testing, high volume manufacturing, and system applications. The IEEE Compound Semiconductor IC Symposium (CSICS) provides the ideal forum to present your latest results in high-speed digital, analog, microwave/millimeter wave, mixed mode, and optoelectronic integrated circuits. First-time papers concerned with the utilization and application of InP, GaAs, SiGe, GaN and other compound semiconductors in military and commercial products are invited.

## Symposium Highlights

High quality technical papers will be selected from worldwide submissions for oral presentation and publication in the Symposium Digest. Invited papers and panel sessions on topics of current importance to the Compound Semiconductor IC community will complete the program. Extended versions of selected papers from the Symposium will be published in a special issue of the *IEEE Journal of Solid State Circuits*.

## Compound Semiconductor Primer Course & Short Course

The Symposium will again offer the popular primer course, "Basics of Compound Semiconductor ICs," which is an introductory-level class intended for those wishing to obtain a broad overview of RFIC and High-Speed Analog-Mixed Signal technology. The Sunday evening course will cover Si/SiGe, GaAs, InP and GaN materials and processes, BJT/HBT, HEMT & FET device operation, and both analog/microwave and digital ICs. The Course will be tailored to provide the specific background needed for participants to understand and appreciate the papers presented in the Symposium Technical Program.

## 2011 Compound Semiconductor IC Symposium Exhibition

As in past years, the Symposium will sponsor an exhibition of products from various vendors of materials, IC products, processing equipment, test equipment, CAD tools, and foundry services specifically addressing the Compound Semiconductor industry. Numerous vendors will be on-hand to discuss their products and to answer questions. Inquiries concerning the exhibits should be addressed to: **Jim Carroll**, AWR Corporation, Tel: +1 469-248-5462, Email: jim.carroll@awrcorp.com

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# NXP brings GaN-on-SiC technology to the masses

AT IMS2011, NXP Semiconductors showcased a live demo of its next-generation products based on GaN-on-SiC technology. The GaN demo includes a 50-W wideband amplifier, the CLF1G0530-50, covering 500 to 3000 MHz; 2.1-GHz and 2.7-GHz Doherty power amplifiers for base stations; and a 100-W amplifier, the CLF1G2535-100, covering 2.5 - 3.5 GHz.

NXP has developed its high-frequency, high-power GaN process technology in collaboration with United Monolithic Semiconductors and the Fraunhofer Institute for Applied Solid State Physics. NXP's GaN devices are manufactured on SiC substrates for enhanced RF and thermal performance. Target end-user applications include cellular communications, wideband amplifiers, ISM, PMR, radar, avionics, RF lighting, medical, CATV and digital transmitters for cellular and broadcast.

With its high power densities, GaN has the potential to expand into applications such as high power broadcast

applications, where solid-state power amplifiers (PAs) built with vacuum tubes are still the norm.

While most base station PAs today are limited to specific applications, this new GaN process technology supports a roadmap towards a "universal transmitter" that can be applied in multiple systems and frequencies, simplifying transmitter production and logistics, and allowing operators to switch between frequency bands to instantly meet demands in a base station's coverage area.

"As GaN continues to gain traction, the entry of semiconductor companies such as NXP helps to validate GaN as a 'technology of choice' for RF power semiconductors, and will help to accelerate broader adoption," said ABI Research director Lance Wilson.

"We were overwhelmed by the extraordinarily positive response to our GaN roadmap presentation at CS Europe earlier this year, from customers



and partners, as well as other semiconductor companies – in large part due to the economies of scale we're able to bring to the equation.

As we release new products based on GaN, we'll also be working with our partners to build a European supply chain that optimizes costs at every step in the value chain, and continue to offer our customers choice when it comes to selecting the best alternatives – LDMOS or GaN – for high-efficiency applications," commented John Croteau, senior vice president and general manager, high performance RF, NXP Semiconductors.

## Fujitsu develops world's first GaN HEMT T/R C-Ku band module

FUJITSU LABORATORIES has successfully developed what it claims is the world's first transmitter/receiver (T/R) module using GaN HEMT technology that features an output of 10 W and operates in a wide bandwidth range of C-band, X-band, and Ku-band (C-Ku band) radio frequencies over 6-18 GHz.

By combining the world's best performing GaN power amplifier (PA) developed last year with the newly developed GaN low-noise amplifier (LNA), the researchers achieved a compact T/R module that generates a high-output.

This technology makes possible the integration of multiple types of communications equipment—each currently operated at a different frequency range—into a single module,

making for the development of smaller, lighter radar equipment and wireless communication systems.

GaN is used as a blue-LED in traffic signal lights, and compared to the conventional semiconductor materials of silicon and GaAs, it features a high saturation carrier velocity and relative resistance to the breakdown caused by voltage.

Given these characteristics, GaN HEMTs show promise for high-output and exceptionally efficient operations.

In line with the advance of a network-based society, radio wave demand in a variety of wireless systems is expected to increase even further. For example, aircraft radar typically switches between the C-band, which can detect distant



objects and works well in rain, and the X- and Ku-bands which are able to measure physical objects with high-precision.

Currently, this demand for multiple frequency ranges requires different communications equipment each suited to their respective frequency band.

However, a single T/R module capable of covering the entire C-Ku band range would meet a variety of needs, allowing systems to become more compact.

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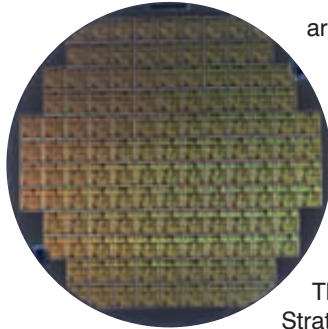
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# Compound Semiconductor Technologies clinches deal with China

CST'S recent deals with China which sees the company develop and manufacture laser chips for use in industrial, communications and defence applications, is set to potentially double the company's expected turnover to £5m within the next three years.



are becoming an option to backhaul the data from the edge to the core. Rapidly increasing mobile data use by consumers and businesses will fuel growth in wireless point-to-point radios.

The recently released Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs) Data Model, "Wireless Point-to-Point Radio Component Demand," forecasts that wireless point-to-point radios, used to backhaul mobile data, will grow from nearly 1.4 million in 2010 to slightly more than 2 million in 2015. This growth in demand will account for \$300 million of GaAs device revenue in 2015.

The news comes as CST also reaches a production milestone, with the company having manufactured two million high performance laser chips since acquiring its new manufacturing premises in 2010.

Neil Martin, chief executive officer of CST, said, "We have been making considerable headway in the Chinese market for some time and have now reached a key milestone, which underscores the investment we've made in developing our own proprietary modular process technology platforms."

"Chinese companies are increasingly looking to develop their own operations beyond pure manufacturing. Even though these markets have been traditionally high volume low cost, we have achieved considerable success in working with such companies to incorporate their custom-built CST laser technologies into their products."

"The development of our own modular technology platforms has allowed us to remain both competitive and agile. From a practical perspective, it means we don't need to go back to R&D team every time a new requirement comes along, which accelerates time to market for our customers."

GaAs radio component revenue to top \$300 million Strategy Analytics' latest report says that as operators deploy more base stations to handle the data increase, wireless point-to-point radios

Strategy Analytics also forecasts that the Asia-Pacific region will account for slightly more than 50 percent of wireless point-to-point radio shipments over this period. This analysis indicates strong growth for point-to-point radios above 60 GHz, but this segment will account for less than 3 % of the total radio volume at this time.

According to this Data Model, the highest volume of point-to-point radio shipments will occur in the 10-20 GHz frequency range, accounting for nearly 46% of global shipments over the forecast period.

"The tremendous increase in mobile data consumption is rippling through many market segments," noted Eric Higham, Director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "As operators deploy more base stations to handle the data increase, wireless point-to-point radios are becoming an extremely attractive option to backhaul the data from the edge to the core of the network."

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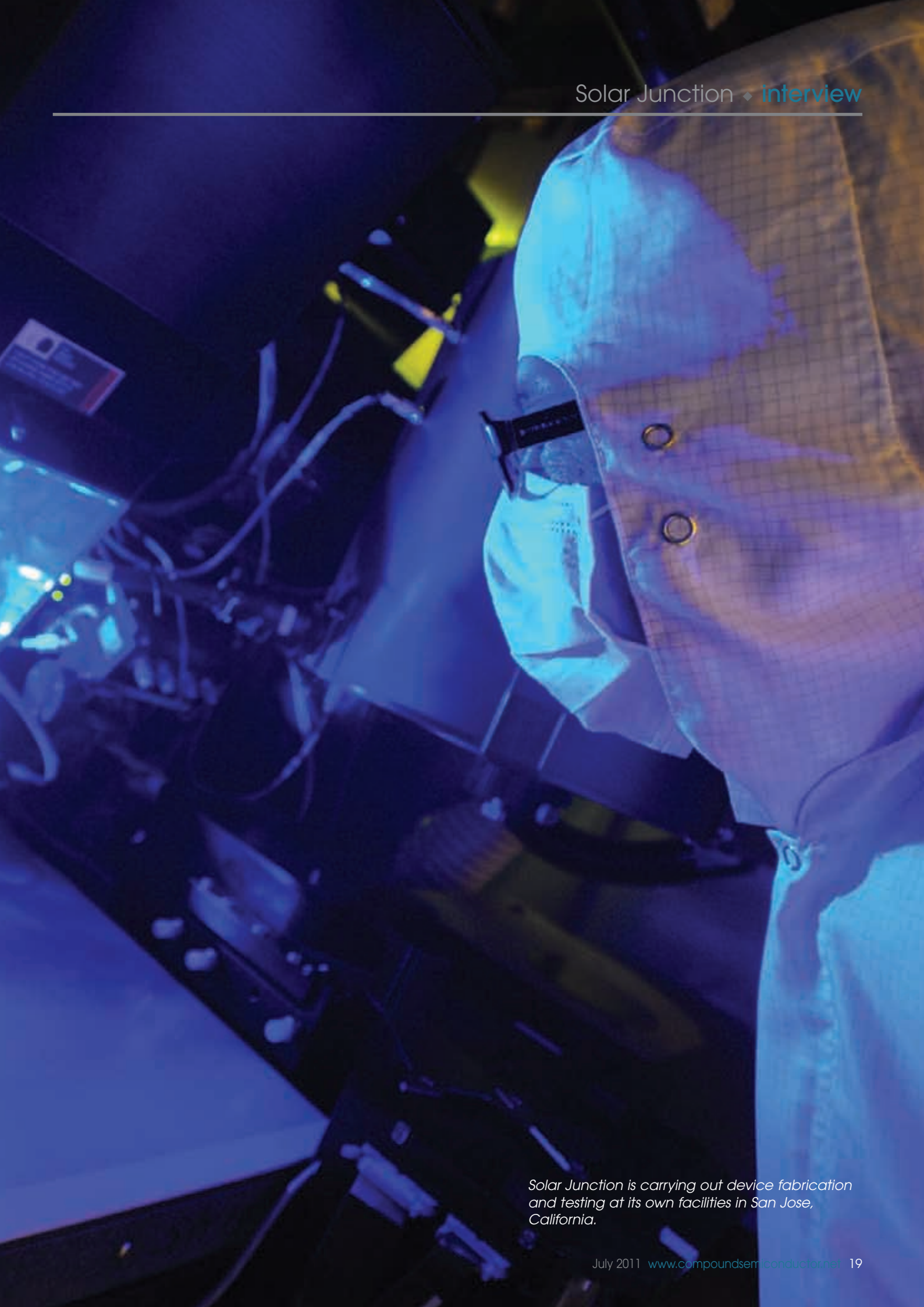
## Dilute nitrides give Solar Junction a critical edge

Following years of quiet development, Solar Junction has recently shot to fame with record-breaking triple-junction cells incorporating dilute nitrides. The next phase for the company is to ramp its manufacturing capacity and help CPV to carve out its own segment in the PV market. **Richard Stevenson** catches up with the plans of the Stanford start-up.

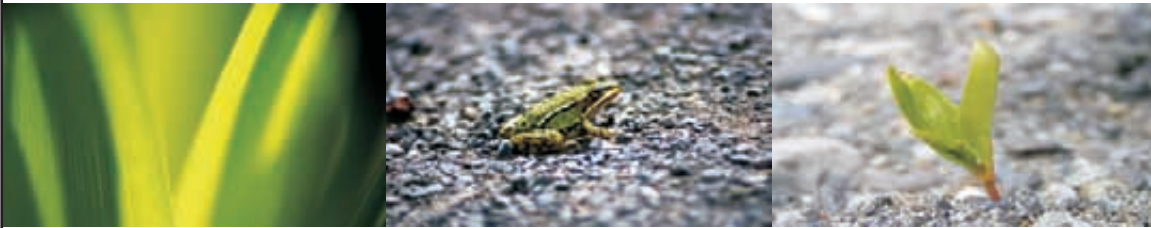
**W**ithin the fraternity of multi-junction solar cells makers, bragging rights rest with those making the most efficient devices. Up until recently, the record for cells operating under high concentrations would regularly change hands between well-established manufacturers of triple-junction cells, such as Spectrolab and Emcore, and government-funded institutions, such as Fraunhofer ISE and the National Renewable Energy Laboratory (NREL). But recently, it has been a pair of smaller firms that have been driving solar cell efficiency to new levels. Late last year Spire Semiconductor unveiled a record-breaking cell efficiency of 42.3 percent, and this April Solar Junction trumped that effort with a 43.5 percent efficient device.

One incredibly impressive characteristic of the Solar Junction cell is its high level of performance at very high concentrations. Peak performance occurs at 400-600 suns, and efficiency in excess of 43 percent is recorded at 1000 suns. Increase concentration further to 2000 suns – an operating condition that is often unavailable in tests performed by independent labs to verify performance – and the cell's efficiency is believed to still be above 42 percent.





*Solar Junction is carrying out device fabrication and testing at its own facilities in San Jose, California.*



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These groundbreaking efficiencies at very high concentration factors are a mouth-watering prospect for any concentrating photovoltaic system (CPV) manufacturer. If they could get their hands on large numbers of cells delivering this level of performance, they could cut production costs for systems with a given output power, thanks to the combination of fewer devices, fewer focusing elements and smaller tracking systems. What's more, Solar Junction promises to elevate solar cell performance to new levels over the next few years. The current design can potentially produce efficiencies of 44 percent or more, and future variants that do not require any major technical innovation could hit efficiencies approaching 50 percent.

### From lasers to CPV

The trailblazing technology that lies at the heart of Solar Junction can be traced back to James Harris' group at Stanford University, CA. Research programmes run by Harris include the development of telecom lasers based around the dilute nitride InGaAsNSb. This material can be grown in a lattice-matched fashion on GaAs substrates, which are cheaper and less fragile than their InP cousins commonly used as a platform for making 1.3  $\mu\text{m}$  and 1.55  $\mu\text{m}$  lasers.

In the mid-noughties, many multi-junction cell developers were trying to fabricate efficient devices that incorporated a bottom junction made from dilute nitrides, which are strong absorbers in the infrared. The Stanford team had a brief stab at this problem, and unlike everyone else, they succeeded. They detailed their efforts in a joint paper with NREL.

Harris discussed these promising results at a conference in 2007, and they piqued the interest of Arno Penzias, a Nobel-prize winning physicist famous for his measurements of microwave background radiation. At that point in his career, Penzias was no longer a researcher – he had racked up ten years as a Venture Partner at New Energy Associates, a major investor in clean technology and a financial backer of the CPV system maker Sol Focus. Penzias was convinced that the Stanford team's dilute nitride technology could play a major role in accelerating the deployment of CPV technology, and it didn't take him long to convince NEA to fund a venture to try and make this happen.

A handful of alumni from Harris' group were tremendously enthused by this opportunity to start a solar cell company. Stanford is renowned for fostering a culture of entrepreneurship, and back in early 2007 many of the founders of Solar Junction were working for local start-up Translucent, a developer of epitaxial materials for the electronics, photonics and solar industries.

On July 16, 2007 three former employees of Translucent and graduates of Stanford's dilute nitride

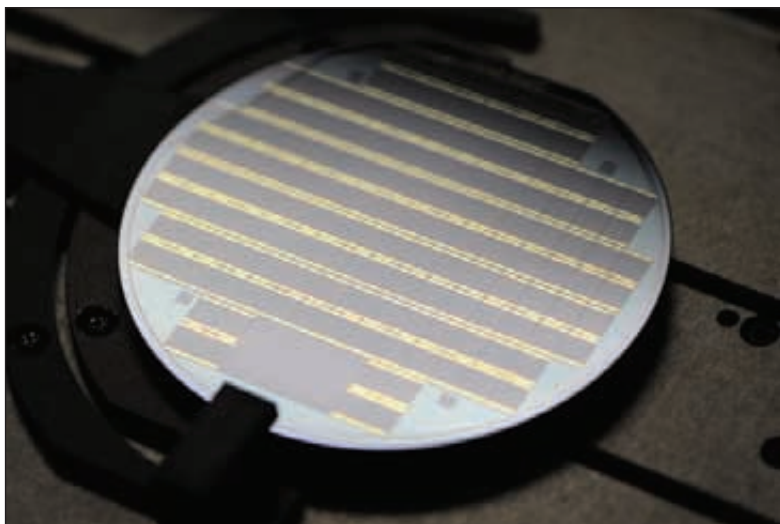
group – Homan Yuen, Vijit Sabnis and Mike Wiemer – co-founded Solar Junction, in conjunction with Harris, Craig Stauffer and Jim Weldon. The latter is a former COO of Translucent, and has 29 years of experience in managing a technology company.

To begin with, the founders of Solar Junction based themselves in Cupertino, which is about a mile from Apple's headquarters. "We were basically just a bunch of guys cramped into one room, with a couple of laptops and some seed funding, working out what to do next," reminisces Sabnis, the company's Vice President of Technology.

As they sat together, they tried to figure out what their business model should be. And the key question that they chewed over was this: should they adopt an outsourcing model, following in the footsteps of Cyrium and Quantasol; or should they be an integrated device-making company? While the founders mulled over this question, they were able to continue developing their material technology by booking time at the public fabrication facility at Stanford University. In addition, they worked with epifoundries. "That wasn't surrounding our proprietary IP – we were basically getting our feet wet in multi-junction technology," explains Sabnis. In addition, the team learnt how to model multi-cell devices.

After the Stanford spin-off had been going for a few months, its founders started trying to secure investment. And by April 2008 they had won funding from three VCs: NEA, Advanced Technology Ventures and Draper Fisher Jurvetson. The team had also come to a conclusion about the company's future. "We decided that, at least at the early stage of our existence, we would do everything internally," says Sabnis. "We were not going to rely on outsourced vendors. The technology was too complicated to use an epifoundry, or even a wafer-processing foundry."





Taking that decision put the founders of Solar Junction in control of their destiny. They were well aware that they had to develop their technology fast to keep hitting the milestones agreed with investors, and felt that the only way to execute on this front was to have their own facility. The VCs supported this decision, even though it required a substantial amount of money to build a fab. In June 2008 the company moved to its current headquarters in San Jose, before bringing up an epi-reactor in a few months. The team hit a major technical milestone that December, upgraded the fabrication facility in early 2009, and made its first triple-junction cell that April. It had an efficiency of 10 percent. “We were surprised,” says Yuen. “It was a shot in the dark – we thought we were going to get 0.02 percent!” From that day on cell efficiencies climbed fast, hitting 30 percent in August, and making further gains throughout 2010. This January the company reported an NREL-verified efficiency of 40.9 percent, and this February and April it announced efficiencies of 41.4 and 43.5 percent.

### Simple structures

The device behind these record-breaking figures is anything but esoteric – Yuen, Solar Junction’s Vice President of Research and Development, goes so far as to describe it as “boring”. It’s a justifiable description, because the cell is free from quantum wells, quantum dots and metamorphic layers. Instead, it is just a stack of bulk layers on a GaAs substrate – a dilute nitride for the base, and GaAs and GaInP for the middle and top cells, respectively. The dilute nitride can take the role of a tuneable infrared absorber, with a bandgap that can be adjusted from 0.8 eV to 1.4 eV by altering alloy composition.

Another great benefit of dilute nitrides is that they can be lattice-matched to GaAs or germanium substrates. This gives Solar Junction a significant edge over

many of its rivals, including Spectrolab and Emcore. These incumbents have turned to metamorphic buffer layers to alter the lattice constant within the device, so that they can tune the bandgaps of the cells and ultimately reach higher efficiencies. “Those graded [buffer] layers introduce a lot of crystalline defects, such as dislocations, and managing those defects is a difficult thing,” says Yuen. Yields can fall, and the increased thickness of the epilayers in an inverted metamorphic design adds to production costs. “It is also very difficult to ensure that those cells are going to remain reliable over a twenty-to-thirty year time frame,” claims Yuen, who expects these issues to slow commercial introduction of inverted metamorphic triple-junction cells. In his opinion, these delays are very damaging to the commercial prospects of CPV, which faces strong competition with thin-film and silicon technologies that are getting better and better, and cheaper and cheaper. “There’s no time,” argues Yuen. “You can’t wait five years for a metamorphic structure to be available – you need it here and now.” He argues that if CPV is to be successful, cells must deliver rapid, consistent and sustained improvements in efficiency, reliability and tuneability. “That’s why Solar Junction’s story resonates so well with our customers.”

These customers can already receive limited quantities of cells with typically 41.5 percent efficiency, and Solar Junction plans to make this product widely available next year. “We have a roadmap that is going to take us up into the forties and even reach fifty percent, using a four or five junction cell that utilises a dilute nitride platform, in addition to using gallium arsenide, aluminium gallium arsenide and indium aluminium gallium phosphide,” says Yuen. This roadmap should enable Solar Junction to deliver significant hikes in device efficiency on a biannual basis, thanks to the introduction of additional cells and evolutionary improvements that occur when devices are made in high volumes.

The high efficiency of Solar Junction’s cell, along with its potential to get markedly better over the next few years, should help to enable CPV to grab a significant share of the PV market.

“The dream of CPV is for the PV market to see some real segmentation,” says Yuen. He hopes that in locations with intense solar radiation, the financial case for installing CPV will be so strong that it will soon start to dominate this segment of the market.

Employing Solar Junction’s devices in CPV systems operating in these environments can cut generating costs associated with the technology, because these cells are capable of operating efficiently at very high concentrations, such as 1000 suns. Magnification

There is a point at which if we sell our device at a certain price, (makers of 39.2 percent efficient cells) have to give it away, or pay for the customer to take it. At some point, cell efficiency trumps everything.

always leads to 'hot spots' – in this case local concentrations of 1500 or 2000 suns that produce very high current densities. "If your tunnel junction isn't very good, you kill cell performance," says Sabnis. He claims that tunnel junction performance typically falls off above 1000 suns. "Using our approach you can have tunnel junctions that approach 8000 [suns] without any failure, so system manufacturers don't have to worry about hot spots with our cells."

Makers of CPV systems also want cells with high levels of reliability. Solar Junction has carried out well-known reliability and ageing tests on its cells, which have revealed device lifetimes of many, many decades. The company currently carries out a 'flash test' on every cell produced, evaluating performance at the concentration that the cell is intended for. But in future Solar Junction is likely to use sample testing, an approach that the company says it can justify, thanks to the high yield of its production process. However, if customers prefer, each cell can be tested prior to shipment.

The costs associated with the production of the company's cells are similar to those of traditional triple-junction devices, according to Jeff Allen, Solar Junction's Director of Business Development. "And as the incumbents adopt a metamorphic cell, which requires thicker graded-buffer layers and lift-off, we become cost-advantageous." What's more, by employing a dilute nitride platform, the addition of a fourth and fifth junction does not lead to a significant change in overall device thickness. "So our advantage from a cost standpoint increases, because we get a substantial improvement in power output and efficiency while costs are very flat," adds Allen.

Today, Solar Junction is sampling cells to all the major CPV system manufacturers, plus many of their smaller rivals. And according to Yuen, feedback is excellent: "It is the most power output they have seen from all the cells they have." The Stanford start-up is now entering qualification with some of these companies, and also taking orders.

Solar Junction's highly efficient cells seem to be destined to have a profound impact on the CPV cell market. Modelling by the Stanford spin-off has compared the performance of CPV systems employing cells with 41 or 42 percent efficiency, and those delivering 39.2 percent, the value quoted for Spectrolab's devices that it is shipping today. "There

is a point at which if we sell our device at a certain price, [makers of 39.2 percent efficient cells] have to give it away free, or pay for the customer to take it," claims Wiemer. "At some point, cell efficiency trumps everything."

Arguably, the only significant obstacle in the path of Solar Junction's future success is the raising of cash needed to expand manufacturing capacity from today's level, 7 MW, to 250 MW (capacities assume cell operation at 1000 suns). Urgency in this capacity build-out is critical, says Sabnis, because the likes of Soitec, Ammonix and Sol Focus are experiencing a tremendous ramp in orders for their CPV systems. "Our biggest focus right now is getting designed into their systems, going through the various qualification procedures necessary to do that, and developing a reliability data path on our cells."

If Solar Junction can raise the capital to expand its manufacturing capacity, it will surely have every opportunity to become one of the biggest makers of CPV cells in the world. And the company is giving itself a great chance of executing on this by not getting distracted by thoughts of becoming a vertically-integrated supplier of CPV modules and systems, and not diluting its resources by also battling to break into the market for solar cells for powering satellites. Any by focusing on what it does best – making really efficient cells – it to be promises to become a major force in helping CPV to establish its own space within the CPV market.

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## Dies and integrated assemblies

Customers can choose to either buy bare die from Solar Junction, or integrated solar assemblies. The San Jose start-up never intended to offer the latter on a commercial basis – it planned to just use the assemblies for testing. However, the company received several requests for this product from customers, who explained that known good-die shipped by the big solar cell manufacturers were failing after contract manufacturers had inserted them in solar assemblies. "[Our customers] were basically pleading with us: 'We just wish the cell manufacturers would do this for us to prevent this problem'," says Jeff Allen, Solar Junction's Director of Business Development. The company was well placed to address this issue, because it had hired engineers with tremendous expertise in packaging and reliability.



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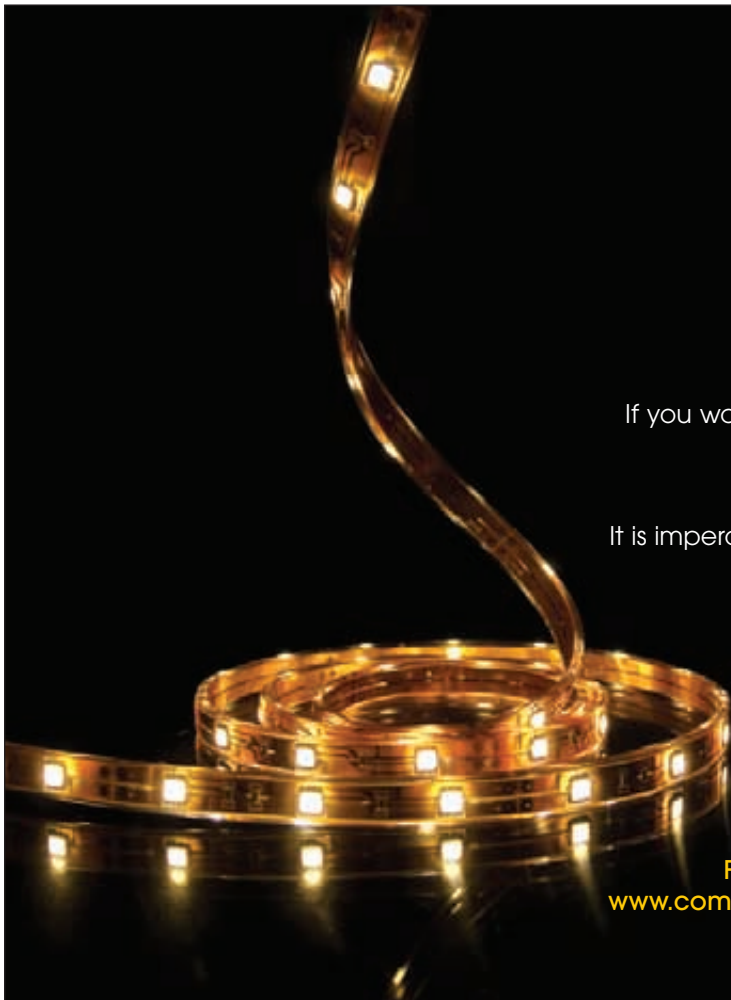
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# General illumination takes centre stage at euroLED

An internationally diverse, well-attended exhibition at euroLED showcased the tremendous growth of LED lighting products for general illumination. Although these solid-state sources account for only a tiny fraction of total lighting sales, many conference speakers argued that far greater market penetration will follow once these products are far cheaper and deliver better colour quality. **Richard Stevenson reports.**

If you want to quickly assess the health of an industry, one option is to take a brief look at the progression of its conferences. In the case of the euroLED conference series and the sector of the III-V industry that it supports, this approach provides an excellent overview of current trends. The inaugural euroLED meeting held in the UK back in the early noughties was a very small affair, but over the years the conference has moved to larger premises, first to the National Motor Museum in Birmingham and more recently to the Ricoh Arena, part of a complex that is also home to Coventry City Football Club.

The migration to larger conference premises is reflected in the attendance figures for euroLED, which was held this year on 8-9 June. Although the size of the audience listening to the talks at euroLED 2011 was comparable to that of a few years ago, many more delegates were mingling in the exhibition hall. In this cavernous arena, companies from all around the world were displaying a vast array of solid-state lighting products, plus ancillaries for driving and testing them. The exhibition included an incredibly strong showing from China, with many, many firms showcasing their portfolios of LED lamps in various guises.



*In recent times, euroLED has been held at the Ricoh Arena, a stadium complex containing a 32,600-seater football stadium for Coventry City, plus a 6,000 square-metre exhibition hall, a hotel, a leisure club and a casino*

The topic of LEDs for general illumination was also the focus of the opening remarks given by Bob Pollock, Senior Vice President of Worldwide Sales at LED chipmaker Cree. Pollock did not spend time justifying why the LED lighting revolution is a certainty, rather than just a possibility, because he knew that he would have been preaching to the converted. So instead he showed the audience how they can play their part in driving this sea-change in the lighting business, by giving them a crash-course in how to make the best possible case for LED lighting.

Pollock did this by showing delegates a great resource for promoting the strengths of LED lighting – a two-and-a-half minute video by General Electric. This video clearly sets out the major benefits of LEDs for general illumination: greater efficiency than incumbent sources, lower maintenance that stems from longer lifetimes, and a product that is better for the environment. According to the film clip, in terms of efficiency, the LED is 68 percent more efficient than a high-pressure sodium lamp for area lighting and 80 percent more efficient than neon lights used in signage lighting. What's more, its lifetime of



50,000 hours is more than double that of fluorescent and high-intensity discharge lamps, and it has good green credentials, thanks to the absence of mercury, lead and glass. These attributes translate into significant cash savings - a city with a million people that switches from high-pressure sodium streetlights to LED-based equivalents could save \$6 million over the lifetime of the solid-state lamp.

The greater emphasis that the LED industry now places on general illumination was also a central message in the opening talk, which was given by Jamie Fox, Research Manager for LEDs at the UK-based firm IMS Research. "In 2011, general lighting has, for the first time, become the top focus for component manufacturers," said Fox.

According to him, the reason for this shift in focus is that the LED market for TV backlighting will saturate around 2013, and chipmakers are now looking at how they can grow their sales through the latter part of this decade and beyond. TV backlighting accounted for about half of the LED revenue ramp from \$6.1 billion in 2009 to \$10.2 billion in 2010, and will significantly contribute to the more modest global revenue growth in 2011. However, by 2016, LEDs for general illumination will be a major part of the LED business, due to a growth in revenue from around

\$1 billion today to \$6 billion in 2016.

Fox also discussed the massive ramp in MOCVD reactor shipments to China, which have been spurred by government subsidies of up to \$1.8 million per tool. In 2009, global MOCVD tool shipments stood at 227, and IMS expects this to shoot up to 1089 this year. This tremendous growth in worldwide production capacity is expected to lead to oversupply of LED chips and downward pricing pressures on these products, issues that were detailed at length in an interview with Fox's colleague, Ross Young, in the previous issue of *Compound Semiconductor* (see "China's LED chipmaking boom fuels overcapacity" June p.38).

### A European perspective

Reflecting the focus of the conference, Fox offered an overview of the European LED market. Here Philips and Zumtobel lead luminaire and fixtures sales, and Philips, Osram, and General Electric dominate shipments of LED lamps (replacements for incandescents and compact fluorescents). Of the 105-110 million LED lamps shipped in 2010, 27 million went to Western Europe. Sales to this region are tipped to grow at 50 to 100 percent per year, according to Fox who is preparing a more accurate forecast. He believes that high levels of LED lamp penetration will only occur when prices plummet to \$10 or less.

Following Fox on the podium was Mark van den Berg, Philips Lumileds' Director of Marketing for Europe, the Middle-East and Africa. He discussed the quality of

LED light, which he believes has overtaken efficacy as the principle focus for chip improvement; and he spoke about what is needed to drive market adoption. In his opinion, the greatest threat that Lumileds faces to expanding its sales does not come from rival chipmakers, such as Cree, Osram and Samsung, but from makers of compact fluorescents.

van den Berg pointed out that one of the biggest obstacles to greater adoption of LED lighting is the complexity associated with defining the performance of this light source. In his opinion, it is only possible to make a good decision on what product to use after scrutinizing datasheets and understanding the application.

According to van den Berg, an LED light source must excel in five separate areas if it is to give a high quality of white light. For starters, it must have a colour-rendering index (CRI) exceeding 80, and ideally 90, with particular attention paid to the rendering of shades of red. The solid-state lighting source must also be evaluated at its running temperature, and it must deliver colour consistency between the LED and the luminaire. In addition, the LED sources must deliver great colour consistency within the beam, and over the lifetime of the device.

To drive far higher market adoption, van den Berg claimed that LEDs must deliver a higher quality of light at a far lower price. In addition, he said that standards applied to this form of light



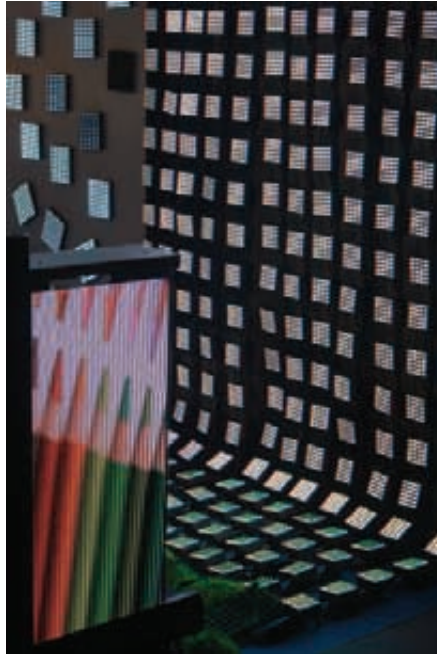
must approve – “[today] it is quite a mess and not consistent.”

Other factors also come into play, which depend on the target application. For example, for the lighting of outdoor areas, van den Berg said that the payback associated with LED deployment is too long, and must reduce to less than three years through improvement in the cost per lumen and chip efficiency. Warmer colour temperatures that are stable for decades are also needed.

Another sector, office light, is a “tough market” to penetrate, according van den Berg. He pointed out that the T5 fluorescent is a very cheap incumbent with an efficacy comparable to that of the best LEDs of today. To have success here, makers of LED lighting must convince owners of offices to re-consider their approach to lighting this space by looking at lux levels. If they think along these lines, they may switch to greater use of task lighting and to lower ambient lighting, changes that may lead to increased LED deployment.

To enable LEDs to penetrate these areas and also replace conventional bulbs in the lighting of shops, van den Berg believes that the cost per lumen must fall by 95 percent. Delivering this massive hike in affordability will require improvements to recombination, extraction and phosphor conversion efficiencies, plus higher drive current densities, superior package designs, higher chip yields, greater fab utilization and the availability of better production tools.

When Pollock spoke, he echoed many of the points made by van den Berg. But he also ventured into new territory, showing the audience how far the LED community had progressed in recent years: between 2006 and 2011, the efficacy of industry-leading cool-white LED products driven at their maximum drive current increased from 50 lm/W to 90 lm/W, and the cost per lumen fell by more than an order of magnitude. Pollock also detailed the improvement to the quality of Cree’s LR6 downlight over a similar timeframe. Back in 2007,



this high-quality white-light source that blends the emission of white LEDs with red-emitting variants employed 42 devices consuming a total of 12 W to deliver 650 lumens. Last year, the same light output was realized with 8 LEDs consuming 10.5 W, and this product was far more affordable – it had fallen from a commercial wholesale price of more than \$100 in 2007 to a retail price tag of just \$50.

### Failings of the CRI metric

Issues relating to categorizing the quality of light were highlighted in a presentation from Yoshi Ohno from the National Institute of Standards and Technology. He began his talk by explaining that colour quality was governed by both the chromaticity of the light source and colour rendering, which is a measure of how the colours of an object are reproduced under this illumination. He then gave clear examples of how two sources with the same CRI could make objects appear to have very different colours.

For years and years, makers of LEDs have been trying to increase the efficacy of their LED chips. The theoretical maximum for any lighting source is 683 lm/W, but that is for a green source of a particular wavelength; a low-pressure sodium lamp could hit 520 lm/W, but the colour rendering of this source is poor.

Putting these figures in perspective, Ohno explained that blue LEDs with yellow phosphors are capable of 294 lm/W, and sources that employ colour mixing of red, green and blue devices could just top 400 lm/W. The quality of the colour rendering provided by such schemes depends on the width of the sources. During fifty years of refinement of the fluorescent lamp, broadband sources have been replaced by narrowband equivalents to improve colour rendering, and Ohno expects the same shift to occur in the LED industry.

Although the presentations of Ohno and many of the other speakers showed that there is still much work to do for the LED lighting industry, the general mood is that this technology is certain to lead a lighting revolution. Many exhibitors highlighted the breadth of LED lighting products that are available today, and this industry is set to thrive as it makes improvements to colour quality and efficacy, alongside lower prices.

### Resources

General Electric’s video promoting LEDs can be found at: [www.youtube.com/watch?v=Dbl21vyZbY](http://www.youtube.com/watch?v=Dbl21vyZbY)

*The world market for lamps and luminaires in general & exterior lighting, 2011 edition* by IMS Research

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## The leading LED chipmakers

According to IMS research, the leading manufacturers for LEDs in 2010, in terms of revenue, were:

Nichia	15 percent
Samsung	10 percent
Osram	9 percent
Seoul Semiconductor	8 percent
Cree	6 percent
Philips Lumileds	5 percent
LG Innotek	4 percent
Everlight	4 percent

## Wafer bonding: selecting the right process for making powerful, vertical LEDs

LEDs with a vertical geometry are promising candidates for deployment in solid-state lighting products because they can handle the high drive currents needed to deliver a high luminous output. Manufacturing this form of LED requires a wafer-to-wafer bonding process, which involves many variables that need to be optimised for the specific device design, say **Thomas Uhrmann, Eric Pabo, Viorel Dragoi and Thorsten Matthias** from EV Group.

**W**hite LEDs are already impacting the general lighting market, and their penetration in this sector is widely expected to rise. The rate of adoption will be governed by three factors: luminous efficiency, cost per lumen installed, and lumens per socket.

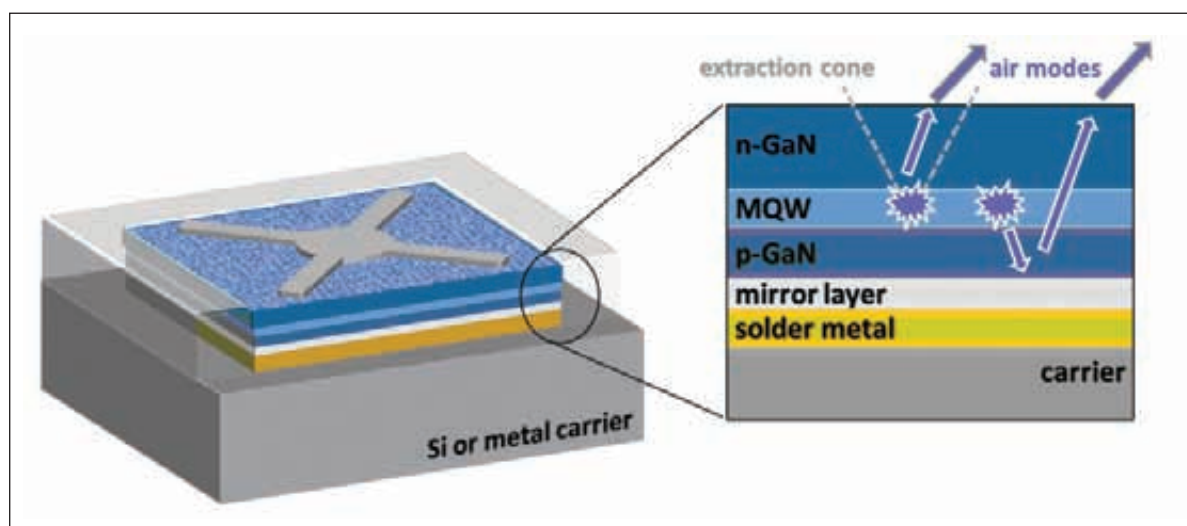
One way to improve all three areas simultaneously is to increase LED efficiency. But even greater gains to the lumen output of the luminaire and its cost-per-lumen are possible by combining gains in efficiency with a higher drive current for the device. Cranking this up, however, increases LED heating. And to cope with this, the system designer must carefully

manage heat that flows from the device junction to the package, fixture and surrounding environment.

It is possible to increase the rate that heat flows out of the LED by using metal wafer bonding for transfer of the epistructure to another substrate. Take this step and the LED benefits on two fronts: it can rapidly conduct heat away through a metal bond with a low thermal resistance, and it can dissipate heat through a substrate with low thermal resistance.

This approach can not only enhance the electrical properties of the nitride-based white LED, but also its blue variant and its red, orange and yellow cousins

*Figure 1: A key feature of the vertical LED is its highly reflective sub-structure that excels at conducting the heat away. This allows the device to operate at high currents, and consequently high luminous output*



that are made from the AlInGaP material family. At EV Group, which is based in St. Florian, Austria, we are supporting the manufacturing of LEDs produced with a metal bonding process. Our involvement includes the recent launch of the first tool dedicated to this fabrication step – the EVG 560HBL. This piece of equipment is designed to deliver very high yields thanks to optimisation of pressure and temperature distributions, and it sets a new benchmark for throughput of up to 176 bonds-per-hour for 2-inch wafer equivalents.

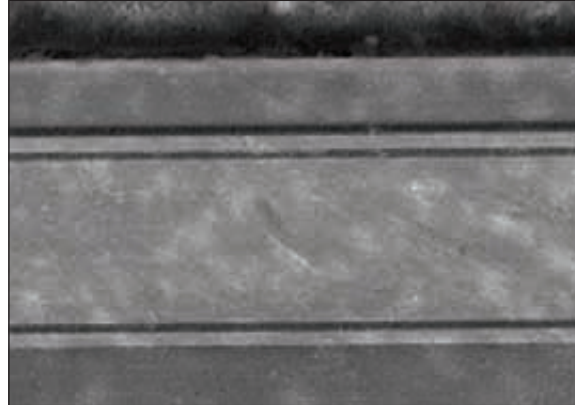
### A little history...

Wafer-to-wafer bonding is not new. It was developed 20-30 years' ago to address the need for wafer-level capping of MEMS devices. Pioneers of wafer-bonding used anodic bonding and glass frit bonding to attach one wafer to another. However, these two approaches are being superseded by metal bonding technologies, which offer a lower form factor.

The metal bonding approach is the only one that is applicable to high-brightness LEDs, due to the requirement for low thermal resistance. This is not the only benefit of this type of bond, however – it can also increase the luminous efficiency of the device. It was first used in AlInGaP-based LEDs that are grown on GaAs substrates. Spontaneous emission from these devices is assumed to be isotropic, with half of all the light generated propagating towards the substrate, where most of it is absorbed, leading to lowering of overall device efficiency. Inserting a distributed Bragg reflector beneath the light-generating region of the LED could prevent this light loss to the substrate, but in practice this only works effectively on one optimised direction of light emission, and it is better to turn to wafer bonding, where a reflective layer is included in the metal stack (see Figure 1).

Manufacturing nitride LEDs with a metal bonding process presents some different challenges. Sapphire, the most widely used platform for making blue and white LEDs, has the desirable attribute of high transparency, but it is a poor heat conductor. Consequently, high-power LEDs employing a lateral design are poor at dissipating their heat and run hot, which degrades device performance. To combat this, some LED manufacturers have developed vertical LED designs, which involve substituting sapphire for another carrier with higher thermal conductivity (see Figure 1).

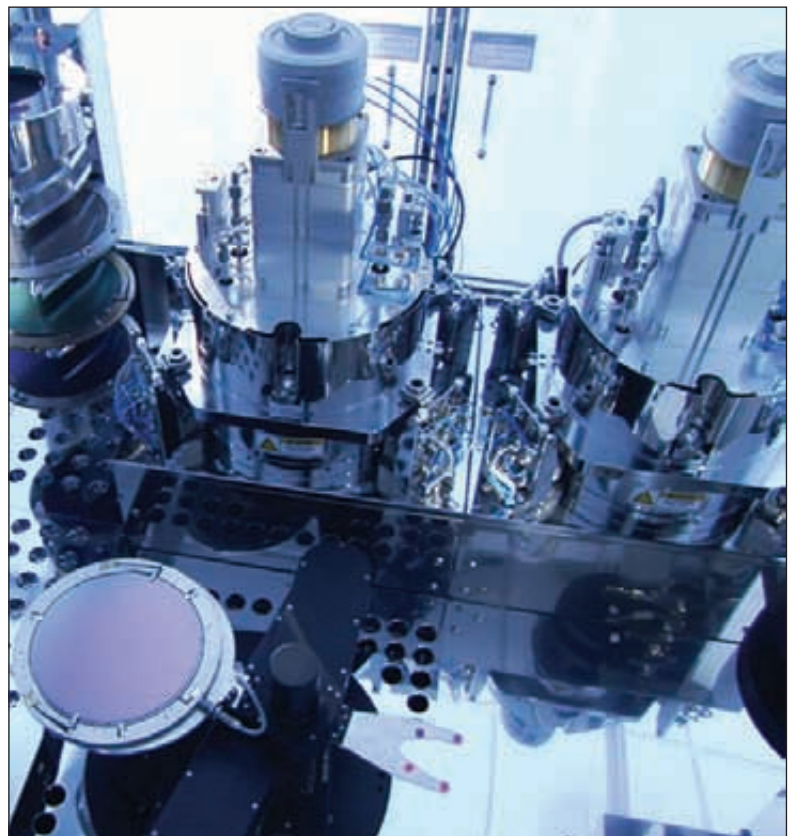
Switching to this design also simplifies the manufacturing process by eliminating an etching step required to form the n-contact in a lateral LED. In addition, the vertical architecture produces a vertical current path, leading to a lower forward bias and eliminating current crowding issues that are frequently seen for other LED designs. And there are



*Figure 2: A scanning electron microscopy cross-sectional image highlights the high quality of the join between an InP and GaAs wafer after Au:Sn eutectic wafer bonding*

other benefits too: the addition of the metal bonding layer ensures that all of the light exits from the top of the LED; and manufacturing may be simplified, because the vertical LED design uses the same process flow for different die sizes.

Every vertical LED process flow begins by depositing a stack of epitaxial layers on a substrate by MOCVD. Some engineers will then turn to the patterning of the LED dies, while others will begin with layer transfer by wafer bonding. The decision of what order to perform the various processing steps is primarily governed by the nature of downstream processing

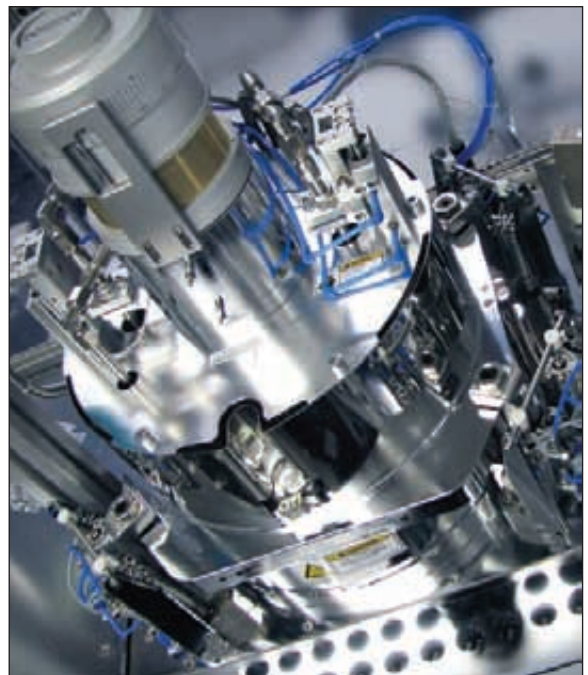


used to remove the growth substrate and individual design differences.

Manufacturers of AlInGaP LEDs tend to carry out full-area wafer bonding prior to patterning, because this process does not introduce strain and the substrate can be removed by grinding and chemical removal. Making nitride LEDs is more complicated, however. When sapphire is separated from the epitaxial film by the widely employed process of laser lift-off, strain is induced at a die or in multiple die regions. This strain stems from decomposition of the interfacial GaN layer, which is triggered by high power ultraviolet irradiation. Cracking of the active layers can occur, impacting yield, but this can be addressed by confining the strain region via previous structuring of the die.

### Bonding options

In addition to high thermal conductivity, the bond interface in a vertical high-brightness LED must have excellent electrical conductivity. Fortunately, high thermal conductivity and high electrical conductivity tend to go hand-in-hand, and are found in germanium and metallic substrates. Both of these are popular, but silicon is emerging as a carrier material, featuring high heat dissipation and low thermal expansion. Using silicon also enables vertical LED producers to include a Zener diode directly into the carrier substrate, which serves for the electrostatic protection of the sensitive GaN LEDs.



Thermal expansion coefficients must also be considered when selecting a substrate material to bond to the epiwafer. All common wafer-to-wafer bonding processes require elevated temperatures and the bond process is fine tuned to accommodate thermal expansion mismatch between the substrates.

The bonding process must be based on metallic bonding layers because the technique used for wafer-to-wafer bonding must meet requirements for high thermal and high electrical conductivity. This limits the bonding process choices to solder (which includes eutectic and transient liquid phase) and thermo-compression bonding. Both approaches are discussed in detail in the side panel "Attaching the wafers together".

To decide which process is most appropriate, makers of vertical LEDs must consider the characteristics of both the growth and carrier substrates, and account for differences, such



*Figure 3: The EVG560HBL, which is available in both fully automated and semi-automated operation, supports metal, adhesive and fusion bonds of various substrate types. EVG claims that it is well suited to high-volume LED manufacture, thanks to its combination of cassette-to-cassette operation, multi-substrate bonding capability and its modular design that features up to four swap-in process modules. According to the toolmaker, the combination of field-proven wafer bonding technology and a unique approach to low-temperature metal wafer bonding results in unprecedented throughput and yield*

as those in thermal expansion and surface properties. For AllnGaP LEDs, which usually have a highly flat surface thanks to their lattice match to the GaAs substrate, thermo-compression bonding between two gold surfaces is frequently used.

For InGaN LEDs, however, surface roughness and defect density are considerably larger and eutectic or transient liquid phase bonding is preferred. This tends to result in a high yielding bonding process (see the example of Au:Sn bonding in Figure 2).

Further decisions to be made by any vertical LED manufacturer include the thickness of the bonding metals and how they are deposited, and also the selection of adhesion and barrier layers. These layers – typically made from platinum, aluminium and gold, or stacks combining these metals – are often needed to ensure sufficient adhesion and prevent migration of bonding metals into either of the substrates.

Yet another choice facing any vertical LED manufacturer is the choice of tool that will use for the bonding process, which will include alignment of the wafers prior to bonding. We believe that our EVG 560 HBL is worthy of consideration, thanks in part to its combination of high throughput and versatility – it supports metal, adhesive and fusion bonds of various substrate types. It also delivers high yields, so it is capable of helping to drive far greater adoption of LEDs in general lighting, by helping to make these devices deliver more light more efficiently.

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#### Further reading

E.F. Pabo, V. Dragoi, "Wafer Bonding Process Selection", MEMS Industry Group

## Attaching the wafers together

The two approaches to bond one wafer to another during the manufacture of high brightness LEDs are solder bonding (also known as eutectic or diffusion bonding) and thermo-compression bonding.

Solder bonding is a general term for a metal bond formed by liquid metal, which could be a pure metal, but is typically a binary alloy and in some cases a ternary one. A eutectic wafer bonding alloy is formed at the bonding interface in a process which goes through a liquid phase: for this reason, eutectic bonding is less sensitive to surface flatness irregularities, scratches, and particle contamination, compared to the direct wafer bonding methods.

A successful eutectic bonding process requires bonding equipment that combines good temperature control with temperature uniformity across the entire wafer. The temperature ramp for heating and cooling processes are important. Selection of the details of this process should depend on the particular substrate materials employed to avoid thermal shock for dissimilar materials, and should also be governed by device requirements. For example, process engineers must consider whether the device will be impaired by heating or cooling cycles.

The liquid melt formed during the bond process allows the embedding of interfacial particles in the melt without creating defects. Good wetting is achieved even on very rough surfaces, which are typical for InGaN-based LEDs. This contributes to enhanced device yield and performance.

For some high-brightness LED manufacturing process flows, the material should be kept below the bonding

temperatures for the most usual eutectic alloys (300°C - 400°C). In such situations an alternative process can be used – diffusion soldering or transient liquid phase (TLP) bonding, which results in an inter-metallic compound bonding layer. This technique uses one thin metal layer – typically 1-10 µm thick – which inter-diffuses with its bonding partner during a thermal process to yield an inter-metallic compound layer with a re-melting temperature higher than the bonding temperature. Cu-Sn and Au-Sn are the most popular TLP systems. Like eutectic wafer bonding, diffusion soldering bonding is an attractive option for high-brightness LED manufacturing, because it can planarize over surface defects or particles resulting from prior processes due to surface wetting by the molten metal.

The alternative process, thermo-compression bonding, involves adhesion of two surfaces to one another through diffusion of the metal molecules, such as gold, copper and aluminium, across the bond interface. The diffusion rate is a function of: the metal; the diffusion barriers on the surface, such as oxides; the pressure; the temperature; and the surface roughness. Cranking up the pressure increases the fundamental diffusion rate and also enhances diffusion. The latter results from deformation of the two surfaces in contact, which leads to disruption of any intervening surface films and enables increased metal-to-metal contact. As this diffusion continues, grain growth occurs across the bond interface. Heating the metal increases diffusion and slightly softens the metals, increasing deformation at any given pressure. Excellent bonding yield results when a high force capability combines with pressure uniformity across the bonding area.



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The key to your success



# Comprehensive inspection techniques can underpin high-yield LED manufacturing

A hike in LED manufacturing yields can ensure profitable production of lower cost chips and spur the growth of solid-state lighting. One way for fabs to produce more die that are in-spec is to introduce inspection tools for various steps of the process, alongside software that collates all the data and pin points process issues, says KLA-Tencor's Director of Product Marketing, John Robinson.

The LED industry is not standing still. Leading manufacturers are upgrading production to 6-inch wafers and turning to LED architectures that are significantly more sophisticated – two trends that increase the cost invested at the die and wafer level. Where these chips are going is also shifting, with more and more of them being deployed in automobile headlights, LED TVs, personal electronics and architectural lighting. The emergence of the incredibly lucrative solid-state LED lighting market is also underway, which should enable widespread replacement of conventional incandescent lighting with energy efficient, mercury-free, alternatives.

This evolution of the LED industry has impacted the approach taken to inspect the product during its manufacture. In the past, manufacturers had minimal incentive to deploy in-line yield-improvement strategies because the cost-per-device was low, and the applications for these LEDs were far less demanding on chip performance. Back then, a “test-and-sort” methodology involving selection of good devices at the final production stage could satisfy customer requirements.

Today it's very different. Not only are customers demanding far higher, tighter specs – the price of the LED has also plummeted, and chipmakers must hit higher yields to ensure profitability. Consequently, most leading manufacturers are turning to comprehensive yield management methods to better serve the needs of their markets while retaining cost

competitiveness. At KLA-Tencor, a US-based manufacturer of inspection tools for the semiconductor industry, we are firm believers in the benefits of a holistic approach to LED yield management strategy. Ideally this should include: in-line automated inspection at key points throughout the production process; fast detection of process excursions; timely root cause identification through Defect Source Analysis; use of advanced Spatial Signature Analysis; and a comprehensive universal software system for aggregating, analysing and utilizing information to minimize propagation of production errors and drive timely corrective actions.

## Tremendous opportunities

Two key targets set out in the US Department of Energy's roadmap for solid-state lighting are a doubling of LED efficiency and a halving of its price per lumen over the 2009-2015 timeframe (see Figure

*Figure 1: In-line inspection and yield management will cut the cost and improve the performance of LED manufacturing*



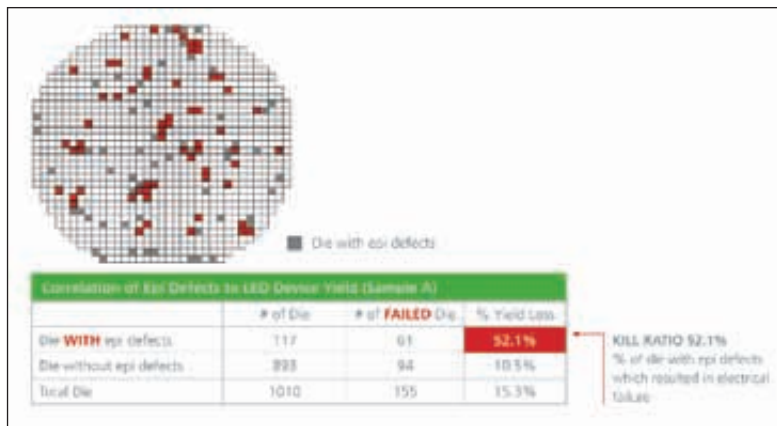


Figure 2: Automated wafer inspection correlates epitaxial defects with electrical failures, which were assessed at the end of the manufacturing process

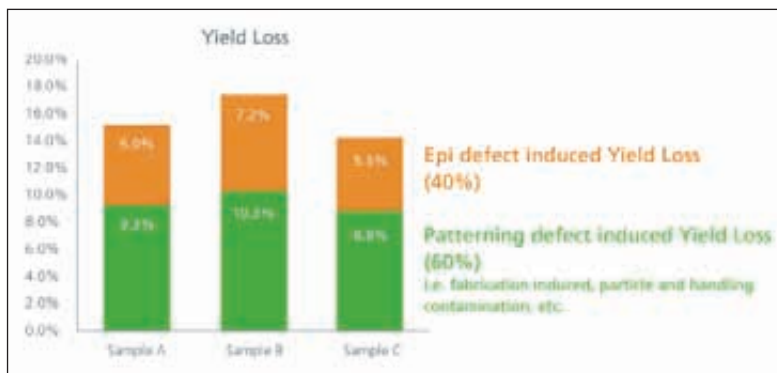


Figure 3: Patterning defects are a bigger cause of yield loss than epi-related issues

1). To fulfil these goals, more than half of the cost reduction will have to come from improvements to in-line inspection, process control and other techniques to increase yield.

If LED fabs continue to employ manual methods for defect and yield analysis, they will fail to increase yields enough to get the chip costs down by 50 percent or more. With this traditional approach, the bulk of engineering time is spent gathering and formatting information – little time is devoted to the crucial tasks of analysis and taking corrective actions where appropriate. In addition, this outdated approach suffers from inconsistency within manual data collection methods, plus the absence of a comprehensive approach to relate critical information between different production processes, such as inspection of bare wafers, epitaxial films, patterned wafers and dice.

This inefficient combination of slow data collection and little analysis can fail to quickly address a process that is deviating beyond acceptable

parameters and leading to the production of a large number of bad die. There is additional cost, too - the expense associated with all operations performed on the bad parts in subsequent production steps. What is abundantly clear from empirical data is that by deploying sophisticated in-line inspection tools at key points early in the process, it is possible to garner excellent predictive information regarding yields resulting from subsequent steps. This gain is highlighted in die maps that compare predicted failures according to post-epi inspection with actual failures during electrical testing (see Figure 2). These maps expose the high correlation between epitaxial defects and LED failures at electrical test - more than 52 percent of the predicted bad die result in electrical failures.

This high “kill ratio” strongly suggests that there is a problem in the epitaxial chamber. However, without the benefit of in-line epitaxial inspection coupled with timely analysis and corrective action, this problem could continue unchecked for two to four weeks, before the error spike shows up in final ‘e-test’. In an LED fab running 20,000 wafers per month, this problem could remain hidden until 10,000 to 15,000 wafers with high defect rates are produced. By itself, integration of in-line epitaxial inspection with timely analysis and correction can save millions of dollars per year in a typical LED fab.

### Manual verses automatic

Although in-line inspection of epiwafers pays dividends, even greater yield improvements are possible when this is combined with other approaches (see Figure 3). We believe that in order to identify process excursions in real-time and support timely corrective actions, automated in-line inspection is essential at all key points in the manufacturing process, which must be used in conjunction with well-targeted Statistical Process Control (SPC). It is imperative to deploy in-line inspection at the points where the defects are being created and to implement corrective actions in real-time. This works best when the approach goes beyond simple-minded “total defect count” SPC methods and instead utilises the most advanced methods.

Interestingly, experience shows that the size of the excursion is less important than the time that it takes to discover and correct it. ‘Major’ excursions can even be spotted with inefficient manual methods, so the risk that they will impair production yields is fairly low. In comparison, it is far harder to uncover more subtle “minor” process excursions, which do not show a dramatic deviation beyond acceptable parameters. These can go undetected for considerable time, putting more product at risk and increasing the potential for big financial losses. This view has been backed up with empirical financial

analysis, which shows that a one-sigma variation is more damaging than a three-sigma or ten-sigma variation. Automated in-line inspection can capture these small deviations by narrowing the distribution and enabling much cleaner SPC charting (see Figure 4).

One of the major downsides of manual inspection is that it is inherently dependent on a variety of uncontrolled variables, including the level of operator training, time of day, attentiveness to task, inspection speed and the amount of product that can be inspected. The upshot of all these uncontrolled variables is excessive “noise” in the statistical distribution of inspection results, which makes it far harder to uncover subtle process excursions (see Figure 4). In contrast, automated in-line inspection systems eliminate subjectivity and variability in the inspection process. Engineers can then direct all their focus at identifying variability in the production process, which speeds the identification of minor excursions that have the potential to make a major impact. Automated in-line inspection stations can be deployed at key points throughout the fab, tailored to the complexity of the particular LED fab processes (see Figure 5). If customers choose to employ our tools, they will be equipping their chipmaking facilities with inspection technologies and platforms that have already undergone extensive evolution and refinement in fabs making silicon ICs.

Our automated tools employ advanced optics that features scan and detection algorithms for enabling high-throughput, high-sensitivity inspection. It is easy to configure them for both smaller die sizes that are difficult to handle with manual methods, and larger die sizes that require rapid yield improvement. At the final output step, these automated inspectors also combine go/no-go assessment and accurate multi-bin defect classification with rule-based binning algorithms.

## Exposing defects

Ideally, process engineers in LED fabs will quickly spot excursions at key production steps. This will empower them to determine root causes and take corrective action before the wave of cumulative errors propagates throughout the rest of the production line. The good news is that this is relatively easy to do when automated in-line inspection is combined with Defect Source Analysis (DSA), which can relate the various sources of defects to impacts later in the production sequence.

Defect information, such as from the Klarity LED product, from key points throughout the production flow is communicated to the centralised database as industry-standard KLARF data (KLA Report File). This data can include images, sort/bin data, and other fab inputs that enable seamless correlation of

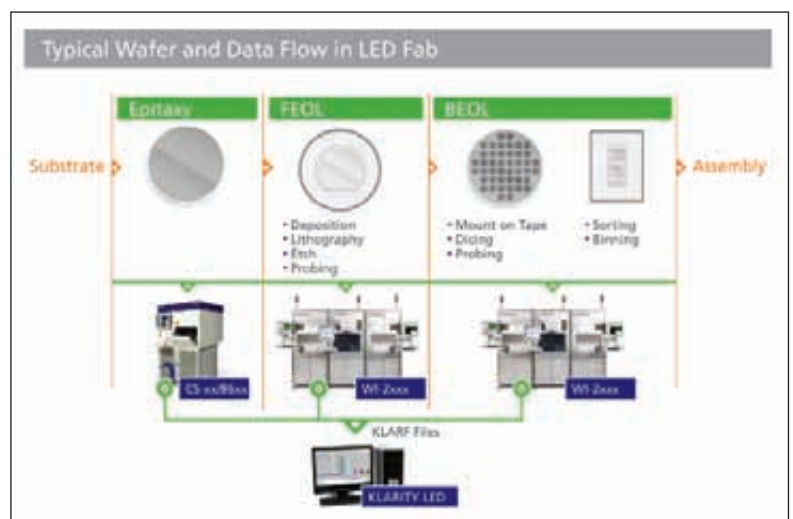


Figure 4: Manual inspection introduces a substantial amount of noise into any measurement. The upshot is that deviations can go unnoticed when manual inspection is used, but are easy to spot when automated inspection is employed

information from throughout the fab (see Figure 6). Each KLARF contains detailed information, including the ID, location and size of the defect, as well as other information from the inspection tools. Engineers can access the defect data in the centralized database from PC-based clients through the system, enabling them to quickly perform a range of analysis functions, such as creating/updating SPC control charts, or generating wafer maps, Pareto charts or image galleries to support DSA activities.

Thanks to automated event-based triggers, engineers – who can access a full range of inspection data and perform extensive analysis functions directly from their desks or workstations – can quickly determine root causes of defects without having to make multiple trips into the cleanroom or assemble and tabulate defect data by hand. It is also possible for engineers to track the morphology

Figure 5: Key LED process points for deploying automated in-line inspection based on third-generation tools



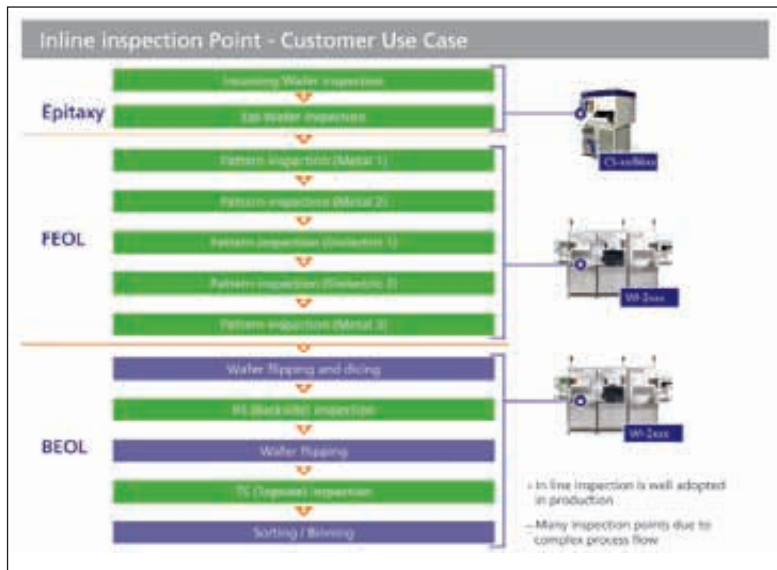


Figure 6: The best approach to defect analysis begins with the aggregation of defect data in a centralized database

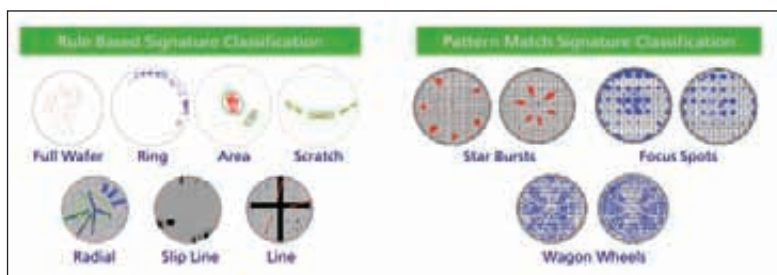


Figure 7: Spatial Signature Analysis (SSA) identifies key process signatures

of defect changes from layer to layer throughout the process with a Defect Transition Table (DDT), an advanced feature of DSA. This allows them to narrow the search for the sources of problems, and it also supports tracing of the transition of defects on a wafer as this moves between steps in the flow. Using DDT in combination with quantitative layer-by-layer ‘adder’ analysis and wafer map galleries allows rapid identification of root causes. By being able to compare data and images from throughout the process, engineers are also better placed to see the ‘big picture’ and determine interrelationships that are not obvious. The result: faster, more accurate DSA for supporting corrective actions.

Another powerful tool is Spatial Signature Analysis (SSA). This enables detection and classification of spatial signatures, such as defect clusters and patterns, which can indicate an out-of-spec process or a process tool problem. Tailored SSA recipes can be set up to automatically identify, analyse and characterize process-induced signatures and defect clusters for specific LED designs. This allows SSA to

automatically alert the engineer to process excursions based on signature classification and analysis, even if wafers have a defect count that is within spec. SSA also enables defect signature monitoring by zone, associating spatial signature classes - including ring, radial, scratch, and line - with pre-defined areas of the wafer, such as its edge. By using SSA in combination with SPC and DSA, engineers can utilise quantifiable data to support timely, real-world decision making. For example, it is possible to set up trend charts to monitor the occurrence of specific edge signatures and/or clusters. Feedback from DSA functions can also be used to confirm and/or modify SSA rules and SPC charts.

What’s more, SSA signature data can be used to identify and ignore non yield-limiting nuisance defects that do not impact failure rates. For example, post-epi particle defects rarely impact LED yield, but if they occur in large numbers and vary significantly from lot-to-lot they can trigger a false-excursion event. SSA algorithms can be pre-tuned to recognize such conditions and to avoid false alerts.

Engineers have the option to use the SSA Recipe Editor to effectively “train” the SSA node, by customizing rules and incorporating signatures from sample wafer data (see Figure 7). This can lead to refinements of process control methods, if SSA recipes are saved into the universal database and linked to DSA files and SPC charts.

### Summing the parts

Tying everything together is our Klarity LED comprehensive yield management software system. This leverages proven techniques that produce excellent results in the silicon industry. However, this software has been adapted to address the specific requirements and unique challenges of LED manufacturing. It caters for small die and thousands of devices on a typical LED wafer, enabling far more efficient and effective management of LED fab yields than is possible with manually managed systems. The automated software approach spans the entire production flow from end-to-end; combining yield analysis, excursion responses, front-end to back-end correlations, and corrective actions.

By adopting a holistic approach to yield management, all of the pieces of the puzzle can be brought together, leading to accelerated process development, faster ramp up of production yields, improved quality levels, faster excursion detection, and an overall more cost-effective LED manufacturing process. This will help to drive down the cost of LEDs, and fuel their deployment in emerging markets, such as general illumination.

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# Quaternary barrier cuts droop in UV LEDs

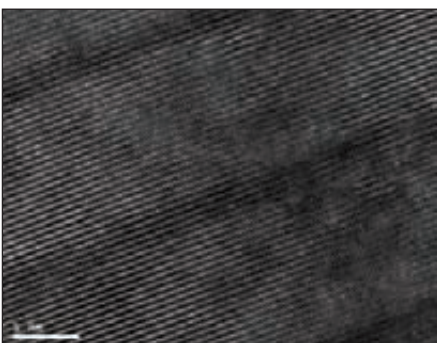
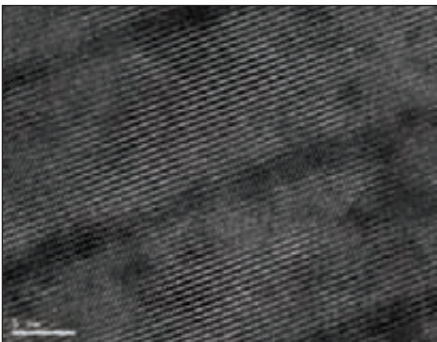
*InAlGaN barrier boosts ultra-violet LED output at high current densities*

BY SWITCHING the barrier in an ultra-violet LED from AlGa<sub>0.975</sub>N to InAlGa<sub>0.8803</sub>N, a Taiwanese team has reduced droop, which is the decline in device efficiency at higher drive currents.

The engineers arrived at this conclusion after fabricating a conventional 1 mm by 1 mm, 380 nm LED with an AlGa<sub>0.975</sub>N barrier and a variant that only differed in the composition of the barrier, which was switched to InAlGa<sub>0.8803</sub>N. The conventional design suffered from a 34 percent decline in efficiency as current was cranked up from 350 mA to 1000 mA, compared to just 13 percent for the variant with the quaternary barrier.

The superior barrier developed by researchers from National Chiao-Tung University, National Chung Hsing University and Advanced Optoelectronic Technology could help to increase the efficiency of ultra-violet LEDs to a level where they are attractive candidates for air conditioning.

LED epistuctures were deposited on



*Cross-sectional TEM images reveal that the switch from an AlGa<sub>0.975</sub>N barrier (top) to one made from InAlGa<sub>0.8803</sub>N (bottom) does not have an impact on crystal quality*



*LED structures were produced on a Taiyo Nippon Sanso SR-4000 tool that has a capacity of three 2-inch wafers*

sapphire in a Taiyo Nippon Sanso SR-4000 MOCVD reactor. These structures featured a ten-period multi-quantum well, which is a typical active region for this class of device, according to lead author Po-Min Tu from National Chiao-Tung University: "Because efficiency decreases drastically under the low indium composition [needed to make ultra-violet LEDs], more quantum wells are needed to obtain better recombination rates."

The active region of the control sample comprised 2.6 nm-thick In<sub>0.025</sub>Ga<sub>0.975</sub>N wells and 11.7 nm-thick, silicon-doped Al<sub>0.08</sub>Ga<sub>0.92</sub>N barriers. In the droop-combating structure, In<sub>0.0085</sub>Al<sub>0.112</sub>Ga<sub>0.8803</sub>N replaced the ternary barrier. To determine the precise composition of the wells and barriers in both structures, the researchers employed the combination of Bede D1 double-crystal X-ray diffraction measurements and simulations using dynamical diffraction theory.

After processing epiwafers into mesa-type chips that were packaged in epoxy-free metal cans, the researchers drove their devices with 100 μs pulses at a 1 percent duty cycle to prevent self-heating. The device with the quaternary barrier produced a light output power 25 percent and 55 percent higher than the control at drive currents of 350 mA and 1000 mA, respectively. To understand the superior performance of the LED

with the InAlGa<sub>0.8803</sub>N barrier, the researchers modelled both device architectures with Crosslight's APSYS software. The team obtained a good fit to the experimental data when they assumed that the structure with quaternary barriers produced deeper wells for the electrons and shallower ones for the holes – for the control LED and its variant with the quaternary barrier, the team used band-offset ratios of 6:4 and 7:3, respectively.

Modelling of both LED structures revealed that the reasons behind the superior performance of the device with a quaternary barrier were an increase in 26 and 35 percent in electron and hole concentrations in the quantum wells, and a wider distribution of carriers across the active region.

Tu claims that the primary culprit for droop in these ultra-violet LEDs is poor hole distribution. And he believes that at current densities below 100 A/cm<sup>2</sup>, Auger recombination – a non-radiative process involving three carriers – is not a major contributor to droop.

The next goal for the team is to apply their quaternary barriers to LEDs emitting at around 365 nm, a wavelength that is suitable for UV curing applications.

P.-M. Tu *et al.* (2011) *Appl. Phys. Lett.* **98** 211107

# Chemical etching improves thin-film LEDs

*Photochemical etching with potassium hydroxide creates LEDs with reduced strain and higher efficiencies.*

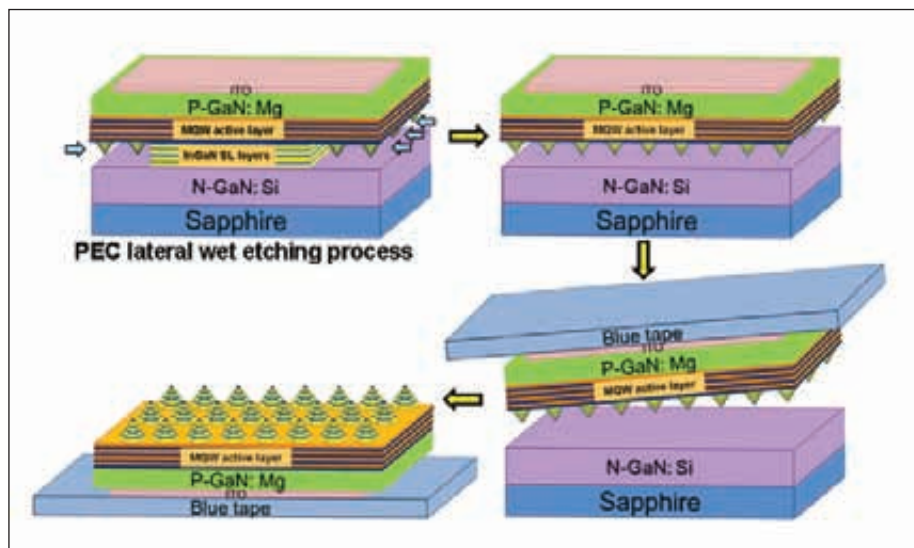
TAIWANESE RESEARCHERS claim to have developed a superior alternative to the widely used laser lift-off process employed for the manufacture of thin-film, high-brightness LEDs.

“Conventional laser lift-off processes on InGaN LED structures increase dislocation density,” explains corresponding author Chia-Feng Lin from National Chung Hsing University. According to him, this results in an increase in reverse bias leakage current and destruction of GaN by local heating during laser treatment. The approach of Lin and his co-workers addresses all these issues and begins with the insertion of a sacrificial silicon-doped superlattice of alternating, 3 nm-thick layers of InGaN and GaN. This superlattice is removed by a photochemical etch in potassium hydroxide, before the buffer and substrate are separated from all of the rest of the device by a mechanical lift-off process employing adhesive tape.

A 50 mW, 405 nm laser diode provides the light source for the 10-minute photochemical etching step. “The lateral wet-etching rate of the InGaN/GaN sacrificial layer is higher than that for a heavily silicon-doped GaN layer,” says Lin, who adds that a +1 V bias was applied to the structure during etching to prevent damage to the top InGaN layer.

One of the great strengths of the chemical mechanical lift-off process is that, in addition to yielding thin-film devices, it produces high-quality GaN-on-sapphire templates that can be used for subsequent device growth. Lin estimates that using these substrates can increase MOCVD reactor throughput from three to four runs per day.

The Taiwanese team is not the only one to have developed a chemical lift-off process – other research groups have



*A photochemical lift-off process can create a thin-film LED with reduced strain in the device.*

had success with CrN, ZnO and tungsten. However, Lin argues that the approach he and his co-workers take is more attractive, because it uses materials that are associated with the growth of nitride LEDs.

Another strength of this particular approach is that it leads to a partial release of the strain in the device. Reducing the strain, which stems from the lattice mismatch between the nitride layers and the sapphire substrate, leads to a blue shift in emission from 526 nm to 511 nm. This shift, which results from a reduction in the distortion of the conduction band and valence band profiles, also promises to increase the internal quantum efficiency of the LED. What’s more, the etching process leads to an increase in extraction efficiency, because it creates cone-shaped structures that reduce internal reflection within the chip.

Lin told *Compound Semiconductor* that the team has compared the performance

of conventional LEDs that have not been subjected to any laser-based processing to those made with its chemical lift-off process. At a drive current of 20 mA, the latter are brighter and have a shorter peak emission wavelength. “The forward voltage and leakage current of both structures are almost the same,” adds Lin.

One of the team’s next goals is to apply its process to high-power LEDs on electroplated copper substrates. In addition, the researchers want to develop InGaN-LED/Ga<sub>2</sub>O<sub>3</sub>/GaN templates. “The un-doped GaN epitaxial layer can be oxidized as a Ga<sub>2</sub>O<sub>3</sub> layer through the photoelectrochemical oxidation process,” explains Lin. “And after the epitaxial re-growth process in the MOCVD system, the Ga<sub>2</sub>O<sub>3</sub> layer can be etched in a dilute hydrochloric acid solution as a sacrificial layer for the chemical lift-off process.”

M.-S. Lin et. al. *Appl. Phys. Express* 4 062101 (2011)

One of the great strengths of the chemical mechanical lift-off process is that, in addition to yielding thin-film devices, it produces high-quality GaN-on-sapphire templates that can be used for subsequent device growth

# Freestanding $\alpha$ -plane substrate boosts HFET performance

*Normally-off GaN HFETs deliver a drain current of 220 mA/mm when built on commercial, native  $\alpha$ -plane substrates.*

A TEAM of Japanese engineers has smashed the drain current record for an  $\alpha$ -plane, normally off HFET by turning to device growth on a freestanding GaN substrate.

Normally off HFETs are far less common than their normally on cousins, which are easier to make and combine high breakdown voltages with high temperature operation and a very high current density. However, in many applications normally off variants delivering the same performance are highly desired, because they cut standby power dissipation, lead to simpler circuits and are essential for making fail-safe circuits.

To make normally off HFETs, researchers tend to turn to non-polar substrates. This allows the density of the two-dimensional electron gas in the channel layer to be controlled by adjusting the donor concentration in the barrier layer.

Some teams, including one from the University of California, Santa Barbara, have used free-standing  $m$ -plane substrates to make their normally off HFETs, but this foundation results in high oxygen contamination in the nitride epilayers. Although the high leakage current that results can be tempered with iron doping, this dopant contaminates the channel, reducing drain current and increasing current collapse.

Device performance is also unsatisfactory when HFETs are grown on  $\alpha$ -plane GaN on  $r$ -plane sapphire, because the transistor is then riddled with dislocations and stacking faults.

However, it is possible to produce HFETs with a high material quality on free-standing  $\alpha$ -plane GaN substrates if

growth conditions are optimised, says corresponding author Yasuhiro Isobe from Meijo University.

Isobe and his co-workers fabricated their transistors on commercially available  $\alpha$ -plane GaN substrates produced by the likes of Kyma Technologies and Sumitomo Electric Industries.

These devices featured an unintentionally doped GaN buffer with a thickness exceeding 7  $\mu\text{m}$ , followed by three  $\text{Al}_{0.34}\text{Ga}_{0.64}\text{N}$  layers with thicknesses of 1 nm, 3 nm, and 16 nm. The thinnest and thickest quaternary layers were unintentionally doped, and the 3 nm-thick film sandwiched between them was silicon-doped to a level of  $3.5 \times 10^{19} \text{ cm}^{-3}$ .

According to secondary-ion mass spectrometry, the oxygen level in  $\alpha$ -plane GaN layers was below the instrument detection limit of  $2 \times 10^{16} \text{ cm}^{-3}$ .

At a gate-source voltage of 3 V, HFETs fabricated with a 2  $\mu\text{m}$ -wide gate and a source-drain spacing of 8  $\mu\text{m}$  delivered a peak drain current of 220 mA/mm. When this voltage was adjusted to  $-20 \text{ V}$ , leakage current was  $8 \times 10^{-6} \text{ A/mm}$  – a value that the Japanese team says is lower than that for HFETs grown on the widely used  $c$ -plane. Transconductance peaked at 56.6 mS/mm, and the threshold voltage was  $-1.6 \text{ V}$  at a drain-source voltage of  $+8 \text{ V}$ .

The team are now trying to fabricate devices with higher levels of performance. They have already had some success, says Isobe, but have also uncovered several issues – a paper detailing all of this will emerge in due course.

Y. Isobe *et al.* *Appl. Phys. Express* 4 064102 (2011)

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# QCLs with internal frequency doubling target gas sensing

*Intra-cavity frequency doubling creates 3 μm QCLs from the pairing of GaInAs and AlInAs*

A US TEAM has substantially improved the output power of its short wavelength of GaInAs/AlInAs quantum cascade lasers (QCLs) that feature a frequency-doubling region.

The QCL made by engineers from The University of Texas at Austin and Adtech Optics delivers room-temperature emission at 2.95 μm, which is within the ideal wavelength range for chemical sensing and spectroscopy applications. That's because the spectral range 2.5-3.5 μm contains several important

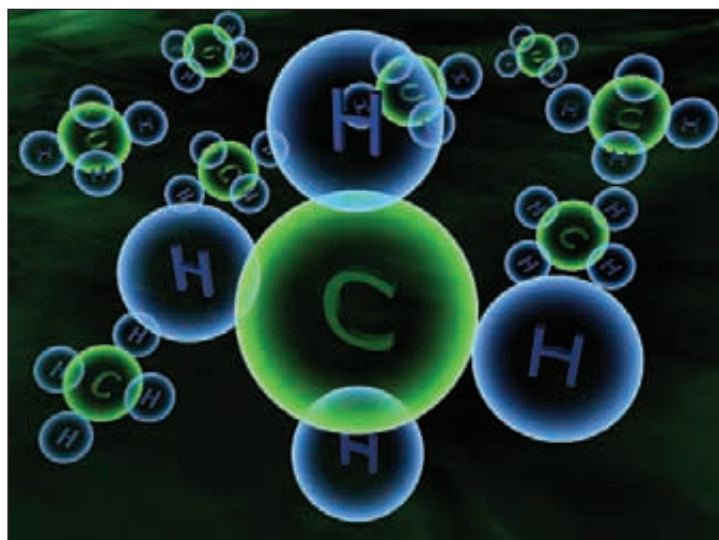
molecular absorption lines, including those for methane and ammonia.

Antimonide materials can also be used to produce diode lasers, QCLs and interband cascade lasers. However, these types of device are tricky to grow and process, according to corresponding author Mikhail Belkin from The University of Texas at Austin.

His view is that a far more cost-effective platform for making mid-infrared lasers for spectroscopy is the more mature InGaAs and AlInAs materials system that is also used to make telecom lasers. Conventional QCLs made from these materials can operate in continuous-wave (CW) mode at room temperature and span the 3.5-12 μm range. To reach the shorter wavelengths, strain compensated superlattices are used to make deeper wells and higher barriers.

However, with this conventional design it is very challenging to produce QCLs emitting below 3.5 μm. "Although the gamma points in InGaAs and AlInAs have high energy offsets, electrons may scatter from a gamma valley in InGaAs to an X-valley in AlInAs," explains Belkin, who adds that at certain aluminium compositions, the bandgap of AlInAs is indirect.

To extend GaInAs/AlInAs QCLs to 3 μm,



the US team inserted a non-linear layer on top of the active region of the device that is tailored to have resonant optical non-linearity for second harmonic generation.

First-generation devices that were reported by the Belkin group in 2010 in collaboration with teams from Princeton University and the University of Maryland delivered peak output powers below 10 μW at 3.6 μm. This has now been increased to 35 μW at 2.95 μm, using a 10 μm-wide, 3 mm-long ridge laser that was driven with 50 ns pulses at a 100 kHz repetition rate. The latest device – which features a non-linear layer containing 28 repetitions of a multi-quantum well structure made from the pairing of In<sub>0.67</sub>Ga<sub>0.33</sub>As and Al<sub>0.57</sub>Ga<sub>0.43</sub>As – produced a room-temperature threshold current density of just 2.2 kA/cm<sup>2</sup>, a low enough value to suggest that this design is capable of yielding CW QCLs.

The increase in power of these novel lasers stemmed from improvements in material quality. Better materials were possible thanks to the collaboration of the university team with Adtech Optics, a commercial foundry that produces QCLs. "We also used strain compensated structures that allowed for more design flexibility in the non-linear layer," adds Belkin.

Although this partnership between academia and industry led to success, there is still plenty of room for further improvement. "We had to overgrow our non-linear layer onto the Adtech Optics' existing QCL structure, and as a result, the active region and waveguide configuration was not quite optimal for the second harmonic generation device," explains Belkin.

The upshot of this lack of optimisation was a poor degree of overlap of the pump modes with the non-

linear section. Belkin admits that the team also made a slight mistake in its calculations of the bandstructure in the non-linear section of the device. This prevents a perfect double resonance from occurring in the QCL.

Once the team addresses these issues, it should be capable of fabricating lasers with output powers of at least 1 mW.

"We then plan to process these lasers as buried heterostructure devices to demonstrate CW operation," says Belkin. If successful, the researchers will have made devices meeting the typical output power requirements for chemical sensing and spectroscopy applications.

Another goal is to demonstrate external-cavity tuning of their devices, which will highlight their promise for spectroscopic applications. "Finally, we are also collaborating with Markus-Christian Amann's group on designing second-harmonic generation lasers that can be tuneable over 0.5-1 μm in the 2.5-4 μm spectral range," says Belkin. "This will require additional optimisation of the non-linear section and waveguide structure that will support efficient quasi-phase-matched second harmonic generation for different pump wavelengths."

M. Jang et al. *Electron. Lett.* **47** 667 (2011)



# Putting order into III-V surface oxides

Researchers have produced the first well-defined two-dimensional oxide layers on III-Vs by oxidising InGaAs, InAs, and InSb substrate surfaces.

OXIDISED III-V surfaces have a poor amorphous (or polycrystalline) structure and they exhibit defects that are detrimental to device processing. In particular, this problem has hindered the development of III-V channel MOSFETs. Now a Finnish-Swedish collaboration led by the University of Turku claims to have found, for the first time, that when intentionally oxidised, long-range ordered surface oxide layers are formed at the III-V(100) surface. This provides a model platform to study the oxide properties and a novel template for manufacturing the insulator/III-V interfaces, where avoiding the oxygen

reaction is not critical. What's more, these findings help to explain the improvement of device characteristics in a MOSFET incorporating a thermally grown interfacial InAsO<sub>x</sub> layer.

Using a surface-science/engineering approach and ab initio calculations, the European team found that the crystallisation of the surface oxides arises from an interplay of the initial III-V surface structure, substrate temperature, and oxygen pressure.

The starting GaAs(100), InAs(100), and InSb(100) substrates had a well-ordered  $c(8 \times 2)$  surface structure while the InP(100) had the  $(2 \times 4)$  structure. The InGaAs(100) $c(8 \times 2)$  surface was obtained by depositing 1-2 monolayers of indium on the pure GaAs and heating the sample up to 500-550 °C. The O<sub>2</sub> gas was then introduced into a vacuum chamber, and the O<sub>2</sub> pressure set to  $3-4 \times 10^{-6}$  mbar during the oxidation. The O<sub>2</sub> exposure time varied between 5 and 30 min, and the substrate temperature was 350-520 °C depending on the material. These conditions

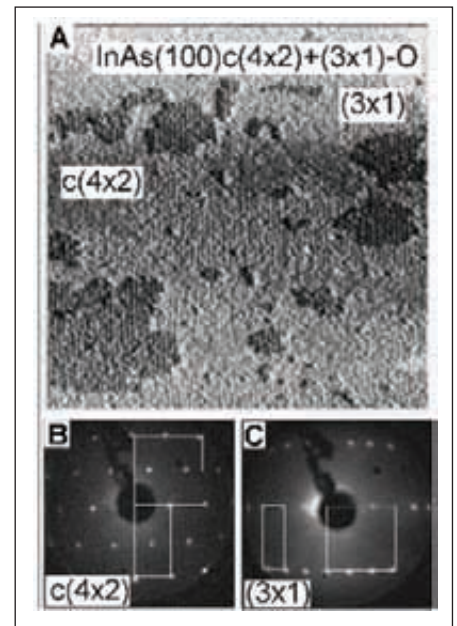


Figure 2 . (A) STM image of the oxidised InAs(100) surface. (B) and (C) The corresponding LEED patterns with sharp intensity spots which reveal good crystal quality on a large scale.

produced smooth topography with two-dimensional islands for the crystalline oxidised surfaces as deduced by low-energy electron diffraction (LEED), scanning tunnelling microscopy (STM), and photoemission. The next step for the team is to study the performance of III-V channel MOSFETs with the ordered oxide interface between the III-V material and high- $\kappa$  (e.g., Al<sub>2</sub>O<sub>3</sub>) gate dielectric stack.

<83> M. P. J. Punkkinen et al. *Physical Review B*, 83, 195329 (2011)

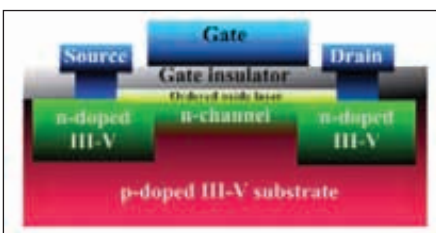


Figure 1 : Schematic showing how the crystalline oxygen-containing surface layer of III-V can be utilised as "part" of the III-V channel MOS

## Lesker Valves



## Featured

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# How to grow defect-free GaAs nanowires on silicon

Scientists have found that employing different growth conditions can improve the properties of gallium arsenide nanowires grown on silicon (111) substrates.

If you want to use nanowires in optoelectronic devices, they need to have a pure crystal structure without defects such as twins, phase polytypism and stacking faults.

Now a research group at the Australian National University led by Chennupati Jagadish has developed defect-free GaAs nanowires on silicon substrates by employing special growth processes. To determine if it was possible to improve nanowire crystal quality, the scientists, led by Jagadish, grew GaAs NWs on Si (111) substrates using 3 different conditions (Fig. 1). By growing GaAs buffer layers to minimise mismatch in lattice constants and thermal coefficients, the researchers achieved straight GaAs NWs when vertically grown on the silicon substrates.

In collaboration with research groups in the University of Queensland (headed by Jin Zou) and University of Cincinnati, USA (led by Howard Jackson), the scientists then investigated the crystallographic structures and optical properties of the nanowires. Scanning electron microscopy (SEM), transmission electron microscopy (TEM), and micro- and time resolved-

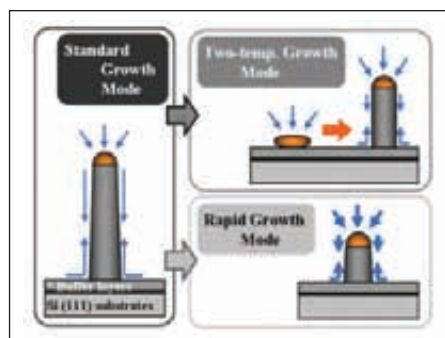


Figure 1: Schematics showing the three-different growth methods

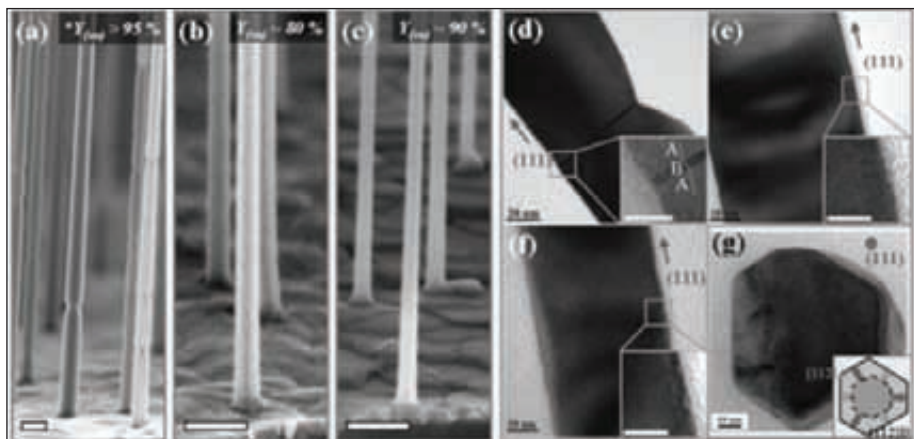


Figure 2. High resolution-SEM images of (a) Standard GaAs NWs with grooved surface, (b) two-temperature grown GaAs NWs and (c) rapidly grown GaAs NWs showing less tapering without any surface defects, respectively: scale bars represent 200 nm and \*Y(vn) means yield of vertical NWs; high resolution-TEM images of (d) the standard NWs having twin defects, (e) the two-temperature grown NWs and (f) the rapidly grown NWs showing pure zinc-blende crystal structure and (g) Cross-sectional TEM image of the standard NWs showing truncated triangular shape. The schematic inset shows the evolution of shape change. All scale bars in insets are 5 nm

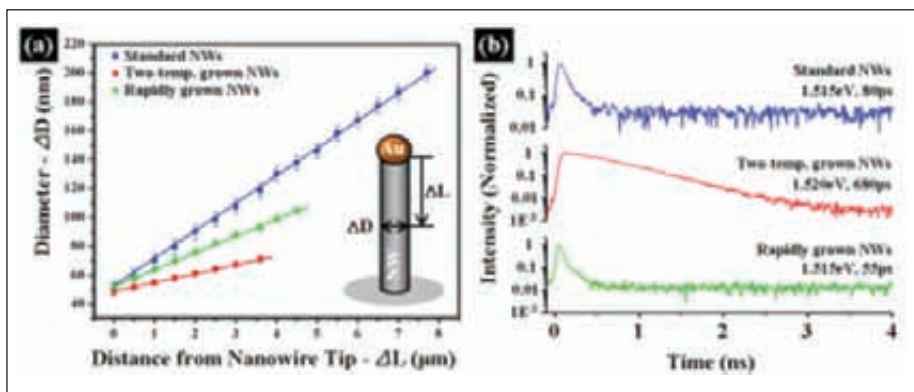


Figure 3 (a) Plot of NW diameter measured at distance from the top of nanowires and illustration of the change in diameter per unit of NW length. All 3 types of GaAs NWs were measured at each 0.5 μm point; (b) Low temperature (15K)

photoluminescence ( $\mu$ -TR-PL) measurements were the main analysis techniques used in the study. Modifying the growth conditions by using two-temperature growth and a rapid growth rate yielded vertical GaAs NWs without surface roughness and structural defects (Fig. 2).

The rapid growth rate method resulted in the highest yield of straight and vertical NWs while the two-temperature growth method yielded NWs with the longest exciton life-time ( $\sim$  600 ps) and least tapered shape (Fig. 3), desirable

for optoelectronic device applications.

These results show promise for integrating III-V nanowire optoelectronic devices with silicon based microelectronic devices. The research group at the Australian National University is now working with the collaborators to investigate multiple applications of GaAs NWs as well as other III-V compound semiconductor nanowires for device applications.

Jung-Hyun Kang et al. *Crystal Growth & Design*

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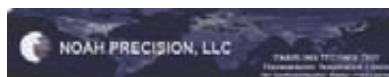
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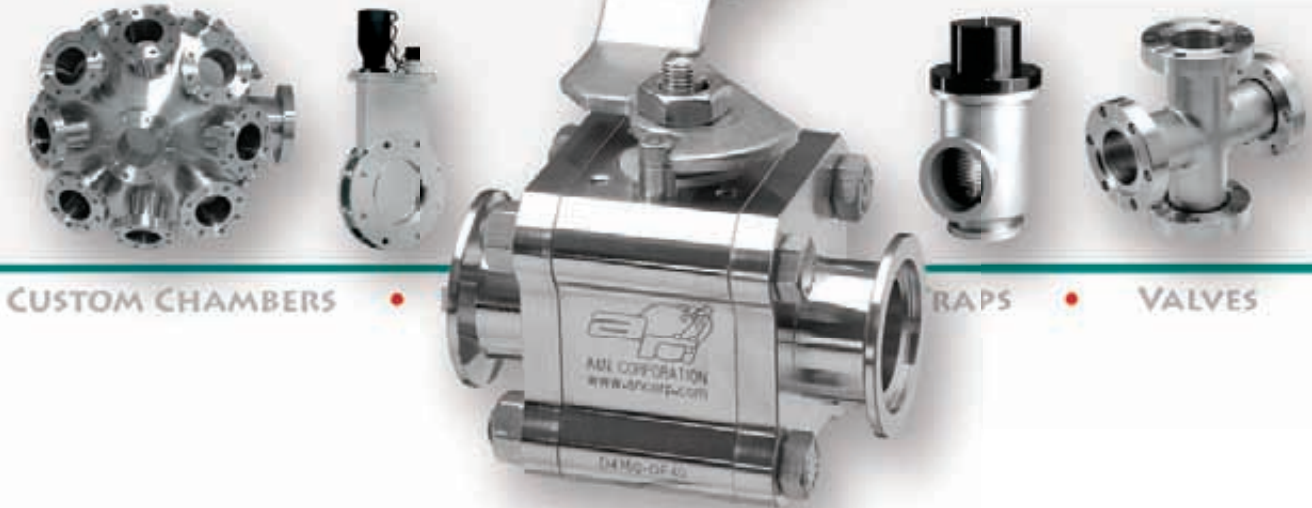
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# News Digest Contents

**46** - LEDs

**61** - Telecoms

**67** - RF Electronics

**74** - Lasers

**76** - Solar

**88** - Power Electronics

**96** - Equipment and Materials

**103** - Novel Devices

# LEDs

## China SemiLEDs acquires Novellus VECTOR LED system

The highly productive PECVD system will be used for the manufacture of metal alloy III-V nitride based LED chips.

Novellus Systems, a maker of process equipment for semiconductor and LED manufacturing, has shipped a VECTOR plasma-enhanced chemical vapour deposition (PECVD) system to Xurui Guangdian (China SemiLEDs).

China SemiLEDs is a joint venture company in the People's Republic of China in which SemiLEDs Corporation, a leading manufacturer of high-brightness LEDs, is a partner. The VECTOR tool will be installed at the China SemiLEDs' plant in Foshan, China, and will be used for the manufacturing of SemiLEDs' MvpLED high-efficiency LED products.

SemiLEDs develops and manufactures metal alloy vertical LED chips in blue (white), green and UV using its MvpLED technology, which incorporates III-V nitride based layers. The company says this unique design allows for higher performance and longer lumen maintenance. SemiLEDs new high power I-core MvpLEDs can deliver over 120lm/W.

Cost-per-die and cost-per-lumen are critical factors in driving the adoption of LED technology into the mainstream lighting market. Current LED manufacturing technology is predominantly based on sapphire substrates in 2", 3" and 4" diameters. The inherently low-productivity manufacturing process used in making LEDs consumes a considerable amount of energy. On average, incredibly over 200 kWh of electricity is spent in making a 2" sapphire wafer.

The VECTOR system has leading process performance, a wide process window, and high productivity, a combination of factors which provides a lower manufacturing cost-per-die in comparison to traditional LED manufacturing solutions.

With a multi-wafer carrier configuration, the VECTOR LED system is capable of handling all wafer sizes -- 2", 3", 4", 6", 8" and 12" -- with exceptional throughput, film quality and uniformity at each size. In contrast to a traditional PECVD reactor used in LED manufacturing, the VECTOR LED also deposits films at lower temperatures, and is claimed to provide better manufacturing process control be more energy-efficient.

"The new VECTOR LED system is the LED manufacturing industry's most productive PECVD solution," said Sessa Varadarajan, senior vice president and general manager of Novellus' Electrofill and PECVD business units. "We are pleased to add VECTOR LED to the company's existing suite of products for LED manufacturing, including our process solutions for photoresist strip, descum, PVD, electroplating, and wafer polishing and thinning."

"In our continual effort to increase productivity and energy efficiencies, we will be placing the VECTOR LED system at China SemiLEDs' Foshan plant," said Marco Mora, general manager of China SemiLEDs. "Novellus' infrastructure and service capabilities in China made the selection of this vendor a very logical choice for China SemiLEDs."

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## Siltronic jumps onboard imec's GaN-on-silicon research train

The organisations will jointly develop technology for next-generation gallium nitride power semiconductors and LEDs on 200 mm diameter silicon substrates. They aim to enhance properties and reduced production costs.

Siltronic AG and the Belgian nano-electronics research institute imec have concluded an agreement to collaborate on the development of silicon wafers with a GaN layer.

This partnership will be part of imec's GaN-on-silicon industrial affiliation program (IIAP) and aims to enable production of LEDs and next generation power semiconductors on 200 mm silicon wafers.

GaN is a very promising material; it combines

superior electron mobility, high breakdown voltage and good thermal conductivity and is particularly suitable for optoelectronics and advanced power semiconductors.

These are used, for example, in wind power turbines, solar power systems, electric vehicles and energy-saving kitchen appliances. In comparison with conventional, silicon-based applications, structures with GaN/(Al)GaN layers evidence a very efficient switching behaviour.

However, GaN technology still needs further refinement to also be economically competitive. To achieve this, inexpensive and efficient production methods for epitaxial deposition of GaN/(Al)GaN structures on larger-diameter silicon wafers are very promising.

As a global provider of silicon wafers, Siltronic AG can draw on decades of experience in epitaxial deposition of materials on silicon substrates. Imec is a pioneer in the area of GaN deposition on silicon substrates with diameters of 2-6 inches. Economies of scale in the production of 200 mm wafers could significantly reduce the manufacturing costs for GaN-based LEDs and power semiconductors.

In addition to Siltronic, other participants such as integrated device manufacturers, foundries, silicon compound producers and substrate manufacturers are also involved in this multinational research platform. Siltronic will actively use the facilities and technical resources of imec in Leuven, Belgium.

This coordinated on-site approach enables inter-company collaboration between all involved partners, while at the same time providing very early access to process and equipment technology for the next generation of LEDs and power semiconductors.

“We are delighted to welcome Siltronic into our research network,” said Rudi Cartuyvels, Vice President R&D Business Lines at imec. “Siltronic has an enormous amount of experience in epitaxial deposition on silicon wafers that will increase the momentum of our GaN program to deliver a manufacturable GaN technology on 200 mm silicon wafers.”

“Siltronic is already the world market leader for silicon wafers used to manufacture discrete and

integrated power devices,” points out Rüdiger Schmolke, Senior Vice President Technology at Siltronic. “This research project will help us to further consolidate our leadership position in this market.”

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## Early payback on investment in science

Oxford Instruments says that the scientific commercial and academic sectors can unite to solve many of society’s problems and turn smart science into commercially successful products.

Investment in science can pay dividends right now, as well as driving long term prosperity. That was the key message given by Jonathan Flint, Chief Executive of Oxford Instruments, speaking at an event in Parliament on 28 June.

He said, “My position as Chief Executive of a publicly listed company and as a council member of the Institute of Physics allows me to straddle the commercial and scientific worlds. It gives me a perspective on the difficult path between the spark of a new idea, and seeing the effects of that idea in society at large.”

“The global challenges we face today cannot be addressed without a partnership between the commercial and the academic sectors. I see businesses forming the bridge between science and the consumer. Science is capable of coming up with the solutions to many of society’s problems and companies like Oxford Instruments will turn that smart science into commercially successful products.”

Speaking on behalf of the Institute of Physics at the Royal Society of Chemistry’s Parliamentary Links Day, Flint identified examples where his company’s advanced technology is contributing to future energy options, from fusion power to low energy lighting, and testing for hazardous materials in the environment. But his key message was that investment in science is delivering real economic benefits, today, through the manufacture of the high technology equipment involved.

He continued, “Supplying high performance equipment gives real revenues, real jobs, today. We

should do more to educate people about the power of science and its importance to our world, for the future, and for today.”

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## Global SVP appointed at LED & laser developer Soraa

The U.S. developer of gallium nitride based LEDs and laser diode products has added former Hewlett Packard Imaging and Printing SVP Neal Woods to its team.

Soraa has appointed former Neal Woods as Senior Vice President of Worldwide Operations.

“Neal brings a breadth of operations management experience that is necessary to guide our organisation as we commercialise and begin volume production of truly disruptive products,” said Eric Kim, Chief Executive Officer. “We are very excited that he has chosen to join our world-class team and is committed to helping us fulfil the potential of our solid state illumination products,” he later added.

Woods, will be based at Soraa’s Fremont, California, headquarters and have responsibility for all aspects of manufacturing, supply chain operations, quality functions, and worldwide operations planning.

Woods has served as Senior Vice President of Operations for Hewlett-Packard’s Imaging & Printing Group since 2008. While at HP, Woods had ownership for IPG’s entire supply chain with \$30 billion in annual revenue. He was previously the VP of Global Manufacturing Operations for Cisco Systems.

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## Aixtron a bull in China

Demand for gallium nitride LEDs in China has soared, prompting Aixtron to form a new subsidiary in Shanghai which should help accommodate requirements.

Supplier of MOCVD equipment for LED production, Aixtron, is opening a wholly owned Chinese subsidiary Aixtron China Ltd. as the next step

towards the company’s plans for further expansion in China.

The new entity replaces the representative office and operates out of expanded facilities in Shanghai. This move is intended to support Aixtron’s growing base of Chinese customers and makes it easier to grow by opening other facilities throughout China in the near future.

“This is the next logical step in terms of our increasing commitment to support China’s aggressive plans to become one of the world’s leading countries in LED production. This also reflects the strong growth in Aixtron’s MOCVD installed base and our increasingly competitive edge in this exciting market”, says Christian Geng, Aixtron Vice President Greater China. “It allows us to further enhance our Customer Support, which will result in reducing operating costs for our customers through streamlined processes and a broader range of services.”

Going forward, this significant investment will make it possible to supply customers with spare parts and service support even faster and more efficiently on a local basis. Aixtron intends to continue expanding with further investments in China later this year.

“We are deeply impressed by China’s commitment to introduce efficient lighting with LEDs and taking a leading role”, says Bernd Schulte, Aixtron’s Executive Vice President and Chief Operating Officer. “We are fully supportive of our increasing customer base and the government agencies involved.”

Aixtron’s recent growth in China has meant that the number of employees in Aixtron’s Chinese operation has tripled in the last two years and will continue to grow throughout the year. “We set high standards for our staff – it is not without good reason that Aixtron’s service teams are considered to be the most experienced in this field”, comments Geng.



## SDK to strengthen capacity in East Asia for high purity ammonia

The company is expanding total capacity by 5,000 tonnes per year in Japan, Taiwan and China to cope with demand for ammonia gas, which is used in many electronic applications including gallium nitride LEDs.

Showa Denko K.K. (SDK) will increase its production capacity for high-purity ammonia to meet growing demand from the electronics industry.

Specifically, production capacities at three sites - Japan, Taiwan, and China - will be increased from the current levels of 1,000 t/y, 1,500 t/y and 500 t/y; to 1,500 t/y, 2,500 t/y and 1,000 t/y, respectively, by the end of 2011.

The capacity increase will be carried out through expansions of filling/storage facilities and improvement in production efficiency. As a result, the Showa Denko Group's total high-purity ammonia production capacity will increase from 3,000 t/y at present, to 5,000 t/y.

High-purity ammonia is used as a material gas in the production of GaN LEDs and other compound semiconductors. Anticipating further growth in the electronics market in East Asian countries and to ensure stable supply of high-purity ammonia, SDK has decided to increase production capacities at its sites in Japan, Taiwan and China.

Under its medium-term consolidated business plan PEGASUS, SDK classifies its business in high-purity ammonia and other high-purity gases (for semiconductor/display production) under the category of "growth" business. SDK will continue to encourage the growth of this business by increasing competitiveness of existing products and developing new products.

Showa Denko Group's high-purity ammonia production sites: are in

1. Japan: Kawasaki Plant, SDK (Kawasaki City)
2. Taiwan: Taiwan Showa Chemicals Manufacturing Co., Ltd. (Tainan City; owned 90% jointly by SDK

and its subsidiary)

3. China: Zhejiang Quzhou Juhua Showa Electronic Chemical Materials Co., Ltd. (Quzhou, Zhejiang Province; owned 51% by SDK)

## AkzoNobel to expand in Texas with two plants for LED precursors

The new TMGa production plant, to be completed in 2012, will be three times the size of the existing unit. The second facility for TMIIn manufacture will increase capacity by 400 % and should be completed by Dec 2011.

Responding to continued strong global demand for its High Purity MetalOrganics (HPMO) product range, AkzoNobel will significantly expand its production capacity for two of its key products; Trimethyl Gallium (TMGa) and Trimethyl Indium (TMIIn).

The HPMO business, part of Business Unit Functional Chemicals, is a leading producer of semiconductor grade indium-, gallium-, aluminum and zinc- and magnesium-based metalorganics which are used as precursor materials in the production of LEDs, solar cells and other semiconductor devices.

In June 2010 AkzoNobel doubled its production capacity for TMGa. The capacity of this unit has been quickly doubled again in January 2011, and the new capacity has been successfully ramped up during the past four months, making AkzoNobel the largest global producer of this specialty chemical.

"Our customers' response to these expansions has been very positive, and their continued strong demand keeps absorbing our recently enlarged capacities" says Michiel Floor, Global Business Manager of the HPMO product group. He adds: "We firmly believe in significant long term growth of the LED and III/V solar cell industries, so we have decided to advance our plans for further major capacity additions with two new world-scale production units."

The company plans to build a large new production

plant for TMGa, which will be three times the size of the existing unit. With this expansion, AkzoNobel's total capacity for gallium based metalorganics will exceed 100 tons per year, from two independent production lines. This project is already well advanced; construction of the plant will start in 2011 with completion in 2012.

A large second production unit for another key LED precursor, TMIn, will be built as well, giving a 400% increase of capacity. Construction of this unit is already in progress and will be completed by December 2011.

Both units will be built at AkzoNobel's Laporte (Texas, US) manufacturing site, which serves the global plastics, pharma and electronic industries with large scale, fully integrated bulk metalorganics production plants.

The company will also enhance its global distribution network by establishing regional transfilling capabilities in Asia.

"These continued investments in the HPMO business show AkzoNobel's commitment to support the LED industry in the coming years. Our capacity additions will enable our customers to maintain their growth pace, which will be increasingly driven by general lighting applications, says Jan Svård, Managing Director of Functional Chemicals. "This business also supports our efforts in sustainability, by focussing on applications that drive energy efficiency and lower energy usage, like LEDs and solar cells".

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## European motorists could get stung to replace LED lights

On a positive note for new buyers, Astra Automotive says that new business for the replacement LED bulb market will not be seen for at least three years due to manufacturers' warranties.

According to an interview with just-auto.com, UK aftermarket lighting specialist Astra Automotive suggests that as the European Commission has recently mandated the use of daytime running lights for newly-registered vehicles, European motorists

could get stung if their LED lights fail, because they may have to stump up the cost of replacing whole lighting units.

Just-auto's analyst Matthew Beecham interviewed Astra Automotive's Leon Callahan and managing director Robert Jones.

Just-auto asked, "The European Commission recently mandated the use of daytime running lights for newly-registered vehicles. All new types of passenger cars and small delivery vans will have to be equipped with the lights, while trucks and buses will follow in August 2012. Does this spell out good news for your business?"

Astra Automotive responded, "The daytime running lights that we have seen are mostly LEDs, therefore this will not bring in new business for the replacement bulb market for at least three years, because in nearly all cases they will be covered under manufacturers' warranties."

"Even then, most will be fitted with LED model specific lighting systems such as the LED "Eyebrow" effect of the Audi and LED circle around the front side lights on the latest Land Rover and Range Rovers."

"These units, as we see it, will be sealed in manufacture so if a LED light was to fail, it will almost certainly be impossible to just replace the bulb. Instead the motorist will have to replace the whole light assembly, which will prove expensive in terms of replacement and garage time. The same goes for truck and bus operators who are more conscious of vehicle downtime and costs."

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## CEA-Leti and Neolux to industrialise intelligent LED systems in France

The firms will develop third-generation gallium nitride LEDs in the MODULED project which aims to simplify the functioning and assembly of current LED systems.

CEA-Leti and Neolux have announced a new partnership aimed at developing and manufacturing innovative LED modules and products for lighting.

The three-year project, known as MODULED, will industrialise smart LED systems in France by simplifying functioning and assembly, reducing the mechanics and electronics of current LED systems, and incorporating the latest LED features. The project also will include establishing processes to allow the fabrication of next-generation LED modules while reducing the costs of acquisition for OEMs.

"The next generation of LEDs will react with their environment -- the lighting of the space and the presence of a person -- and the lighting envelope will assure heat dissipation," said Ludovic Labidurie, CEO of Neolux. "Together, these developments will significantly reduce the cost of these products, and our project will take advantage of these changes to develop a new generation of intelligent LED systems."

Leti has focused on LED lighting technology since 2006 and in recent years has launched a variety of projects to deal with the key issues of thermal management, light extraction and wavelength conversion.

"LEDs offer unparalleled possibilities to integrate new features beyond their energy efficiency," said Laurent Malier, Leti CEO. "I am convinced that we are at the dawn of a generation of 'intelligent' lighting objects that is similar to what we saw happening in communications products 10 years ago. Leti has been preparing for this evolution for several years and the successful integration of our new technologies will allow Neolux to open new markets, while reinforcing its offer against increasingly tough competition."

The partnership will give Neolux, which conceives and commercialises LED lighting solutions, access to the project's first qualified product.

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## Rubicon qualified to supply 6-inch polished sapphire wafers

The firm's Malaysian plant also aims to produce 8-inch sapphire wafers in volume to cope with increasing demand from the global LED industry.

Rubicon Technology, a provider of sapphire substrates, has two critical milestones that enable its new state-of-the-art facility in Penang, Malaysia to move into volume production of six- and eight-inch polished sapphire wafers.

Rubicon's new Malaysia facility recently completed qualification of its six-inch wafers by a key customer, and also successfully completed an ISO certification audit. Both of these milestones enable the Malaysian facility to move into volume production of six-inch polished wafers, which are in high demand as LED chip manufacturers continue to migrate to larger diameter substrates to realise greater efficiencies. The facility is also capable of processing and polishing eight-inch wafers that Rubicon provides to customers in R&D volumes.

Rubicon's customers demand exceptional quality -- consistently delivered -- and often require vendors to achieve and maintain globally recognized quality standards, such as those set by the International Organization for Standardization (ISO). Rubicon's Malaysia facility recently passed the rigorous audit by ISO inspectors with zero findings and has been recommended for ISO 9001:2008 certification, which is expected to be formally issued upon final review by the registrar.

Most companies in the semi-conductor industry also require vendors to re-qualify products when a new manufacturing facility is opened. Rubicon has been in the re-qualification process with a number of existing customers who have previously purchased six-inch wafers produced in Rubicon's U.S. facility. The Malaysian facility now has qualified with a major customer. The qualification process involves successful production of LED chips on Rubicon six-inch sapphire wafers and rigorous testing of those chips in various applications.

Rubicon's custom equipment and manufacturing processes position the company as the leading provider of high quality, large diameter sapphire wafers to manufacturers of LEDs worldwide. Rubicon's Malaysia facility, combined with its new crystal growth facility in Batavia, IL -- both leveraging large-diameter sapphire -- were established to deliver the sapphire capacity necessary to support the growing demand for LEDs in the consumer electronics and general lighting industries.

“Our facility in Malaysia further increases our ability to deliver large diameter sapphire wafers in large volumes to customers worldwide,” said Raja Parvez, Rubicon President and CEO. “I am very pleased with the progress we have made in the establishing this state-of-the-art facility and am proud of the work our team has done in implementing the same world class systems we maintain in our U.S. operations.”

Market research firm iSuppli expects the global LED market to nearly double to nearly \$14.3bn by 2013, driven by the penetration of LEDs into the general illumination market including light bulbs. LEDs are a popular option for backlighting screens from HDTVs, traffic lights and large displays as well as in a broad range of popular consumer devices including tablets, notebooks, laptops, mobile phones, navigation devices, digital music players, digital photo frames, digital cameras and keypads. LED use in general lighting applications is also increasing significantly, particularly in applications like street lighting, industrial lighting and architectural lighting.

Parvez continued, “The ability of our new Malaysia operation to fabricate larger diameter high quality, polished wafers perfectly complements our existing large diameter crystal growth capability and makes Rubicon the world’s leading vertically integrated provider of large diameter sapphire substrates. The location and capabilities of our manufacturing facilities around the globe minimizes the risk of business interruption while lowering cost and providing proximity to our valued Asian customers.”

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## Crystal IS appoints leading entrepreneur to Board of Directors

With this step, the firm intends to speed up commercialisation of its aluminium nitride substrate based ultraviolet (UV) LEDs.

Crystal IS has appointed Kevin J. Knopp to its Board of Directors. Most recently Knopp served as Vice-President for Thermo Fisher Scientific in its Portable Optical Analysis Business Unit.

“With Kevin Knopp’s success in commercialising

innovative technology, particularly in the compound semiconductor industry, we are fortunate to have his counsel and recommendations as we begin delivering UVC LED’s to market on a global basis,” commented Nicholas Wood, Chairman of Crystal IS. “We expect our products to significantly impact the landscape of water, air, and surface disinfection technology, bringing about much-needed change for the world. Today we are working with large global customers to integrate our technology into their designs.”

Knopp has held numerous roles from R&D to sales and operations leadership in his career. Most recently he co-founded Ahura Scientific in 2002 and was responsible for engineering, government research, operations, and the safety & security business vertical. He then transitioned to business leader for one of Thermo Fisher’s global business units once Ahura was acquired by them.

Previously, Knopp was the manager of vertical-cavity laser development at CoreTek, which was acquired by Nortel Networks for \$1.4B in 2000. He has more than 15 US patents and his products have received R&D 100, Business Week IDEA, GSN, CPhI Gold, Cygnus, and Frost & Sullivan awards. Knopp received a B.S.E.E from Boston University, M.S.E.E, and Ph.D degrees in Optics from the University of Colorado.

“The team at Crystal IS are in a unique position just now,” commented Knopp. “They have proven to be the technology benchmark in the emerging space of UVC LED’s. Now they need to bring the business into full realisation with clear and focused customer strategies and selective partnerships that will change the game and multiply the possibilities for the world. I look forward to being an integral part of that.”

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## Miami miniaturises LED lighting

Using indium gallium nitride on a silicon substrate, novel etching, layout and thermal management strategies, researchers have produced much smaller and lower temperature LEDs than current LEDs using the same electrical power.

University of Miami professor at the College of

Engineering, Jizhou Song, has helped design an LED light that uses an array of LEDs 100 times smaller than conventional LEDs.

The institute says that the new device has flexibility, maintains lower temperature and has an increased life-span over existing LEDs. The findings are published online by the "Proceedings of the National Academy of Science."

In this study, the scientists focused on improving certain features of LED lights, like size, flexibility and temperature. Song's role in the project was to analyse the thermal management and establish an analytical model that reduces the temperature of the device.

"The new model uses a silicon substrate, novel etching strategies, a unique layout and innovative thermal management method," says Song, co-author of the study. "The combination of these manufacturing techniques allows the new design to be much smaller and keep lower temperatures than current LEDs using the same electrical power."

In the future, the researchers intend to make the device stretchable, allowing them to be used on any surface, such as deformable display monitors and biomedical devices that adapt to the curvilinear surfaces of the human body.

More details of this work are published in the paper "*Unusual Strategies for Using InGaN Grown on Silicon (111) for Solid State Lighting*" by J. Rogers, R. Nuzzo, G. L. Clark, Y Huang and J Cummings.

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## Obama hails Cree at Durham LED manufacturing plant

The president told Cree employees, "You're helping to lead a clean energy revolution. You're helping lead the comeback of American manufacturing. This is a company where the future will be won."

President Barack Obama visited LED manufacturer Cree on Monday, June 13, 2011, touring its Durham, N.C. manufacturing facilities and speaking with Cree employees and other guests.

During his visit, Obama met with his Jobs and Competitiveness Council to discuss initiatives and

policies to spur economic growth, promote job creation and accelerate hiring across the United States.

Obama made remarks to a crowd that included Senator Kay Hagan, Representatives David Price, Brad Miller, G.K. Butterfield and other local and state leaders as well as hundreds of Cree employees. He stated, "So today the small business that a group of N.C. State engineering students founded almost 25 years ago is a global company...Next month, your new production line will begin running 24/7. So you're helping to lead a clean energy revolution. You're helping lead the comeback of American manufacturing. This is a company where the future will be won."

Cree currently employs over 5,000 employees globally, keeping pace with a growing international market for energy-efficient LED lighting. Most recently, Cree has added LED fixture manufacturing lines in Durham, N.C.

President Obama joined Cree CEO Chuck Swoboda on a tour of these new production lines, which include one of the world's most efficient troffers, the CR series. These new lights are designed to replace fluorescent troffer lighting commonly seen in office and other commercial buildings, delivering higher quality light and increased efficiency at prices comparable to their fluorescent counterparts.

"President Obama's visit yesterday highlighted topics critical to the success of the LED lighting revolution, including workforce training and education," said Swoboda. "Cree remains committed to innovating, growing and successfully addressing the global appetite for energy-efficient technologies."

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## AquaLite boosts LED capacity with Aixtron CRIUS II

Since its purchase of 6 CRIUS 31x2-inch reactors last November, AquaLite is seeing a stronger demand for power chip gallium nitride based LEDs and is looking to the 55x2-inch CRIUS II to increase throughput.

Aixtron SE has a new order of one MOCVD system to power chip expert and existing customer AquaLite in China.

The contract is for one 55x2-inch CRIUS II reactor which will be dedicated to the growth of materials for high brightness LEDs and high Voltage (HV) LED production.

The system was ordered in the first quarter of 2011 and the local Aixtron support team will install and commission the new reactor in the second quarter of 2011 at the dedicated AquaLite power chip LED facility within its mainland China production plant.

James Dong, CEO of AquaLite, comments, "As the main supplier of power chip devices in China we have an unequalled understanding of the challenges of volume production of HB LED structures and HV LEDs. We therefore require the reactor with the best process economics, user control and uptime which are all strong features of the CRIUS II reactor."

"Our thorough familiarity with the CRIUS systems and the easy process transfer to the CRIUS II mean there will be few if any problems ahead so the new system will quickly become a major asset. Aixtron has always supplied epitaxy equipment with excellent specifications and back that up with their highly rated support service. AquaLite is seeing a stronger demand for power chip LEDs so we look to the CRIUS II with its higher throughput to boost our capacity," he continued.

"Last November, we acquired six CRIUS 31x2-inch configuration systems for high-power LED production, so I am confident that the new reactor will also be a very worthwhile new addition when it comes onstream."

With state of the art epitaxial crystal growth and chip process technology, AquaLite's LED chips have reached over the 100 lm/W efficiency, and thus are widely used in street lighting, lighting bars, light bulbs, and LED back lighting units.

## Luminus launches RGB chipsets for ultra-mobile LED projectors

The new surface-mount products are individually assembled in a small footprint composed of red, green and blue LEDs.

LED innovator Luminus Devices is marketing the Compact SBT-16 and SBT-39 chipsets. These are the company's newest Red-Green-Blue (RGB) LED chipsets targeted primarily to consumer projectors.

Both chipsets come in a surface mount package (SMT) and were designed to address the market demand for increasingly compact form factors while retaining very high brightness output.

Personal and ultra-mobile LED projectors are an emerging class of miniature projection devices with sizes typically ranging from 150 to 400 cm<sup>3</sup>. These projectors may include built-in digital media players and can connect to portable devices such as PDAs and notebook computers to provide a large display experience.

The new chipsets consist of red, green and blue LEDs that are individually assembled in a small footprint, performance surface mount package.

Each Compact SBT-16 device comes with a 1.6mm<sup>2</sup> LED emitter and has a 18.5 mm<sup>2</sup> footprint, a 70 % reduction over the previous generation device. They are engineered for the most compact palm-size or embedded projectors with performance ranging from 30 to 150 lumens depending on the available power budget.

The SBT-39 devices include a 3.9 mm<sup>2</sup> LED emitter with a package footprint of only 33 mm<sup>2</sup> and are designed for mid-range projectors whose performance ranges from 150 to 300 lumens.

"The Compact SBT-16 and SBT-39 chipsets integrate the latest advances in LED technology and allow our customers to create thinner, more compact projectors while retaining the high brightness that consumers expect from LED projectors," said Stephane Bellosguardo, director of global product marketing, Display Business Group, Luminus. "Continued innovation in light source

technology enables new applications and product differentiation, fuelling an increasingly segmented market that research firms predict will be a multi-million unit market by 2013.”

The Compact SBT-16 and SBT-39 integrate seamlessly with standard SMT manufacturing processes and equipment. Luminus Big Chip LEDs are RoHS compliant, and unlike traditional projector lamps they are free of hazardous materials such as mercury. Their high reliability eliminates the need for light source replacement, resulting in maintenance-free, worry-free projectors. Samples of both chipsets are now available to lead customers.

## LED chip manufacturers target general illumination market

Strategy Analytics' latest report which includes developments from Cree, Seoul Semiconductor, Philips Lumileds and Luminus describes the impact of recently released lighting class products.

As the lighting market begins the transition from incandescent bulbs to more efficient alternatives, LED manufacturers continue to develop products aimed at general illumination markets.

The recently published Strategy Analytics GaAs and Compound Semiconductor Technologies Service (GaAs) viewpoint, "Compound Semiconductor Industry Review April 2011: Optoelectronics, Materials and Equipment," captures the product, technology, contract and financial announcements for optoelectronic companies, such as Aixtron, Kopin, Cree, Philips Lumileds, Ciena and GT Solar for March 2011.

"The global effort aimed at phasing out less-than-efficient incandescent light bulb creates a big opportunity for alternative lighting sources," noted Eric Higham, Director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service. "LED manufacturers are responding with products and technology that reduce costs while improving LED-based general lighting aesthetics."

Asif Anwar, Director, Strategy Analytics Strategic Technologies Practice, added, "In addition to

LEDs, the optoelectronics industry is realising energy savings with product developments and investments aimed at increasing capacity and efficiency of solar energy infrastructure."

This report summarises April 2011 financial, product, contract and employment announcements from major optoelectronic material, device and equipment suppliers and are categorised by material and equipment, laser, LED and compound photovoltaic activity.

## Rubicon reaffirms Q2 2011 guidance

The firm has had another solid quarter and estimates that revenue in the second quarter should come in at the high end of the \$40 million and \$43 million range of its previously provided guidance.

Rubicon Technology, a provider of sapphire substrates and products to the LED, RFIC, semiconductor and optical industries has reaffirmed its previously issued second quarter 2011 revenue and earnings guidance and clarified its projected tax rate for the second quarter and remainder of the year.

The Company reported that it is having another solid quarter and estimates that revenue in the second quarter should come in at the high end of the \$40 million and \$43 million range of its previously provided guidance. Pre-tax earnings are also expected to be at the high end of the previous estimates. The Company's second quarter EPS guidance of \$0.82 to \$0.86 assumed a diluted share count of 24 million shares and a tax rate of 7 %, which represents accrual for state income taxes only.

When providing this guidance, the management indicated that a determination might be made to begin accruing for federal income tax as soon as the second quarter due to a number factors, including the dramatic increase in earnings of the Company. William Weissman, Rubicon's Chief Financial Officer, has confirmed that the Company will begin accruing for federal income tax beginning the second quarter of this year, which will bring the Company's effective tax rate up to approximately 40 % for the second quarter and for the remainder

of this year. Weissman also confirmed that the projected effective tax rate for 2012 remains at 30 to 35 %. Factoring in the higher tax rate adjusts previously issued EPS guidance to between \$0.53 and \$0.55.

Weissman said, "We are having another strong quarter and expect our revenue and earnings to come in at the high end of our previous estimates. We indicated in our last earnings call that we might begin accruing for federal income tax in the second quarter and, based on our continued strong earnings, it has been determined that accruing for federal tax in the second quarter is appropriate. The high end of our EPS guidance, adjusted for the higher tax rate is \$0.55."

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## Tegal announces 1-for-5 reverse stock split

The Board's decision to implement the reverse stock split was made to help Tegal maintain its Nasdaq listing as well as to increase the share price to make our stock more attractive to investors.

LED and solar cell innovator Tegal Corporation has announced that its Board of Directors, as authorised by Tegal stockholders, will implement a one-for-five reverse stock split of its common stock.

The Company will file a charter amendment to implement the reverse stock split, which is expected to become effective on June 15, 2011. The reverse stock split was authorized by Tegal's stockholders at a special meeting on June 15, 2011.

"The Tegal Board has given considerable thought to the decision of a reverse stock split," said Thomas Mika, Chairman, President and CEO of Tegal. "The Board's decision to implement the reverse stock split was made to help Tegal maintain its Nasdaq listing as well as to increase the share price to make our stock more attractive to investors." The bid price of the Company's common stock must close at \$1.00 or higher for ten consecutive business days prior to July 5, 2011 in order for the Company to maintain its listing on the Nasdaq Capital Market.

As a result of the reverse stock split, each five (5) outstanding shares of pre-split common stock will

be automatically combined into one (1) share of post-split common stock. No fractional shares will be issued. Instead, the Company will pay cash in an amount equal to such fraction multiplied by the average of the high and low trading prices on The Nasdaq Capital Market of the Company's common stock for the five previous trading days (as adjusted to give effect to the reverse split).

The Company's registered stockholders will receive instructions from Registrar and Transfer Company, the Company's transfer agent, regarding the exchange of outstanding pre-split stock certificates for certificates representing post-split shares of common stock. Upon submission of the necessary documentation by a stockholder of record to the Company's transfer agent pursuant to such instructions, the transfer agent will distribute to such stockholder a new certificate together with a cash payment in lieu of fractional shares. Proportional adjustments will be made to the Company's outstanding stock warrants, stock options and other equity awards and to the Company's equity compensation plans to reflect the reverse stock split.

The Company expects that trading of the Company's common stock on the Nasdaq Capital Market on a split-adjusted basis will begin at the opening of trading on June 17, 2011. The Company's common stock will continue to trade on the Nasdaq Capital Market under the symbol "TGAL" and will include the letter "D" appended to the trading symbol for a period of 20 trading days to indicate that the reverse stock split has occurred, after which time it will revert to trading under the symbol "TGAL."

Since its founding in 1972, Tegal Corporation has been dedicated to the development and application of emerging technologies such as LEDs, filtering and sensing devices for advanced smart phones and most recently, solar cells. The company is now evaluating opportunities for partnerships with other diversified technology-based companies.



## Tsinghua Tongfang buys Veeco's MaxBright tool for HB LEDs

The firm has added the MOCVD system to its China fab. The MaxBright reactor delivers up to a 500% productivity gain and 2.5x increase in footprint efficiency over the K465i system.

Veeco Instruments has announced that Tsinghua Tongfang Company, a Beijing-based publicly listed division of the Tsinghua Holdings Company Limited, has placed an order for Veeco's new TurboDisc MaxBright Multi-Reactor MOCVD System for production of high-brightness LEDs (HB LEDs).

Liu Gang, General Manager of Nantong Tongfang commented, "Last year we selected Veeco as our primary supplier for our new production facility in NanTong, China that was completed at the end of 2010. We are very pleased with the performance of Veeco's single-chamber K465i systems, and are now excited to add the multi-chamber MaxBright system to help further improve our fab's productivity."

William J. Miller, Executive Vice President, Veeco LED & Solar, added, "Tsinghua Tongfang has done a great job building their LED business, and we are extremely pleased to continue to support their further capacity expansion with our latest generation product."

Veeco claims that the MaxBright system is the industry's most productive, lowest cost of ownership MOCVD system available to manufacture high brightness LEDs. Available in a 2 or 4-reactor cluster architecture, the MaxBright system delivers up to a 500% productivity gain and 2.5x increase in footprint efficiency over the K465i system.

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## FOREPI orders Veeco Maxbright MOCVD systems

The reactors, to be used for indium gallium nitride HB LED production, deliver up to a 500% productivity gain and a 2.5x increase in footprint efficiency over the K465i system.

Veeco Instruments has a new order from Taiwan-based Formosa Epitaxy (FOREPI) and its Chinese affiliate, Jiangsu Canyang Corporation.

The companies have placed a multi-unit order for Veeco's recently released TurboDisc MaxBright multi-reactor MOCVD System for production of high-brightness (HB) LEDs.

Frank Chien, President of Jiangsu Canyang said, "We are impressed with MaxBright's high productivity, flexible process capabilities, and compact architecture, and think it will be a great choice for our high-production fabs. We have selected the four-chamber configuration as we believe it will provide the best cost of ownership and value for our investment."

William J. Miller, Executive Vice President, Veeco LED & Solar, added, "We believe that the MaxBright system is the ideal solution for best cost of ownership LED production by top manufacturers such as FOREPI and its Chinese affiliate Canyang. It is exciting to have our new tool selected by one of Taiwan's top LED manufacturers as part of their expansion in both Taiwan and China."

The MaxBright system is designed for HBLED production and is available in a 2 or 4-reactor cluster architecture and delivers up to a 500% productivity gain and 2.5x increase in footprint efficiency over Veeco's K465i reactor.

FOREPI was formed in November 1999 and is a pure-play high power InGaN LED wafer and chip manufacturer. It claims to be the only Taiwanese LED company with the capability of offering the full spectrum including high power InGaN blue, green and near-UV LEDs.

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## Samsung LED bites back against Osram

The firm has filed lawsuits related to LED chip and package technology used in LED light lenses and high power applications which are widely used in LED headlights and LED lightings.

On June 10, 2011, Samsung LED filed a patent infringement lawsuit against Osram Korea and two other defendants at the Seoul Central District Court.

Samsung LED is requesting an injunction from unauthorised use of its intellectual property and is seeking money damages. The defendants include Osram Korea and two companies that sell Osram's products in Korea, Barun Electronics and Dabo Industrial System.

The 8 patents-in-suit relate to LED chip and package technology used in LED light lenses and high power applications which are widely used in LED headlights and LED lightings.

The Korean suit is Samsung LED's first response to Osram's initiation of lawsuits against Samsung LED in the US (District Court of Delaware and the U.S. International Trade Commission) and Germany. Samsung LED is developing a measured response.

Samsung LED has a considerable number of core LED patents and patent applications. The firm currently has about 700 US patents and patent applications and about 2000 Korean patents and patent applications.

"We are developing evidence to show that Samsung LED is not infringing any valid claim of Osram's patents, as well as evidence of Osram's unauthorised use of our patents, we are evaluating every contingency and will vigorously defend our technology," said Jun Sung Park, Vice President and the head of the IP and Legal Affairs Team at Samsung LED.

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## Kyma updates progress on AlGaIn and AlN development

The firm which uses a patented III-N PVDNC process, is also seeking partnerships with bulk aluminium nitride materials developers who are interested in improving the optical properties of their materials.

Kyma Technologies, a supplier of crystalline nitride semiconductor materials, has provided an update on its progress in crystalline AlGaIn and AlN materials development and to state its desire to collaborate with bulk AlN developers interested in improving the optical transparency of their materials.

Kyma has over a decade of experience in the

fabrication of AlN templates which are thin films of crystalline AlN deposited on sapphire, silicon, or SiC substrates. The process uses Kyma's patented and proprietary III-N Plasma Vapour Deposition of NanoColumns (PVDNC) technology.

These products are gaining acceptance with customers engaged in blue and green LED manufacturing. The nanocolumnar nature of Kyma's PVDNC AlN templates present an excellent surface for nucleating GaN buffer layers which then can be followed by a high quality GaN LED device structure.

Recently Kyma began extending its process capabilities to develop materials which are designed to support high Al content device layer structures. Such structures are of interest for UV and high temperature and high power electronics applications.

Keith Evans, Kyma's president & CEO, stated: "While our PVDNC AlN templates are excellent substrates for manufacturing GaN-rich devices such as blue and green LEDs and AlGaIn/GaN field effect transistors (FETs), we are also employing other processes to develop materials that are specifically tailored to support the manufacturing of AlN-rich devices such as mid UV LEDs for germicidal irradiation and AlN/AlGaIn FETs for temperature insensitive high power electronics applications."

Towards these goals, Kyma is exploring and has made significant progress in the growth of crystalline AlN and AlGaIn materials using high growth rate hydride vapour phase epitaxy (HVPE).

By adding a novel Al source to their HVPE tools, Kyma is now able to grow crystalline AlN and a broad range of AlGaIn compositions. And just like GaN HVPE, the structural quality of the HVPE grown AlN and AlGaIn crystals are influenced by the seed crystal that they are grown upon.

Kyma has already demonstrated the ability to deposit crystalline AlN by HVPE on a range of starting seed materials, including on AlN structures which were produced by other techniques.

Ed Preble, Kyma's CTO & VP business development, stated, "Our AlN HVPE process appears to have many of the traits of our GaN HVPE process. We are able to rapidly replicate the

quality of the underlying seed and in certain cases then improve its quality as we continue to grow the crystal.”

“Additionally, optical transmission measurements show that our HVPE grown AlN materials have high transparency in the 200nm to 400nm spectral region, an important feature for UV LED applications, and a noted advantage over some competing AlN crystal growth approaches,” added Preble.



## Moving smarter LEDs from Lab to Fab

The Smart Lighting ERC at Rensselaer Polytechnic Institute has engaged key industrial partners including Epistar and Osram to foster and guide LED innovations.

Now in its third year, the Smart Lighting Engineering Research Centre (ERC) has enlisted 21 key industrial partners to help guide the centre’s leading-edge research programs and hasten the transition of important innovations from the lab bench to the marketplace.

The centre is dedicated to developing new LED technologies and applications for smarter, better-performing lighting devices and systems. Launched in 2008 and funded primarily by the National Science Foundation, the ERC is led by Rensselaer Polytechnic Institute.

“The rapidly growing industry membership in the Smart Lighting ERC is a testimony to the quality of the transformative research being conducted on future lighting systems by the ERC faculty and students,” said ERC Director Robert Karlicek.

“It is also firm support for the ERC’s vision of smart lighting systems, which are poised to revolutionise lighting by creating immersive lighting systems that can sense their environment to provide new levels of energy efficiency, health and safety benefits, and enhanced workplace productivity.”

Among the centre’s industrial partners are leading LED companies including Osram Sylvania and Taiwan-based Epistar.

“Riding on the backbone of energy-efficient improvements in materials and performance, the Smart Lighting ERC is providing a state-of-the-art centre in which we from industry engage academia to prove concepts at platform levels, ahead of industry acceptance and uptake,” said Matthew Stough, director of engineering, materials and processes, and research coordinator at Osram Sylvania.

“Epistar is pleased to join the Smart Lighting Engineering Research Centre. Their work on transformative LED and lighting technology is of critical importance to the development of advanced solid state lighting systems, and we look forward to supporting those efforts as a member of the ERC,” said Steve Hong, director of research and development at Epistar.

While the promise of LEDs as a long-lived, energy-efficient heir to light bulbs is undeniable, the true promise of LED and solid-state lighting technology transcends illumination. LEDs offer the potential to control, manipulate, and use light in entirely new ways for a surprisingly diverse range of areas.

To realise the potential of solid-state lighting technology, the ERC team is working to create better LEDs, as well as new sensors and systems required to effectively to monitor and control these LEDs. More than 30 ERC faculty researchers at Rensselaer and partner universities are actively working toward this goal, along with dozens of student researchers, postdoctoral researchers, and visiting industry engineers.

Along with Rensselaer, core ERC university partners are Boston University and the University of New Mexico. ERC university outreach partners

are Howard University in Washington, Morgan State University in Baltimore, and Rose-Hulman Institute of Technology in Terre Haute, Indiana.

The ERC's many industry partners, ranging from major lighting companies to small start-up firms, help guide strategic planning, spur innovation, and provide university students with first-hand experience in entrepreneurship as well as corporate research and development. This summer, four ERC graduate students have taken internships with ERC industrial partners, and two ERC students have started a new company based on ERC technology and will be supported this summer by a Boston-based venture capital firm.

## Osram lights up Munich underground safely and in style

The luminaires from LI-EX employ 15,000 cold-white Golden Dragon Plus LEDs and 50,000 warm-white TopLEDs in the entrance area of the new "Stachus Passagen" in Munich.

For decades, Osram's former slogan – "Hell wie der lichte Tag– As bright as broad daylight" has been gracing the facade of buildings at Munich's Karlsplatz roundabout.

Now the light manufacturer is also represented in the underground area of this bustling city-centre square, in the form of its subsidiary Osram Opto Semiconductors. The challenge was to implement the lighting concept in the entrance area of the newly redesigned station (for the S-Bahn suburban network and U-Bahn city metro).



***The new entrance area of the S-Bahn suburban-network and U-Bahn underground metro station at Munich's Stachus is illuminated by LI-EX profiles, using thousands of LEDs from Osram Opto Semiconductors.***

Schmidt-König, planning office for lighting, and light experts LI-EX constructed their plans based on LEDs from the Regensburg-based semiconductor manufacturer. The result is a Stachus with brilliant illumination and a low requirement for maintenance resources.

Since June 2010 the entrance area of the S-Bahn and U-Bahn station and the "Stachus Passagen" at Munich's Karlsplatz has been reconstructed; in this process, a new lighting concept has been put into effect.

In its project management capacity, the Munich-based Schmidt-König planning office for lighting decided for several reasons in favour of using the LED lighting solutions provided by LI-EX, the Regensburg-based lighting specialist.

It was particularly important for Michael Schmidt and the team to get good longevity of the lamps, to keep service costs low. The lighting technology used also needed to save space and, at the same time, provide high output with defined light-radiating characteristics.

In the course of the eleven-month refurbishment project beneath the Stachus, a total of 65,000 LEDs sourced from Osram Opto were installed into the LI-EX profile. The latter is characterised by its flexibility; the distances between the LEDs are freely selectable, and lengths ranging up to three metres can be supplied.

Two different LED types were installed in the process: for the facade lighting and for the architectural upgrading of the entrance area, as well as for the backlighting of a bronze-coloured glass facade, 15,000 cold-white Golden Dragon Plus LEDs were used. They supply a bright and even illumination, without scattered light or dazzle, and with low power consumption. An additional factor is the good colour rendering index of the LED light sources. This provides a natural colour impression and thus a higher level of safety, due to a more clearly contoured environment.

The handrail, 700 metres long in total, is illuminated by 50,000 warm-white TopLEDs. The LI-EX profiles are outstandingly suitable for this application. As the stairs in the entrance area are different, the length of the luminaires also needs to be adapted individually: for this type of luminaire, this is not a problem.



***The stairs are illuminated via the handrails, providing a high level of brightness accompanied by low energy consumption.***

For construction reasons, the stairs were only able to be illuminated via the handrail – however, the latter was supposed to brightly illuminate the whole surface of the steps. As the lighting for the stairs also simultaneously serves as emergency lighting, powered by a battery in the event of a shutdown in electricity, the need was for lamps with low power consumption.

Thanks to TopLED, 18 metres of handrail illumination requires a mere 100 Watt. In this way, the project in the underground area at Stachus saw the realisation of not only an optically appealing, but also an energy-efficient lighting concept.

The glass facade presented another challenge. Here, there was a need to guarantee an even back-lighting with a high level of brightness and without visible LED light points. However, the short distance between wall and glass facade made challenging demands, both on the light-radiation characteristics of the LEDs and on the interplay with the external lens.

Nevertheless, the LED profiles from LI-EX were able to meet this precondition: “The LED profile sits below at the glass wall and needs to supply a homogeneous brightness across several metres, despite the stray power due to the glass area. For these conditions, the highly-efficient, compact

Golden Dragon Plus LEDs are ideal”, notes Marco Friedrich, chief executive of LI-EX.

Thus visitors to Munich’s Stachus reap the benefit of an efficient lighting solution, merging style with safety.

The refurbishment of “Stachus Passagen” has been in progress since 2007, the project’s client is the Landesbank Baden-Württemberg. The architectural aspects of the project are run by Allmann Sattler Wappner Architekten GmbH, whose concept convinced the decision-makers during the initial architectural competition.

LI-EX is a part of “LED-Light for you”, a network for lighting technology, initiated by Osram, which works jointly with customers on implementing new solutions based on the efficient and multi-faceted light diodes; since the launch of the Stachus project, the network has been providing specialist advice to the architects, Allmann Sattler Wappner.

## Telecoms

### Infinera swoops in to support services following Japan earthquakes

The firm is using its indium phosphide based PICs to provide critical support to Pacnet to restore 400Gb/s of capacity in four weeks.

Following the earthquakes and tsunami which devastated northeast Japan earlier this year, Infinera has delivered technology to support Pacnet’s restoration of damaged terrestrial and subsea optical networks.

Pacnet is one of Asia’s leading independent telecommunications service providers and an operator of a regional network providing connectivity among Japan, Hong Kong, China, the United States and other countries throughout the Pacific Rim.

Days after the disaster, Infinera was given the task to deliver 400Gb/s of capacity over Pacnet’s

Japanese subsea and terrestrial networks as quickly as possible. The firm's response was an immediate commitment to get the network into the customer's desired state.

Infinera immediately assembled a virtual task force in Tokyo, Singapore and Sunnyvale to put in place a detailed recovery plan. Four days later, all the equipment required to restore the 400Gb/s of capacity over the Pacnet subsea and terrestrial networks was shipped to Tokyo.

In all, it took the Infinera Japanese support team -- after battling extreme conditions and tight timelines -- less than four weeks to install, commission and test the entire new 400Gb/s of capacity.

"Pacnet's priority has always been our customers -- we want them to enjoy the latest, most innovative services that meet the highest industry standards regardless of any situation. When the disaster hit, we immediately took action to restore the fault and are very thankful to have Infinera as our partner," said Wilfred Kwan, Chief Technology Officer of Pacnet.

"Throughout the whole process, the Infinera team displayed solid commitment, determination and professionalism in supporting the restoration of our network and service to our customers in record time."

"The task to help restore the Pacnet network under such tight timelines and immense pressure was significant," said Lonny Orona, Infinera Vice-President for Customer Support. "But we were determined to help our customer in any way possible and be with them every step of the way, so they could fully meet their customers' needs. Both the Pacnet and the Infinera teams worked tirelessly to restore service on the network enabling them to roll out services quickly and efficiently."

The Infinera DTN based Submarine Solution delivers the benefits of Infinera's Digital Optical Networks architecture, enabling ease of scalability and operation, as well as seamless interoperability with a terrestrial Infinera network. Infinera has deployed more than 85,000 km of subsea networks across five continents.

## Huawei awards Anadigics for exceptional services

The provider of next generation telecommunications network solutions has said that the level of cooperation and support demonstrated by Anadigics during a critical period in its manufacturing process was significant in ensuring success in the wireless handset market.

Anadigics, a provider of RF semiconductor products has been recognised by Huawei and received its prestigious "Cooperation and Support Award" for outstanding service.

The award was presented to Ron Michels, Anadigics' chief executive officer by Derek Luo, Huawei's terminal parts CEG senior business manager. Luo commented, "Anadigics has been recognised for providing exceptional support in responding to Huawei's ramp-up of 3G smart phones in the second and third quarters of 2010."

Victor Chu, Huawei's business director terminal parts CEG added, "The level of cooperation and support demonstrated by Anadigics during a critical period in our manufacturing process was significant in ensuring our success in the highly competitive wireless handset market."

In receiving the award, Ron Michels commented, "I'm extremely proud to receive this award from Huawei on behalf of our team at Anadigics. We believe this award recognises our commitment to deliver service and support that exceeds customer expectations and reinforces our dedication to growing our partnership with Huawei in the future."

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## Retegal chooses Infinera's InP ATN for Spanish regional network

Telindus will deploy Infinera's indium phosphide based PICs to provide broadband, radio and television services in northwest Spain.

Infinera says that Retegal, the regional network operator owned by the Galicia regional government in Spain, has deployed the Infinera ATN metro

WDM transport platform for a regional network delivering services throughout Galicia in northwest Spain.

Telindus, a Spanish ICT integrator, is managing the deployment and maintenance of the network. The Infinera network will enable Retegal to deliver broadband, radio, and television services throughout the region, and extend broadband services throughout Galicia in the future.

Retegal is playing a key role in the regional government's broadband plan and is supported with a budget of €32 million (\$46 million) to extend broadband access to more than 786,000 citizens in the self-governing region. Galicia is located in the northwestern corner of Spain and includes many coastal fishing villages and inland agricultural communities previously unserved with broadband services.

Retegal operates as an "open access" wholesale network, providing services on an open and equal basis to all private operators such as last-mile service providers. Increased broadband access will play a key role in bringing new jobs and services to the region. The total investment of the Galicia regional government in the regional broadband program is more than €81 million (\$117 million), while total public and private investment in Retegal is more than €221 million (\$320 million).

With an Infinera ATN network for the optical transport infrastructure, Retegal benefits from a flexible, scalable WDM transport solution designed to offer a broad range of services, including Ethernet, SAN, SONET/SDH, OTN and video services. Retegal was a lead customer for ATN Release 2.0 which offers a number of new capabilities including multiservice aggregation to 10Gb/s wavelengths and fully automated optical power management. This year, Retegal is planning to extend the network to more than 1,800 km of total network reach.

"The Infinera solution enables our network to respond to customer demands with a network architecture that provides all the requirements for enabling next generation services," commented Jose Angel Abeal, Managing Director of Retegal.

Telindus deployed the network for Retegal and is providing network monitoring and first-line

maintenance. "Infinera's latest generation of optical networking systems are the best option for telecom operators seeking to simplify their network management and offer value-added services to their customers. For us at Telindus, Retegal's selection of Telindus to manage the deployment of such an advanced network solution demonstrates Telindus's capabilities in the service and support of advanced next-generation technologies," commented Emilio Cabanas, Director General of Telindus.

"We are pleased to provide Retegal with an Infinera network which will provide the scalability, flexibility, and ease of use to support the extension of broadband services throughout the Galicia region and into underserved provinces," said Infinera President and CEO Tom Fallon.

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## Advanced Photonix set to join Russell Microcap Index

The supplier of high-speed optical receivers and terahertz instrumentation for the telecom, homeland security, military, medical and industries believes this is the first step in opening the investment community to its technology and market growth opportunities.

Advanced Photonix will join the Russell Microcap Index when Russell Investments reconstitutes its family of U.S. indexes on June 24, according to a preliminary list of additions posted June 10 on [www.russell.com/indexes](http://www.russell.com/indexes).

Membership in the Russell Microcap Index, which remains in place for one year, means automatic inclusion in the appropriate growth and value style indexes. Russell determines membership for its equity indexes primarily by objective, market-capitalisation rankings and style attributes.

Richard Kurtz, API's Chairman and CEO, said, "We are pleased to be included in the Russell Microcap Index, this is the first step in getting greater exposure and opening the investment community to our technology and market growth opportunities."

Russell Indexes are widely used by investment managers and institutional investors for index funds and as benchmarks for both passive and active investment strategies. An industry-leading

\$3.9 trillion in institutional assets currently are benchmarked to them.

Annual reconstitution of Russell Indexes captures the 4,000 largest U.S. stocks as of the end of May, ranking them by total market capitalisation to create the Russell 3000 and Russell Microcap Indexes. These investment tools originated from Russell's multi-manager investment business in the early 1980s when the company saw the need for a more objective, market-driven set of benchmarks in order to evaluate outside investment managers.

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## GigOptix completes acquisition of Endwave

The firm believes the acquisition will fulfil its long-term vision of building the industry's premier one-stop-shop supplier of analogue and optical components that enable high speed information streaming.

Supplier of semiconductor and optical components that enable high speed information streaming, GigOptix, has announced that at a special Endwave Corporation stockholders meeting, the stockholders voted to approve the acquisition of Endwave by GigOptix.

At the meeting, holders of more than 55% of the outstanding Endwave shares, or more than 98% of the shares represented at the meeting, were voted in favour of the adoption of the acquisition.

Under the terms of the acquisition, all outstanding shares of Endwave common stock will be converted into shares of GigOptix common stock at a conversion ratio of approximately 0.908.

Avi Katz, GigOptix's Chief Executive Officer and Chairman of the Board, stated, "The Endwave acquisition is an exciting step towards fulfilling our long-term vision of building the industry's premier one-stop-shop supplier of analogue and optical components that enable high speed information streaming. We welcome our new colleagues from Endwave and look forward to continuing on our mission to address customers' expanding needs for innovative high speed data communications solutions as well as simplifying our customers' supply chains."

John Mikulsky, Endwave's former Chief Executive Officer and newly appointed member of the GigOptix Board, stated, "the combination of GigOptix and Endwave is an ideal blend of technology, opportunity and vision that will benefit our customers, employees and stockholders. I look forward to working on the GigOptix Board of Directors and continuing to be a part of this exceptional company."

As part of the consolidation, GigOptix will proceed with strategic changes to its leadership structure that include a horizontal class of functional organisations led by three executives, which are supported by three general manager executives each leading specific vertical product lines. This revised structure will assist in streamlining collaboration within GigOptix, while also enabling an expansion of GigOptix's business and product portfolio in order to better position GigOptix for future growth.

Katz concluded, "We have already initiated many preliminary in-house activities in preparation for the physical and operational integration process. As such, we expect the majority of the integration process to be completed early in the third quarter of this year, including the relocation of our corporate headquarters to the current Endwave site at 130 Baytech Drive, San Jose, California 95134. Additionally, we continue to actively pursue the listing of GigOptix's shares on the NYSE Amex, with the closing of this acquisition bringing us one step closer to achieving this goal."

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## GigOptix to supply chipset for use in 40G AOC applications

The advanced feature set of the HXT/R4 family enables customers to optimise the trade-off between power dissipation and performance of the optical link.

GigOptix, a supplier of high performance electronic and electro-optic components that enable next generation 40G and 100G optical networks, has announced that a Taiwanese optical engine manufacturer has entered production with GigOptix's HXT/R4 chipset.



The chipset will be used in a 40G Quad Small Form-factor Pluggable (QSFP) Active Optical Cable (AOC) application.

GigOptix's HXT/R4 chipset has been designed to support multiple applications ranging from 5Gb/s to 10Gb/s per channel. The advanced feature set of the HXT/R4 family enables customers to optimise the trade-off between power dissipation and performance of the optical link. This has been successfully demonstrated by transmitting data over a 100m link with less than 100mW total power dissipation.

Moreover, GigOptix's unique architecture enables customers to examine the detailed status of their product after the fibre has been attached. This functionality allows customers to more easily test and monitor the operation of the VCSEL and Photo Diode devices within the optical engine leading to significant cost savings.

Jay de la Barre, GigOptix's Vice President of Global Sales stated, "We believe that our HXT/R4 chip-set will be key to enabling 40G optical engines for the high volume supercomputing and consumer markets. We are very excited to work with pioneering companies using innovative silicon bench technology along with our VCSEL driver and receiver array chip-set to take their solutions to production."

The HXT/R4 chip-set is designed for use in Infiniband AOC, SNAP12 and QSFP optical modules while serving the fast growing markets of high performance computing optical interconnects, switch and router optical backplanes and the emerging 40G and 100G Ethernet standards.

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## NeoPhotonics quadruples capacity to cope with ICR demand

The company is responding to increased demand for volume shipments of high-speed coherent fibre optic transport systems.

Photonic Integrated Circuit manufacturer NeoPhotonics, which provides PIC based modules and subsystems for bandwidth-intensive, high

speed communications networks, has quadrupled capacity for PIC-based Integrated Coherent Receivers (ICRs) for state-of-the-art 40 and 100Gbps coherent fibre optic transport systems.

The Company believes that the industry is coalescing behind the "coherent technology" approach for high-speed "backbone" networks. By combining the NeoPhotonics PIC-based ICR, which has one of the industry's highest signal detection responses, with advanced digital signal processing on each channel, the coherent approach is designed to provide service providers a solution for leveraging their existing fibre optic cable investments longer, more efficiently and in an "on demand" manner.

"The rapid increase in the use of coherent transmission technology for 40 Gbps on the line side, coupled with an initial ramp of 100 Gbps coherent systems, necessitates a significant increase in volume shipments of ICRs while maintaining stringent optical performance requirements," said Tim Jenks, Chairman and CEO of NeoPhotonics. "Our photonic integration technology utilises our semiconductor-based wafer manufacturing capabilities and is inherently high quality, scalable and cost-effective, which positions us ahead of the demand curve for this important technology," concluded Jenks.

The NeoPhotonics ICR is designed to convert the phase encoded optical signals into electrical signals of varying intensity, which can then be analysed using digital signal processing. As carriers upgrade from 10 Gbps network connections, the coherent solution utilizing the NeoPhotonics ICR not only provides more throughput capacity but also more intelligence. NeoPhotonics has earned multiple design wins for the ICR with its tier 1 customer base and is now shipping ICR products, with or without an internal polarising beam splitter, to multiple customers.

The NeoPhotonics ICR is designed to support the OIF Implementation Agreement for Integrated Dual Polarization Intradyn Coherent Receivers. The PIC-based ICR is designed to provide advanced demodulation to analyse the state-of-polarisation and optical phase of a phase-modulated signal relative to an externally supplied optical reference signal, enabling recovery of the phase-polarisation constellation of 40 or 100 Gbps format signals.

In addition to the ICR, NeoPhotonics currently offers a broad range of PIC-based components for high capacity data transport networks, including 90 Degree Hybrid Coherent Mixers for both 40Gbps and 100Gbps coherent transmission systems, and both small and standard form factor DQPSK Demodulators for 40Gbps transmission.

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## Avago share repurchase program authorised

The repurchase of up to 15 million of the company's ordinary shares has been authorised and should not exceed \$500 million of its shares in the aggregate.

Avago Technologies, a supplier of analogue interface components for communications, industrial and consumer applications, has announced that its Board of Directors has approved a quarterly interim cash dividend of \$0.09 per ordinary share.

The Board has also authorised the repurchase of up to 15 million of the Company's ordinary shares, not to exceed \$500 million of its shares in the aggregate.

The dividend is payable on June 30, 2011 to shareholders of record at the close of business (5:00p.m.) Eastern Time on June 17, 2011.

The authorisation of the share repurchase program was made pursuant to the share purchase mandate approved by the Company's shareholders at its 2011 annual general meeting, which authorises the repurchase by the Company of up to 10% of its outstanding ordinary shares prior to the date of the Company's 2012 annual general meeting.

Share repurchases, if any, will be made in the open market at such times and in such amounts as the Company deems appropriate. The Company intends to effect any share purchases in compliance with Securities and Exchange Commission Rule 10b-18 or pursuant to a trading plan adopted pursuant to Rule 10b5-1.

The timing and actual number of shares repurchased will depend on a variety of factors including price, market conditions and applicable legal requirements. The share repurchase program does not obligate the Company to repurchase any

specific number of shares and may be suspended or terminated at any time without prior notice.

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## Infinera awarded for global telecoms business innovation

In its collaboration with Interoute, Infinera which uses indium phosphide technology in its PICs, won the award for its contribution to high capacity European networks.

Infinera and Interoute won the "Wholesale Service Innovation" award at the Global Telecoms Business Awards.

The award recognises Interoute's innovation as one of the world's first telecom operators to offer a revenue-generating OTN service to a customer. Interoute used the Digital OTN capabilities of its deployed Infinera DTN-based network to deliver the services.

The prestigious award was accepted by Matthew Finnie, Interoute's Chief Technology Officer, and Chris Champion, Infinera's Vice President of Sales EMEA at a Tuesday evening awards ceremony in London attended by more than 300 people from the global telecom industry.

Infinera introduced the DTN platform in 2004 and the firm says it is still the industry's first and only solution that integrates Dense Wave Division Multiplexing (DWDM) directly with OTN switching through the use of the Photonic Integrated Circuit (PIC) which incorporates InP.

This pioneering integration of DWDM and OTN enabled the Digital Optical Network to remove many of the challenges found in traditional analogue optical networks. OTN (Optical Transport Network) is a set of industry standards that enable service reconfigurability and transparent network performance monitoring throughout the network.

In September 2010, Infinera enhanced its OTN capabilities with the introduction of new client interfaces that enabled OTN services (such as ODU1) to be handed off to non-Infinera networks. With Infinera's Digital Optical Network and OTN

capabilities at the core of its pan-European network, Interoute is able to deliver high-capacity connections to multiple organisations on the same fibre, which can be turned up quickly to meet customer demand. The Interoute-Infinera partnership also allows for the delivery of clear channel wavelength links, especially useful for wholesale services needing to carry both bandwidth and management traffic.

“We are thrilled to have had our wholesale services recognised by this award,” said Matthew Finnie, CTO at Interoute. “Interoute’s network is used by all the major incumbents, and is increasingly attractive to operators in the service provider market looking to outsource part or all of their European networks. We continue to invest in the scale and reach of our European network, and Infinera’s Digital Optical Networks architecture, including its Digital OTN features, plays a key part in allowing us to deliver cost-effective, high-capacity networks to our customers in very short time frames.”

“We are very pleased to share this award with Interoute,” said Chris Champion, Infinera Vice-President of Sales for EMEA. “Interoute continues to be an industry leader and is playing a pioneering role by leveraging Infinera’s OTN capabilities to offer these services on a commercial basis. This is an important innovation which will help the industry move to the next generation of services while offering customers end-to-end transparent services.”

In presenting the Awards, Alan Burkitt-Gray, editor of Global Telecoms Business, commented, “This is the fifth time we’ve run the Global Telecoms Business Innovation Awards and this year we saw more nominations, from a greater range of operators and vendors, than ever before.”

“This is a sure sign the industry is working harder and harder to deliver exciting and innovative services to customers worldwide. Congratulations to all of this year’s award winners and to Infinera and Interoute for their wholesale high capacity network.”

## RF Electronics

### M/A-COM marketing 0.5 to 4 GHz LNAs for microwave

The firm’s new series of gallium arsenide based MAAL-0107X LNAs deliver a high linearity performance and are also suited to RF applications including cellular infrastructure receivers.

A new family of Low Noise Amplifiers (LNAs) has been revealed by M/A-COM Tech. The LNAs facilitate easy implementation in multiple RF and microwave front-end circuits including GSM, CDMA, WCDMA and LTE base stations and repeaters.

The GaAs-based amplifiers meet the high performance requirements of telecommunications equipment manufacturers and are optimised for minimum system noise figures and increased receiver sensitivity.



“We are pleased to expand our cellular infrastructure product portfolio with the introduction of this family of low noise amplifiers. The low noise figure coupled with high gain and OIP3 make these LNAs ideal for first and second stage 3G and 4G receivers,” said David Richardson, Market Director, of M/A-COM Tech Infrastructure Products.

The MAAL-010705 and MAAL-010706 are highly linear LNAs with a low noise figure, high gain and excellent input and output return loss designed for operation from 0.5 to 1.6GHz and 1.4 to 4.0 GHz respectively. These two amplifiers share the same pin out and are packaged in an RoHS compliant leadless 2 x 2mm DFN package. The bias current and gain can be set with external resistors allowing the user to customize the current consumption and gain value to fit the application.

The MAAL-010704 is a versatile broadband LNA which operates in the frequency range 0.1 to 3.5GHz and is packaged in SOT-363. Its bias current can also be set externally via the use of a resistor. The LNAs all feature an integrated active bias circuit allowing direct connection to 3V voltage supply while minimising variation over temperature and process.

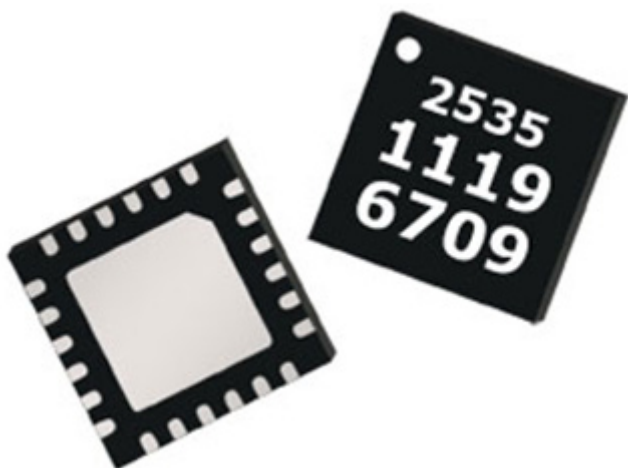
Production quantities and samples of MAAL-010705 and MAAL-010706 are available from stock. The MAAL-010704 will be available for sampling and production in summer 2011.

## TriQuint Introduces 10 – 12 GHz, 2W PA

The power amplifier is best suited for Point to Point radio and X-band communications.

TriQuint Semiconductor has revealed the TGA2535-SM, a high-linearity power amplifier designed to operate from 10 - 12 GHz.

Delivering 43dBm OIP3, the TGA2535-SM offers 25dB small signal gain, P1dB of 33dBm, and saturated power of 34.5dBm at a quiescent bias condition of 6V and 1300mA.



The input and output of the amplifier are matched to 50  $\Omega$  with a typical return loss of 15 dB. Packaged in a 5x5mm QFN, this amplifier is best suited for 10 and 11 GHz Point to Point radio and X-band communications and is pin compatible with the TGA2533-SM (12.7 - 15.4 GHz) amplifier.

Evaluation boards are available upon request.

## Microchip expands RF power amplifier portfolio

The new high-efficiency PA modules based on gallium indium phosphide / gallium arsenide HBT technology are ideal for embedded WLAN applications requiring small size, high efficiency and low battery-voltage operation.

Microchip Technology, a provider of microcontroller, analogue and Flash-IP solutions, has expanded its RF power amplifier portfolio, with the addition of the InGaP/GaAs based SST12LP17E and SST12LP18E devices.



The SST12LP17E is one of the smallest fully matched power amp in its class, requiring only one DC bypass capacitor to achieve optimum performance. The SST12LP18E is a lower-cost, lower-voltage alternative to Microchip's popular SST12LP14E power amp. It offers the lowest operating voltage of any Microchip RF power amp, while operating at -20 to +85 degrees Celsius.

The devices feature operating voltages as low as 2.7V, linear output power as high as 18.5 dBm at 2.5 % EVM using IEEE 802.11g OFDM 54 Mbps, and 23.5 dBm for IEEE 802.11b and a high power-added efficiency of up to 38 % for IEEE 802.11b.

The amps are offered in an 8-pin 2mm x 2mm x .45mm QFN package. They are ideal for embedded WLAN applications where small size, high efficiency and low-battery voltage operation are required, such as in the consumer electronics market, in cell

phones, game consoles, printers and tablets.

Many engineers are under pressure to extend battery life in their applications, and these new devices meet that demand by offering high power-added efficiency to reduce battery current drain, while their low operating voltages further extend battery life.

The SST12LP17E's matched input and output ports are easy to use and enable faster time-to-market. Additionally, this device requires no external RF matching components and requires only one external capacitor, taking up less board space.

"With the release of these new power amps, Microchip can now offer customers the same reliable operation over temperature with even lower operating voltages," said Daniel Chow, vice president of Microchip's Radio Frequency Division. "Combined with high-efficiency operation, these low-operating-voltage devices extend the operating battery life for applications in the consumer-electronics industry."

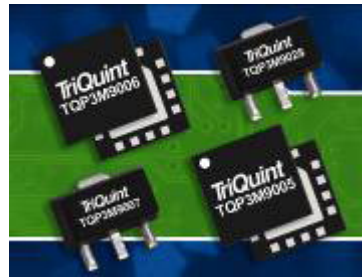
#### Packaging, Pricing and Availability

The new RF power amps are available in an 8-pin 2mm x 2mm x .45mm QFN package. The fully matched, low-power SST12LP17E is priced at \$0.48 each, in 10,000-unit quantities, while the low-power SST12LP18E is available for \$0.29 each, in 10,000-unit quantities. Samples are available today, and volume-production quantities can be ordered today.

## Flexible TriQuint broadband LNAs simplify RF design

The firm's new low noise amplifiers provide flexible, highly-efficient linear solutions for mobile network base stations, repeaters, point-to-point radios, test and other high-performance applications.

Global RF solutions supplier and technology innovator, TriQuint Semiconductor has released four new linear low noise amplifiers (LNAs) that eliminate matching components in a wide range of high-performance broadband applications including 3G/4G base station networks.



TriQuint is focused on bringing performance innovation to essential building blocks in the global network. This network is fraught with demand that continues to grow; according to 2011 Cisco Visual Networking Index, by 2015, the amount of mobile data traffic contributed by tablets alone is expected to equal that of mobile data traffic from all devices combined in 2010.

"Consumer demand for smartphones and tablets means more bandwidth through the network, which leads to the need for greater RF chain linearity", said Vice President Brian P. Balut. Our customers want to integrate functions for simplified design and greater efficiency. TriQuint solutions deliver by leveraging our unique technology portfolio and experience meeting worldwide network RF design requirements."

TriQuint's new low noise amplifiers are part of a wide-ranging portfolio created to provide flexible, highly-efficient linear solutions for broadband markets including mobile network base stations, repeaters, point-to-point radios, test and other high-performance applications.

Available in cost-effective standard surface-mount packages, these cascadable 50  $\Omega$  low noise amplifiers consume as little as 50 mA of electrical current and offer a variety of gain options from 15-19 dB; all operate on a single positive power supply (3V to 5V) and are unconditionally stable. TriQuint innovation includes these new products:

The TQP3M9005 has a low 0.8 dB noise figure and provides 15 dB gain at 1.9 GHz; P1dB RF output is 22.3 dBm; OIP3 is 34 dBm; electrical current consumption ( $I_{dd}$ ) is 50 mA.

The TQP3M9006 on the other hand has a low 1.0 dB noise figure and delivers 13.5 dB gain at 1.9 GHz; P1dB RF output is 22.4 dBm; OIP3 is 38.5 dBm; electrical current consumption ( $I_{dd}$ ) is 90 mA.

The TQP3M9007 gain block operates with a low 1.3 dB noise figure while delivering 13 dB gain at 1.9 GHz; P1dB RF output is 23.6 dBm; OIP3 is 41 dBm; electrical current consumption (I<sub>dd</sub>) is 125 mA.

The TQP3M9028 has a low 2.0 dB noise figure & provides flat gain ( $\pm 0.2$  dB) across a wide bandwidth; it delivers 14.7 dB gain at 1.9 GHz. The device's P1dB RF output power is 21 dBm; OIP3 is 40 dBm; electrical current consumption (I<sub>dd</sub>) is 85 mA.

Samples and evaluation boards are available and further details are available on TriQuint's website.

## Skyworks unveils first stand-alone products for 3G and LTE

The company's new gallium nitride detectors incorporate a high off-state impedance transceiver and minimise loading other detectors connected to the input line.

Skyworks has increased its product portfolio by adding high dynamic range power detectors for smart phones and datacards.

**Industry's First Stand-Alone,  
High-Dynamic Range Power Detectors  
for 3G and LTE Smart Phones and Datacards**



[www.skyworksinc.com](http://www.skyworksinc.com)

Skyworks' RF detectors address the market's

need for small, stand-alone solutions that are compatible with various baseband architectures and accommodate multiple 3G and LTE band combinations.

In addition, these devices have been designed to work with the SKY7770X and SKY7772X series of 3G and 4G power amplifiers to expand the compatibility of the integrated daisy chain coupler for the majority of basebands and transceivers.

The detectors' small size (1.2 mm x 1.5 mm) minimises board space requirements, while their higher dynamic range increases power control and improves total radiated power performance. Their low current consumption enables both longer standby and talk times, and their high off-state impedance level is particularly beneficial for today's demanding, high-end 3G smart phones.

"We are delighted to once again be at the forefront of technology innovation," said Gregory L. Waters, executive vice president and general manager of front-end solutions at Skyworks. "Skyworks' new power detectors are highly compatible with other solutions from our portfolio and allow us to offer our customers a full end-to-end solution for smart phones and data cards."

The SKY77002 is a stand-alone, high dynamic range power detector designed for use in smart phones and data cards in conjunction with Skyworks' power amplifiers in 3G and LTE applications. The detector is manufactured with Skyworks' GaN HBT process offering state-of-the-art reliability, temperature stability and ruggedness.

The SKY77002 detector circuit technology is optimally aligned for transceivers that require external detection for power control. Exceptional temperature and voltage compensation maintains accuracy over extreme operating conditions.

The detector presents high off-state impedance to the transceiver to minimise loading other detectors connected to the input line. The SKY77002 is packaged in the quad flat no-lead package and is fully compliant with current restriction of hazardous substances requirements.

Skyworks' new RF detectors are currently available.

## Integra unveils GaN-On-SiC devices for L-band avionics

The PN IGN0912L500 operates over the instantaneous bandwidth covering 960 GHz to 1215 GHz while the PN IGN1214L500 operates over 1.2 GHz to 1.4 GHz.

Integra Technologies, Inc. (ITI), a manufacturer of high power pulsed RF transistors, has developed two GaN on SiC technology devices targeted for the L-band market. The firm's RF design team have launched two new products characterised in the L-band; the IGN0912L500 and the IGN1214L500.



“Integra further solidifies its leadership position in high power pulsed RF transistors in the L-band radar market with these two new products.” says Jeff Burger, VP of Engineering and original founding member. “We continue to provide superior technology and excellent support to customers in our target market.”

Intended for commercial avionics applications including IFF, TACAN and DME applications, the PN IGN0912L500 operates over the instantaneous bandwidth covering 960 GHz to 1215 GHz in the L-band frequency range. Characterised with a pulse train of 444 x (7us ON, 6us OFF) with 22.7 % LTDC the IGN0912L500 typically supplies a minimum of 500 watts of peak output power. The single ended device provides over 12dB of gain and 62% efficiency. The device is housed in a ceramic flanged package providing excellent thermal advantages over plastic packaged devices.

The PN IGN1214L500 operates over the instantaneous bandwidth covering 1.2 GHz to 1.4 GHz in the L-band frequency range. Intended for L-band radar applications that device is characterized under 1ms and 10% duty cycle conditions and supplies more than 500W of output

power while providing 13dB of gain and 60% efficiency. The single ended device is housed in a ceramic flanged package providing excellent thermal advantages.

The IGN0912L500 and IGN1214L500 are available for sampling in Q3 2011.

## Integra introduces GaN-on-SiC broadband devices

The firm's gallium nitride on silicon carbide RF devices are targeting broadband applications ranging from 30-512MHz to 100-1000MHz.

Integra Technologies, Inc. (ITI), a manufacturer of high power pulsed RF transistors, has developed two GaN on SiC technology devices targeted for the military communication market.

Integra has launched several new products characterised for broadband applications ranging from 30-512MHz to 100-1000MHz.



“Integra is excited by this new technology that allows us to penetrate new markets involving CW applications such as Electronic Warfare (EW) for the defence industry.” says Brian D. Battaglia, Director of Sales and Marketing at Integra, describing the development effort. “GaN technology inherently is broadbandable with the inherent low parasitic capacitance. The GaN technology development effort is a direct result of customer requests for smaller, more efficient power devices with broadband performance.”

## About the IGN12UM21A1, IGN25UM21A1 and IGN50UM21A1

Intended for commercial broadband communication

applications including EW jammers, the devices provide a range of output power from 12W, 25W and 50W. The unmatched devices provide over 15dB of gain and 55% efficiency. The devices are housed in a small single ended ceramic flanged package providing excellent thermal advantages.

***About the IGN24UM22D1, IGN50UM22D1, IGN100UM22D1 and IGN200UM22D1***

Intended for commercial broadband communication applications including EW jammers, the unmatched devices provide a range of output power from 25W to over 200W in a dual lead push-pull configuration ceramic package.

***About the IGN25UM72A1, IGN50UM72A1, IGN100UM72A1 and IGN200UM72A1***

Intended for commercial broadband communication applications including EW jammers, the unmatched devices provide a range of output power from 25W to over 200W in a low parasitic wide lead ceramic package.

***Samples and Availability***

All IGNxxxxxxx devices are available for immediate sampling.

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## **RMD portfolio now features Ember ZigBee technology**

The RF6555 FEM developed with Ember is targeting smart energy applications.

RF Micro Devices, a global designer and manufacturer of high-performance RF components and compound semiconductor technologies, has unveiled the highly integrated RF6555 ZigBee front end module (FEM).

The RF6555 is optimised for smart energy/ advanced metering infrastructure (AMI) applications providing utilities and consumers more control over how they monitor and save energy. ZigBee is a global low power wireless networking standard for monitoring and control across a variety of applications, including energy management, safety and security, home automation, lighting, and electrical appliances.

The highly integrated RF6555 combines the power amplifier, harmonic transmit filtering, and low noise amplifier with bypass mode in a single 5mm x 5mm x 1mm package. It enables customers to shrink product footprint, accelerate product time-to-market, lower bill of material costs (BOM), and reduce power consumption for Smart Energy and Home Area Network (HAN) applications.

RFMD's RF6555 is ideally suited for battery operated smart grid and smart energy applications, such as smart meters, demand response, and HAN devices. The RF6555 is also suited for industrial and other wireless sensing and control applications requiring low power consumption, high performance, and proven reliability.

The RF6555 operates with Ember's EM351 and the EM357 in both system-on-chip (SoC) and network co-processor modes, as well as with Ember's EM250 SoC and EM260 network co-processor.

Bob Van Buskirk, president of RFMD's Multi-Market Products Group, said, "RFMD is pleased to collaborate with Ember to deliver highly integrated, high performance ZigBee solutions that reduce our customers' design cycle times, lower product BOM costs, and accelerate product time to market. Industry analysts forecast global smart energy deployments will continue to grow rapidly, with particular demand anticipated in low-power wireless networking technologies like ZigBee."

Ember's ZigBee networking systems which include chips, ZigBee protocol software and tools simplify the complexity of integrating embedded software, networking and RF for developing low power, wireless products in smart energy, connected home and other remote monitoring and control applications. Since its inception, Ember claims to have been the most deployed ZigBee platform in the market.

The EM300 Series is Ember's next-generation ZigBee chip family, and the world's foremost ARM Cortex-M3 based ZigBee SoC, packing the industry's highest wireless networking performance and application code space into the lowest power-consuming chip set. Ember says the EM250 and EM260 are the most deployed family of ZigBee semiconductors. Ember's ZigBee semiconductors are renowned for delivering excellent RF performance, sensitivity and transmit power for long



range, and 802.11 immunity.

## Skyworks secures SiGe Semiconductor acquisition

The innovator of high reliability analogue and mixed signal semiconductors has closed the acquisition of SiGe Semiconductor.

Skyworks Solutions has closed its acquisition of SiGe Semiconductor, a global supplier of radio frequency front-end solutions that are facilitating wireless multimedia across a wide range of applications.

The companies entered into a definitive agreement on May 17, 2011.

Per the terms of the agreement, Skyworks paid cash for the acquisition, which was approved by Skyworks' board and SiGe's board of directors and stockholders. Excluding any non-recurring acquisition related charges and amortisation of acquired intangibles, the acquisition is expected to be immediately accretive to non-GAAP earnings. More financial and accounting information will be provided during Skyworks' third fiscal quarter 2011 earnings conference call.

## Gore reduces cost of performing RF testing

The firm has added a rugged assembly specifically engineered for high throughput in production test applications in the wireless infrastructure market.

W. L. Gore & Associates, has added a rugged 18 GHz cable assembly to its GORE PHASEFLEX Microwave/RF Test Assemblies line.

This rugged cable assembly is specifically engineered for high throughput production test applications in the wireless infrastructure market. The increased durability of the assembly reduces total costs for testing because it lasts longer, decreasing the frequency of cable assembly replacements. Its stable performance ensures precise measurements and repeatability, which

reduces the risk of testing errors and the need for time-consuming troubleshooting and system calibration.

In addition, the ergonomic design of this cable assembly eliminates the need to use a torque wrench to connect and disconnect accurately, which increases throughput on the manufacturing line.



Gore's new rugged cable assembly maintains the same reliable performance as all GORE PHASEFLEX Microwave/RF Test Assemblies. The robust connectors on these assemblies minimise failure by incorporating maximum strain relief at the point where the cable and connector meet. The assembly's internally ruggedised construction is more durable, delivering crush resistance of 187 pounds per linear inch (85 kg/cm).

Available in 1.0 and 1.5 metre lengths with both SMA and N-type male connectors, this cable assembly is easier for the operator to use because it is smaller and lighter weight, and it can be connected and disconnected manually. These assemblies withstand 100,000 flexures at a minimum bend radius of one inch. Additionally, the crush, torque, and kink-resistant construction also results in longer service life.

Like all GORE PHASEFLEX Microwave/RF Test Assemblies, this cable assembly is engineered to withstand the frequent torque and bending that is common to testing environments on the manufacturing floor.

According to René Burba, GORE Microwave/RF Test Assemblies global product manager, cable assemblies have a significant impact on the total cost of testing in production environments. "Frequent troubleshooting, time-consuming recalibration, and retesting all have a direct impact on throughput in a manufacturing process, which in

turn significantly increase costs.”

“Also, having to use a torque wrench to connect and disconnect each product from the test equipment slows down the testing process,” Burba explained. “After several customers voiced concerns about these issues, we engineered a small, durable microwave/RF cable assembly that reduces costs in production testing by delivering consistently precise measurements in an easy-to-use construction. Using the same internally ruggedized construction as the high-frequency GORE PHASEFLEX Microwave/RF Test Assemblies enabled us to deliver the durability and reliable performance our customers expect.”

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## Lasers

### Emcore’s tunable XFP transceiver Telcordia qualified

The TXFP incorporates Emcore’s “ClearLight” External Cavity Laser (ECL) technology, which has been deployed in worldwide fibre networks by multiple carriers since 2004.

Provider of compound semiconductor-based components, subsystems and systems for the fibre optics and solar power markets, Emcore Corporation, has announced the successful Telcordia qualification and production release of its Tunable XFP (TXFP) transceiver.

“Our successful Telcordia GR-468 qualification and production release of the TXFP represents a major milestone for Emcore. We have demonstrated that our technology exceeds the mandated industry robustness and reliability standards,” stated Rob Stone, Director of Emcore’s Telecom Business Unit.

“We have been successful in our goal of enabling customers to replace their legacy 10Gb/s long-haul tunable interfaces with a more power and size efficient module, which improves both their operational and capital expenses.”

The Tunable XFP incorporates the latest “ClearLight” generation of the Emcore patented ECL technology, which has been deployed in worldwide fibre networks by multiple carriers since 2004. All active optical subcomponents are manufactured in-house, leveraging Emcore’s capability in wafer growth and fabrication. In addition to its current volume manufacturing location, Emcore will be adding additional capacity at its contract manufacturer over the second half of 2011.

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### Global SVP appointed at LED & laser developer Soraa

The U.S. developer of gallium nitride based LEDs and laser diode products has added former Hewlett Packard Imaging and Printing SVP Neal Woods to its team.

Soraa has appointed former Neal Woods as Senior Vice President of Worldwide Operations.

“Neal brings a breadth of operations management experience that is necessary to guide our organisation as we commercialise and begin volume production of truly disruptive products,” said Eric Kim, Chief Executive Officer. “We are very excited that he has chosen to join our world-class team and is committed to helping us fulfil the potential of our solid state illumination products,” he later added.

Woods, will be based at Soraa’s Fremont, California, headquarters and have responsibility for all aspects of manufacturing, supply chain operations, quality functions, and worldwide operations planning.

Woods has served as Senior Vice President of Operations for Hewlett-Packard’s Imaging & Printing Group since 2008. While at HP, Woods had ownership for IPG’s entire supply chain with \$30 billion in annual revenue. He was previously the VP of Global Manufacturing Operations for Cisco Systems.

## IPG Photonics' Gapontsev awarded for laser developments

Laser veteran Valentin Gapontsev has been honoured for his contributions to the field of lasers by the Russian government. His accolades include creating optical quantum generators on a fundamentally new technological platform. For his innovative designs and creation of high-quality fibre lasers, fibre optic backbone and local connection systems, Valentin Gapontsev has been awarded the 2010 Russian Federation National Award in Science and Technology.

Valentin Gapontsev was born on February 23, 1939 in Moscow. He holds a Ph.D. in Physical and Mathematical Sciences and has served as Department Chair at the Moscow Institute of Physics and Technology as well as the Worcester Polytechnic Institute (USA).

He is also the Director General of the IRE-Polus research and technology alliance, and the chair of the Board of Directors and Managing Director of the International research and technology corporation of IPG Photonics.

Gapontsev is a leading specialist in the field of laser physics and technology, fibre optic and opto-electronic technologies, and the founder of IPG Photonics research and production association, which develops and produces high-performance fibre lasers in Russia, Germany and the United States.

Gapontsev's work, which started about twenty years ago in Russia at IRE Polus research and technology association, is based on his idea of creating optical quantum generators on a fundamentally new technological platform.

His merits include his socio-educational work at laser technology science and education centres, where he has trained young Russian scientists and specialists in the field of laser physics.

## Dilas develops new high-efficiency 135W fibre-coupled laser

The 976nm laser has a specially tailored mini-bar architecture where the optical parameter of the emission fits into the 200  $\mu\text{m}$  fibre with the most simple and inexpensive optics.

Dilas, a manufacturer of diode lasers, has developed a state-of-the-art tailored mini-bar architecture for high brightness fibre-coupling which is capable of delivering 135 W output from a 200  $\mu\text{m}$  (NA 0.22) fibre at 976nm.

The tailored mini-bar architecture is an innovative breakthrough by Dilas and is specifically designed to realise high brightness output while maximising fibre-coupling efficiency for an overall high efficiency product. The tailored mini-bar was developed so that the optical parameter of the emission fit into the 200  $\mu\text{m}$  fibre with the most simple and inexpensive optics. This device is a monothical-multi single emitter source which takes advantage of handling multiple emitters during each individual manufacturing step to lower complexity and overall costs.

With scalable concepts further modules will soon be available, such as 976nm, 200W, 200 $\mu\text{m}$  and 976nm, 500W, 200 $\mu\text{m}$ .

These fibre-coupled, multi-bar modules are ideal for direct diode applications as well as for fibre and solid-state laser pumping.

# Solar

## CIGS and CdTe solar cell processing simplified by Singulus

The German based firm has introduced what it says is the first solar cell processing tool to clean rear side and edges in one step and has already received orders for several systems.

At the Intersolar industry exhibition in Munich, Singulus Technologies unveiled an enhanced wet-chemical processing system for thin film solar processing, the VITRUM GEN 2.

The firm will showcase the tool at the Intersolar North America from July 12 to 14 in the Moscone Centre in San Francisco (USA).



With its innovative Solar portfolio including new production and process concepts, the company underlines its leading position of its successful and high-efficiency solar production technologies. The US market launch of the VITRUM GEN 2 will be in the spotlight at the Singulus booth # 9335. The company says it offers substantial cost-saving potential and can easily be integrated into already existing manufacturing lines.

As part of the product family VITRUM GEN 2 the new processing machine simultaneously cleans back-sides and edges of thin film solar cells in a single working step. In addition to the automated process control, the new single-side etching tool protects the active layer by process hoods and performs pencil and rear side etching with brushes and chemicals.

Singulus Says the VITRUM GEN 2 is the only

tool on the market that cleans the rear side and the edges in one single step without any harm to the active layers. It is used for cleaning after oven processes as well as for etching of undesirable coatings on rear side and edges, for example CdTe or CdS.

The VITRUM GEN 2, developed by Singulus STANGL SOLAR in Fürstentfeldbruck (Germany), enables reducing the production steps for a-Si/ $\mu$ c-Si, CIGS and CdTe thin film solar cell and saves production costs.

The VITRUM GEN 2 provides the platform for several different process steps: During a CdTe manufacturing process it performs six steps, starting with glass washing, back side cleaning CdTe, CdCl<sub>2</sub> deposition using roller and salt removal to glass washing and developer. When producing a-Si/ $\mu$ c-Si and CIS/CIGS cells VITRUM features glass washing as well as TCO etching, KCN etching or NH<sub>3</sub> treatment respectively. In addition it also provides NP, DAE and EDTA etching for substrate sizes up to 2,200.

In comparison to dipping processes, the second generation VITRUM enables homogeneous, reliable and reproducible etching. It features further advantages in compared to a dipping bath such as a higher etch length and concentration, a higher process speed of up to 5 m/min and minimized carryover.

The new design of the VITRUM GEN 2 improves the accessibility for optimized maintenance work in a large installation cabinet. Piping is similar for all liquid circuits. It offers a high cycle rate and is also easy to integrate into existing production lines. The new VITRUM GEN 2 substantially reduces the investment outlay and very rapidly pays its way.

Orders for several systems were received straight after the new version's launch in Germany. The first of these innovative systems will be shipped before the end of June 2011. The new system concept was presented at the Intersolar industry exhibition in Munich, and met with considerable interest among customers. Further sales are consequently also under negotiation.

Singulus plans to further expand its activities in the segments Solar and Optical Disc. The goal is to attain a leading position in the silicon and thin film

solar technology and to maintain the technologic leadership in the Optical Disc segment.

## Tellurium price set to rocket and threaten CdTe solar industry

Reduced copper production coupled with the application of new alternative technologies of copper extraction are both affecting the availability of tellurium.

The tellurium market faces a whole host of challenges at the moment. Being a by-product of smelted copper it is highly dependent on the trends in this huge market.

As supply is tightening, the price for the material is skyrocketing. According to Merchant Research and Consulting, a number of market forecasts say that the price of tellurium is set to rise through the coming 2-3 years. Due to reduced copper production and novel alternatives to copper extraction, the availability of tellurium is declining.

On the positive side, there are a number of alternatives to tellurium which could help counteract supply shortages. On the other hand, end-use marketers report that none of these replacements are good enough.

The potential rise in demand for tellurium could well come from developments in thin film solar cell CdTe technology and affect its performance in the future.

## Inkjet printing could transform the CIGS industry

The low-cost technology of inkjet printing, which in recent decades has revolutionised home and small office printing, may soon offer similar benefits for the future of solar energy.

Engineers at Oregon State University say they have found a new way of creating CIGS solar devices using inkjet printing.

The scientists say their technology reduces raw

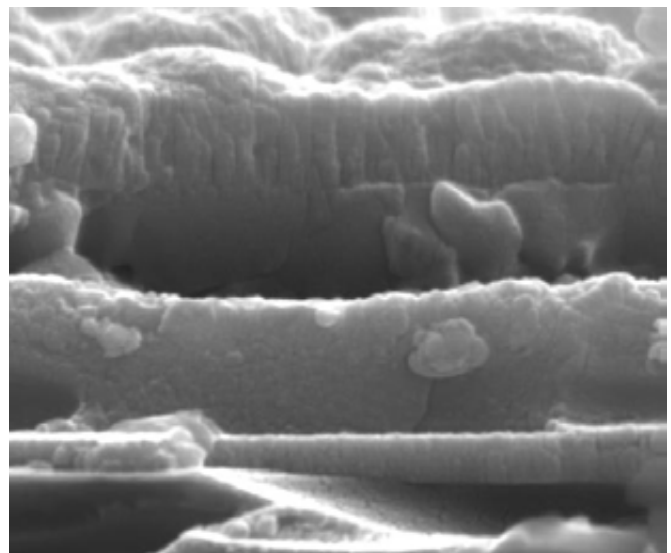
material waste by 90 % and will significantly lower the cost of producing solar energy cells with some very promising compounds. High performing, rapidly produced, ultra-low cost, thin film solar electronics should be possible, the scientists said. The findings have been published in the journal *Solar Energy Materials and Solar Cells* and the scientists have also applied for a patent for the technology.

Further research is needed to increase the efficiency of the cell, but the scientists say their work could lead to a whole new generation of solar energy technology.

“This is very promising and could be an important new technology to add to the solar energy field,” said Chih-hung Chang, from the OSU School of Chemical, Biological and Environmental Engineering. “Until now no one had been able to create working CIGS solar devices with inkjet technology.”

Part of the advantage of this approach, Chang said, is a dramatic reduction in wasted material. Instead of depositing chemical compounds on a substrate with a more expensive vapour phase deposition – wasting most of the material in the process – inkjet technology could be used to create precise patterning with very low waste.

“Some of the materials we want to work with for the most advanced solar cells, such as indium, are relatively expensive,” Chang said. “If that’s what you’re using you can’t really afford to waste it, and the inkjet approach almost eliminates the waste.”



**Figure: Scanning electron microscope, cross-sectional image showing the various compounds of a new chalcopyrite solar cell only a few microns thick, which can be created much less expensively with inkjet printing. (Image courtesy of Oregon State University)**

One of the most promising compounds and the focus of the current study is called chalcopyrite, or CIGS for the copper, indium, gallium and selenium elements of which it's composed. CIGS has extraordinary solar efficiency – a layer of chalcopyrite one or two microns thick has the ability to capture the energy from photons about as efficiently as a 50 µm layer made with silicon.

In the new findings, researchers were able to create an ink that could print chalcopyrite onto substrates with an inkjet approach, with a power conversion efficiency of about 5 %. The OSU researchers say that with continued research they should be able to achieve an efficiency of about 12 %, which would make a commercially viable solar cell.

In related work, being done in collaboration with Greg Herman, from the OSU chemical engineering department, the engineers are studying other compounds that might also be used with inkjet technology, and cost even less.

Some approaches to producing solar cells are time consuming, or require expensive vacuum systems or toxic chemicals. OSU experts are working to eliminate some of those roadblocks and create much less costly solar technology that is also more environmentally friendly. New jobs and industries in the Pacific Northwest could evolve from such initiatives, they say.

The scientists have also said that if costs can be reduced enough and other hurdles breached, it might even be possible to create solar cells that could be built directly into roofing materials, opening a huge new potential for solar energy.

“In summary, a simple, fast, and direct-write, solution-based deposition process is developed for the fabrication of high quality CIGS solar cells,” the researchers wrote in their conclusion. “Safe, cheap, and air-stable inks can be prepared easily by controlling the composition of low-cost metal salt precursors at a molecular level.”

This work was supported by the Daegu Gyeongbuk Institute of Science and Technology, the U.S. Department of Energy and OSU's University Venture Development Fund, which helps donors receive tax benefits while sponsoring projects that will bring new technology, jobs and economic growth to Oregon.

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## China's Guodian orders Aixtron tool for CPV solar cells

The 12x4-inch AIX 2600G3 IC reactor will be used for research and development.

Aixtron SE has an order from a new Chinese customer, Guodian International Economics & Trade Co. for an MOCVD system.

The contract is for one AIX 2600G3 IC reactor in a 12x4-inch configuration which will be dedicated to materials research for concentrator photovoltaic (CPV) solar cells.

Guodian placed the order in the fourth quarter of 2010 and the system will be delivered in the second quarter of 2011. The local Aixtron support team will install and commission the new reactor in a new clean-room at the GD Solar (JiangSu) Co., Ltd., Research Group.

Hong Song, Director of Solar Research Institute at Guodian, comments, “We look forward to the arrival of this powerful new addition to our capabilities in our research for high efficiency CPV solar cells. Already we have been shown how straightforward it is to achieve the requisite uniformity and run-to-run productivity characteristics with the AIX 2600G3 IC reactor.”

“It has become one of the most popular equipments of this type within the CPV industry and will serve us well for many years. Our technical team already has considerable experience with the Aixtron Planetary Reactor technology. They will work well together with the specialist company support staff so I am sure the system will not be long in making a strong contribution to our efforts.”

## Solar Frontier to install its largest CIS facility in North America for Juwi

The solar innovator says that achieving this milestone project immediately after opening its gigawatt-scale factory in Japan highlights the commercial attraction of its CIS modules.

Juwi Solar Inc. (JSI) has chosen Solar Frontier to supply 3.8 MW of solar modules for a project to be operated by a regulated utility in the Northeast United States.

When the project is completed by the end of 2011, it will be the largest Solar Frontier installation to date in North America, and one of the largest solar projects in the Northeast. It is the latest competitive win in Solar Frontier's global strategy to work with nationally and globally leading companies.



### **Solar Frontier: Kunitomi Plant (Miyazaki Plant 3)**

The solar panels will be produced at Solar Frontier's new gigawatt-scale Kunitomi plant in Miyazaki, Japan, using the firm's proprietary CIS technology. Solar Frontier says the Kunitomi factory is unparalleled for its combination of advanced automation, scale, and low-energy, end-to-end processing.

"Achieving this milestone project immediately after opening our gigawatt-scale factory in Japan highlights the commercial attraction of our CIS modules," said Greg Ashley, COO of Solar Frontier Americas. "Our work with JSI is a strong indicator of the growing confidence that global markets have in Solar Frontier's economical and ecological solar

panels."

"JSI provides the most competitive utility-scale solar developments for our clients," said Michael Martin, managing director at JSI, "and Solar Frontier's CIS technology will allow us to deliver a low cost of energy and long-term, reliable energy production for this project and its long-term owner."

## Amonix III-V solar plant receives \$17.9 million in funding

The manufacturing facility for gallium arsenide based multi-junction photovoltaic systems is being financed by a combination of \$5 million in Recovery Act tax credits and \$12 million in private funding.

U.S. Department of Energy (DOE) Secretary Steven Chu visited the new Amonix production facility last week to see first-hand how the Obama Administration's renewable energy policies are turning into economic activity and energy independence.

Chu toured the North Las Vegas facility where Amonix produces concentrated photovoltaic CPV solar power systems for utility-scale power plants, such as the 2 MW power plant in Tucson, Arizona, that showcases one of the world's most efficient solar technologies. After the tour, Chu led a round table discussion with solar industry business leaders at the Amonix facility.

Chu was a co-winner of the Nobel Prize for Physics in 1997 and former director of the DOE's Lawrence Berkeley National Lab, where he led the lab in pursuit of alternative and renewable energy technologies.

"Secretary Chu has a longstanding interest in renewable energy sources. It's an honour to have him visit Amonix to take a closer look at our state-of-the-art manufacturing facility," said Amonix CEO Brian Robertson. "His visit emphasises the reality that utility-scale solar energy is an economically viable reality."

Renewable energy development is a cornerstone of President Barack Obama's long-term economic

strategy. The DOE also recently announced the SunShot Initiative in an effort to cut the cost of solar energy by 75 % by 2020. The 2009 American Recovery and Reinvestment Act included \$70 billion in renewable energy and energy efficiency measures.

The Amonix facility in North Las Vegas was financed with a \$5.9 million investment tax credit from the Recovery Act awarded in 2010 and \$12 million in private capital. The facility will bring \$560 million of overall economic impact, including more than 300 private-sector clean energy jobs, to Southern Nevada in the next five years, according to the Nevada Development Authority.

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## OPEL Solar celebrates its GaAs POET and solar technologies at AGM

At this year's meeting, the firm saluted its gallium arsenide POET technology, which is focused on increasing the speed and decreasing the energy usage in the general purpose server, desktop and laptop microprocessor markets for consumer applications.

OPEL Solar International, a global supplier of high concentration photovoltaic (HCPV) solar panels announced that at its Annual General and Special Meeting (AGM) which took place on June 21, 2011, that the shareholders approved the election of the following nominees to the Board of Directors:

Tristram E. Collins  
Christopher Grasset  
Lawrence R. Kunkel - Chairman  
Samuel Peralta  
Leon M. Pierhal

In a subsequent Board Meeting that followed the AGM, the Board reappointed the following executive officers for the Company:

Leon M. Pierhal, President & Chief Executive Officer  
Michael McCoy, Treasurer & Chief Financial Officer  
Francisco Middleton, Chief Operating Officer and Vice President of Marketing  
Javier Berrios, Vice President of Engineering  
Patricia Venneri Agudow, Vice President of Administration, Public & Government Relations

Michel Lafrance, Corporate Secretary

The shareholders also approved the re-appointment of Marcum LLP, Accountants & Advisors, of New Haven, Connecticut, as the auditors of the Company for the ensuing year.

In addition to the usual matters determined at the AGM, the shareholders approved the Amendment to the Company's Stock Option Plan and a special resolution to change the name of the Company to 'OPEL Technologies Inc.'.

The purpose of the name change was to reflect a more descriptive name to encompass the broadening universe that is OPEL today. The Company has two distinct divisions - OPEL Solar, Inc. and ODIS Inc., the inventor of the GaAs solar POET technology.

OPEL Solar and ODIS product displays were set up at the AGM providing the shareholders a view of the technology advancements of the Company's products. Shareholders were presented with an update by Leon M. Pierhal, the Chief Executive Officer of OPEL, on the status the Company from management's perspective.

Pierhal described management's vision and the achievements successfully attained from the Company's repositioning effort in the last year that was undertaken to with the intent of creating a successful future and revenue outlook. Pierhal took the shareholders through the entire cycle from initial order through installation on the solar business side for a better understanding of the revenue recognition time sequences.

Francisco Middleton, the Chief Operating Officer & Vice-President of Marketing for the Company's solar products also made a presentation to the shareholders. Middleton emphasised that all of the advancements in the OPEL Solar product line were designed to yield cost savings for customers along with increased electric power production per area of land.

Next, supported by Geoff Taylor, the architect of POET who was present, Pierhal showcased OPEL's affiliated company, ODIS, providing the audience a better understanding of the business and potential contribution ODIS will have on shareholder value and the technological progress made since the



valuation of the POET technology and, most recently, its independent technological validation completed by BAE Systems of a working transistor.

The development of this product is focused currently on increasing the speed and decreasing the energy usage in the general purpose server, desktop and laptop microprocessor markets for consumer applications. Also it can be used in smart phone and computer tablet devices.

Following the AGM, the directors granted incentive stock options to the newly-elected directors of the Company to purchase up to an aggregate of 200,000 common shares, representing 0.2% of the outstanding voting shares of the Company. The stock options are exercisable at a price of CA\$0.92 per share, expiring June 21, 2021. The exercise price was the closing price on the day prior to the grant, being June 20, 2011.

There are currently 7,854,250 options outstanding and 92,908,421 voting shares outstanding. The options will vest and be exercisable on the basis of 25% on the date of grant and 25% every six months thereafter. These options were granted subject to provisions of the Company's stock option plan which was approved by shareholders at the AGM, and are subject to the TSX Venture Exchange policies and the applicable securities laws.

## Helmholtz and NREL to collaborate on solar research

Scientists will measure the performance, reliability and thermal stability of different types of solar cells, including CIGS and use electroluminescence, photoluminescence and thermography in characterisation.

German and American researchers will work together more closely on solar energy development as a result of a Memo of Understanding (MOU) between the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) and the German Helmholtz Association.

The MOU identifies several key solar energy topics to explore for joint research cooperation. Scientists from the two countries will cooperate to synthesise and characterise novel materials that are

candidates for more efficient solar cells and solar fuels, including CIGS.

They'll also develop and use fast imaging techniques to help characterise thin-film materials on the micrometre to nanometre scale, and to characterise in situ growth processes.

They will seek a fundamental understanding of grain boundary/interface passivation in thin-film silicon and search for the potential and limits of wide band-gap thin-film solar cells. Thin films, made of copper, indium, gallium, selenium (CIGS) and other emerging materials, could potentially replace silicon as the most efficient materials in next-generation thin-film solar arrays.

To measure performance and reliability of solar cells and modules, the scientists will use electroluminescence, photoluminescence and thermography. They will also investigate the stability of solar cells by subjecting them to high temperatures and light exposures.

New device structures and lower cost catalysts will also be investigated for the generation of hydrogen in photocatalytic solar fuel generation.



### **Contract signing in Berlin**

The MOU was signed in Berlin by NREL Director Dan Arvizu, and leaders of three research institutes within the German Helmholtz Association – the Research Centre Jülich (FZ Jülich), the Helmholtz Centre Berlin (HZB), and the German Aerospace Centre (DLR).

“This agreement promises to advance the state of knowledge and the development of new materials and technologies that will form the basis of next-generation solar cells and solar fuels,” NREL

Director Arvizu said.

In one area, the work builds on an MOU NREL signed two years ago with one of the German organisations, DLR, which involved developing standard test methods to quantitatively assess the reflectance and durability of solar mirrors used for concentrating solar power (CSP) systems. The MOU also called for round robin testing of commercial reflector samples and commercial parabolic trough receivers. In the new MOU, this work will be extended to understanding fundamental mechanisms for soiling rates on CSP mirrors.

Overall, the new MOU sets the basis for collaboration on basic and applied research issues to advance the next generation of solar cells for electricity and solar fuel production. It also addresses the improvement of the performance of concentrating solar thermal power systems.

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## Sono-Tek unveils deposition system for thin film solar cells

The system is ideal for applying buffer layers onto thin-film solar cells (CdS) and active layers such as CIGS and CdTe.

Sono-Tek Corporation based in Milton NY, USA plans to exhibit at SemiCon-Intersolar 2011 July 12-14 in San Francisco, CA in booth #2631 (South Hall).

The firm will display its ExactaCoat Tabletop Coating System along with working demonstrations of its patented precision ultrasonic spray nozzles.



The ExactaCoat Tabletop Coating System is a fully enclosed programmable XYZ motion system

designed for depositing uniform thin-film coatings for electronics and solar applications, including photoresist deposition and various thin-film solar cell coatings.

Particularly suitable for deep well topography coatings, the ExactaCoat is a full coating solution for R&D and low-volume production applications such as depositing photoresist onto wafers and MEMs. The system is also ideal for applying buffer layers onto thin-film solar cells (CdS), active layers such as (CIGS, CdTe), phosphoric doping, organic solar cell coatings, and fluxing of solder bus lines.

The ExactaCoat can be tailored with a number of customisable options including nozzle tilt, dual nozzle, camera, laser pointer, low oxygen atmosphere, and rod coating attachment. Additionally, the ExactaCoat can be configured with any of Sono-Tek's precision ultrasonic atomising nozzles to produce highly uniform targeted thin-film coatings with very little overspray and exceptional non-clogging repeatable performance with significant savings in spray materials, maintenance and cleanup costs.

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## Alta Devices advances solar efficiency basics

The company says that extraction of light generated inside its single junction gallium arsenide based solar devices is critical.

When the scientists at Alta Devices began seeing their solar devices achieve efficiency results beyond what was previously thought possible, they realised that something scientifically important was going on. Their conclusion was that a great solar cell also emits light and collecting that light increases cell performance.

Previously, the efficiency of a solar device was understood to be based in part on the amount of external light that could be captured and retained, but this understanding didn't account for the necessity to maximise the number of photons being generated within the device itself in order to achieve even higher efficiencies. This discovery has the potential to change expectations for the future of solar devices.

At the PVSC37 conference taking place this week in Seattle, Alta will disclose details of how it achieved record cell efficiencies of 27.6% late last year, as well as its best result to date of 28.2%. Both results have been verified by the National Renewable Energy Laboratory (NREL).

These cell efficiencies exceed the previous highest demonstrated efficiency of 26.4%. The theoretical maximum solar cell efficiency limit for a single junction GaAs based device has been shown to be 33.5% (called the "Shockley-Queisser Limit"), but efforts to attain this efficiency have been slow in coming.

"Up until now it was understood that to increase the current from our best solar materials, we had to find ways to get the material to absorb more light," said Alta co-founder Eli Yablonovitch, director of the NSF Centre for Energy Efficient Electronics Science and professor at the University of California at Berkeley.

"But, the voltage is a different story. It was not recognised that to maximise the voltage, we needed the material to generate more photons inside the solar cell. Counter-intuitively, efficient light emission is the key for these high efficiencies." At the conference, Yablonovitch, will present a description and analysis of this scientific discovery.

"In 2009, our team came to me with an aggressive timeline for solar cell efficiency advances, but with a few caveats: they were butting up against what appeared to be entrenched, practical limits," said Christopher Norris, president and CEO of Alta. "Nevertheless, over the past two years, the team has succeeded in meeting each of its milestones." According to Norris, Alta's scientists and engineers have achieved new cell efficiency improvements about once every two months.

"We are committed to using new scientific understanding, such as internal light generation and extraction, to push the limits of solar cell and module efficiencies while simultaneously driving production costs down through other important developments," Norris stated. "The goal of achieving the \$1 per installed watt target set by the Department of Energy has energised our entire company."

The Alta paper being presented at the PVSC37 conference is entitled "27.6% Conversion Efficiency,

A New Record For Single-Junction Solar Cells Under 1 Sun Illumination." [A link to the abstract is: [http://ieeepvsc.org/ePVSC/planner\\_public/abstract\\_popup.php?abstractno=300](http://ieeepvsc.org/ePVSC/planner_public/abstract_popup.php?abstractno=300)]. It will feature Alta's Brendan Kayes, who will explain how Alta achieved its results.

The title of Yablonovitch's paper is "The Physics Required to Approach the Shockley-Queisser Limit", and concentrates on the scientific discovery itself. [A link to the abstract is [http://ieeepvsc.org/ePVSC/planner\\_public/abstract\\_popup.php?abstractno=1102](http://ieeepvsc.org/ePVSC/planner_public/abstract_popup.php?abstractno=1102)].

Harry Atwater, Alta co-founder and Director of the Energy Frontier Research Centre on Light-Matter Interactions as well as Director of the Resnick Institute for Science, Energy and Sustainability at CalTech, will give a plenary talk in this conference entitled "Paths to High Efficiency Low Cost Photovoltaics" [A link to the abstract is [http://ieeepvsc.org/ePVSC/planner\\_public/abstract\\_popup.php?abstractno=1112](http://ieeepvsc.org/ePVSC/planner_public/abstract_popup.php?abstractno=1112)].

Said Atwater, "The energy conversion efficiency results being achieved by Alta, in combination with other manufacturing and form factor advances, will enable new ways to deploy solar without the economic compromises of other technologies."

Alta Devices was founded in 2007 and is focused on improving the production economics of high efficiency solar PV applications. Alta is currently a development stage company and has received venture capital funding from August Capital, Kleiner Perkins Caufield & Byers, Crosslink Capital, AIMCo and others. The company is based in Santa Clara, California.

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## GT Solar completes expansion of sapphire fab

The new facility expects to ramp up to volume production in less than eight months.

GT Solar International, a provider of sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets has celebrated the grand opening of its new state-of-the-art sapphire production facility located in Salem, Massachusetts.

The opening of the newly expanded plant concludes a project that began in the fall of 2010 that triples the sapphire production capacity in its Salem facility. GT invested \$27 million to create a high volume production facility to provide sapphire material for the fast-growing LED market and other industrial material industries.



GT Solar's expanded sapphire production facility in Salem, Massachusetts, opened in June for production

"The investment in this new plant is a testament to our belief in the growth of the sapphire market and our ability to capture a leadership position in this industry," said Tom Gutierrez, GT Solar's president and CEO. "We've leveraged forty years of crystal growth expertise from Crystal Systems and combined it with GT's successful track record of rapid scale-up of commercial crystalline growth technology to create a new state-of-the-art sapphire manufacturing facility capable of producing predictable and repeatable high quality sapphire crystal run after run."

"We are extremely proud of having constructed our world-class manufacturing facility in such a short amount of time, and it is a testament to the dedication and hard work of the team that drove the planning and construction," said Cheryl Diuguid, vice president and general manager of GT's sapphire equipment and materials business unit.

"We are also proud to be able to generate high quality employment opportunities to the people of Salem and throughout the North Shore area. Since the completion of the acquisition of Crystal Systems last summer, we have doubled our employment within our business unit. Our sapphire business is

growing, and at a time of high unemployment for so many Americans, we are pleased that we are in a position to offer high quality manufacturing employment opportunities."

"Governor Patrick has focussed on stimulating economic activity in our Gateway Cities and creating jobs in innovation sectors like clean energy and advanced manufacturing. This expansion project combines all three of those important elements," said Secretary of Housing & Economic Development Greg Bialecki. "On behalf of the Patrick-Murray Administration, I congratulate GT Solar on their significant growth and thank them for their commitment to doing business in Massachusetts."

GT Solar acquired sapphire producer Crystal Systems in July 2010. Construction of the new 20,000 square foot manufacturing facility began in October and is ramping to full volume production over the next several months. The facility is a highly efficient manufacturing environment utilizing the latest production control technology to produce high-yielding boules of consistent size and quality.

The boules produce cores of two, four, six or eight-inch and beyond for downstream processing into high quality wafers for the LED market and other material such as large diameter A and C-axis windows for other industrial markets. The company's crystal growth experts also use the manufacturing facility as a research and development centre – testing advancements in process technology and commercialising process knowledge and know-how that deliver value to its list of ASF equipment customers.

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## Soitec and Schneider to integrate CPV technology in Morocco

Soitec will provide its III-V multi-junction Concentrix solar cells under the partnership in the Mediterranean Solar Plan.

Solar provider Soitec and Schneider Electric, a specialist in energy management, have signed a memorandum of understanding with Masen (Moroccan Agency for Solar Energy).

Masen is a lead player in the Moroccan Solar Plan and plans to integrate Soitec's III-V multi-junction Concentrix solar cell technology into Morocco.

Completion of the project will create a CPV segment serving domestic needs and generating exports of electricity and power plants, thereby contributing to a strategy of controlled energy costs over the long term for Morocco and to the achievement of a plan to build a manufacturing facility in the country. The Franco-Moroccan initiative marks the first utility-scale project under the Mediterranean Solar Plan in one of the 43 member countries of the Union for the Mediterranean (UfM), a partnership uniting Europe with countries in the Mediterranean Basin.

The memorandum of understanding between Soitec, Schneider Electric and Masen is part of the Moroccan Solar Plan. It is supported jointly by the Moroccan and French governments and has four key components.

The research & development initiative involves joint work on CPV R&D subjects for technology sharing, based in part on provision of a demonstrator by Soitec. Secondly, the consortium plan an industrial integration, through development of a local supply chain for CPV system components, including trackers, and opportunity analysis on setting up a CPV modules assembling factory in Morocco.

Training involving transfer of Soitec's CPV know-how to Masen, and joint analysis by all stakeholders on the feasibility of setting up a master's syllabus on management of renewable energies in partnership with Moroccan universities will also take place.

Finally, two Moroccan CPV pilot projects of 5 MW each, with two different generation systems will be set up and all or part of the electricity generated will be exported under the MSP. The first pilot project, scheduled for completion in early 2012, involves development, on the technology platform at Masen's Ouarzazate site, of a 5 MW demonstration unit twinned with Soitec and Schneider Electric facilities in France. A joint basis for research & development will thus be established, facilitating a strategy of knowledge sharing between the partners. The second project involves construction of another 5 MW section using next-generation modules at a site to be approved by the partners.

"This multidimensional pilot partnership on CPV, a

promising solar power technology, fits in perfectly with Masen's vision on integrated development of the Moroccan Solar Plan. This kind of project will undoubtedly be having a positive impact on the sector, and on regional integration, which we're eager to participate in, alongside organisations like Soitec and Schneider Electric, which share our aims," remarked Masen chairman Mustapha Bakkoury.

"We are delighted to be working together with Schneider Electric and Masen on this major initiative in the Mediterranean Basin and France as part of this program to develop the production of solar-generated electricity. Our technology is in the process of being adopted on a large scale in the San Diego region of the United States, where climate conditions are similar and where our technology has proven to be the best suited to regions with abundant sunshine. We are working very closely alongside Masen on rollout of solar power plants in Morocco and to promote the economic development of the region", commented André-Jacques Auberton-Hervé, Soitec's chairman and chief executive officer.

"Schneider Electric has a sixty-year history of working in Morocco, and is delighted to be contributing to the Moroccan Solar Plan. We'll be working jointly with Soitec to address the needs expressed by Masen," noted Laurent Bataille, Schneider Electric's renewable energies director. "Schneider Electric will be harnessing its international expertise in intelligent energy management systems for solar power plants, and its unique know-how in access to renewable energies, to ensure that this Moroccan cooperative project is a resounding industrial, technological, innovative and human success."

Concentrix technology has been optimised for high-capacity industrial-scale solar power plants. The technology is ideal for use in areas with high direct normal irradiance, such as Saharan Africa, southern Africa, the Middle East, Australia, and the Southern and Southwestern United States.

Soitec solar plants have already been built in more than ten countries, including the US Sun Belt, where their two-axis sun-tracking system delivers record yields. Soitec says its Concentrix technology is the most competitive solution on the market, offers the best design for use in sunny regions, is

environmentally friendly and delivers the highest efficiencies.

Schneider Electric's renewable energies access offering covers all needs, from electricity generation through to network connection. It includes feasibility studies, power distribution architecture design, the supply of all types of equipment including junction boxes, inverters, prefabricated transformer substations, MV transformer substations, the supervision system and video surveillance, as well as operation and maintenance of the system.

In taking full responsibility for system operation and maintenance, Schneider Electric assures the operator of installation availability. Specifically, Schneider Electric provides preventive maintenance to forestall dysfunction, and implements control devices at strategic points throughout the system. This equipment outputs information on system operation (inverter and generator module status, deviation warnings with alarm signals, etc.), enabling the operator to take realtime action to remedy fault conditions and promptly resume normal system operation.

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## Tegal announces 1-for-5 reverse stock split

The Board's decision to implement the reverse stock split was made to help Tegal maintain its Nasdaq listing as well as to increase the share price to make our stock more attractive to investors.

LED and solar cell innovator Tegal Corporation has announced that its Board of Directors, as authorised by Tegal stockholders, will implement a one-for-five reverse stock split of its common stock.

The Company will file a charter amendment to implement the reverse stock split, which is expected to become effective on June 15, 2011. The reverse stock split was authorized by Tegal's stockholders at a special meeting on June 15, 2011.

"The Tegal Board has given considerable thought to the decision of a reverse stock split," said Thomas Mika, Chairman, President and CEO of Tegal. "The Board's decision to implement the reverse stock split was made to help Tegal maintain its Nasdaq listing as well as to increase the share price to

make our stock more attractive to investors." The bid price of the Company's common stock must close at \$1.00 or higher for ten consecutive business days prior to July 5, 2011 in order for the Company to maintain its listing on the Nasdaq Capital Market.

As a result of the reverse stock split, each five (5) outstanding shares of pre-split common stock will be automatically combined into one (1) share of post-split common stock. No fractional shares will be issued. Instead, the Company will pay cash in an amount equal to such fraction multiplied by the average of the high and low trading prices on The Nasdaq Capital Market of the Company's common stock for the five previous trading days (as adjusted to give effect to the reverse split).

The Company's registered stockholders will receive instructions from Registrar and Transfer Company, the Company's transfer agent, regarding the exchange of outstanding pre-split stock certificates for certificates representing post-split shares of common stock. Upon submission of the necessary documentation by a stockholder of record to the Company's transfer agent pursuant to such instructions, the transfer agent will distribute to such stockholder a new certificate together with a cash payment in lieu of fractional shares. Proportional adjustments will be made to the Company's outstanding stock warrants, stock options and other equity awards and to the Company's equity compensation plans to reflect the reverse stock split.

The Company expects that trading of the Company's common stock on the Nasdaq Capital Market on a split-adjusted basis will begin at the opening of trading on June 17, 2011. The Company's common stock will continue to trade on the Nasdaq Capital Market under the symbol "TGAL" and will include the letter "D" appended to the trading symbol for a period of 20 trading days to indicate that the reverse stock split has occurred, after which time it will revert to trading under the symbol "TGAL."

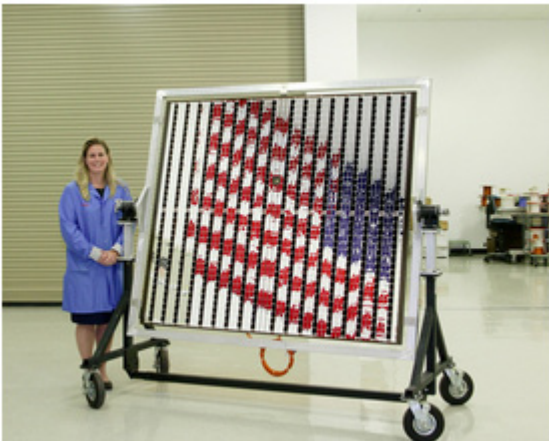
Since its founding in 1972, Tegal Corporation has been dedicated to the development and application of emerging technologies such as LEDs, filtering and sensing devices for advanced smart phones and most recently, solar cells. The company is now evaluating opportunities for partnerships with other

diversified technology-based companies.

## Northrop GaAs solar panels assist NASA spacecraft around Mercury

The MESSENGER probe which incorporates gallium arsenide multi-junction solar cells is able to operate in extreme temperatures and will orbit 730 times around Mercury for a year.

Key technologies and hardware developed by Northrop Grumman Corporation gave the first spacecraft to orbit Mercury a power system that works to its maximum even in the searing heat that surrounds the planet closest to the sun.



***The solar cells and electrical harness for the MESSENGER spacecraft were built by Northrop Grumman***

The solar array on NASA's MErcury Surface, Space ENvironment, GEOchemistry, and Ranging (MESSENGER) spacecraft features advanced triple-junction GaAs solar cells and an electrical harness developed and qualified for this mission by Northrop Grumman Aerospace Systems.

The company also perfected a fully robotic welding process to assemble the photovoltaic cells before they were bonded to the solar array panel. The work was done under the pressure of meeting a launch window that was so tight that missing it would have meant a year-long wait until the next launch opportunity.

"When it launched in 2004, MESSENGER was the first Northrop Grumman program to use these advanced solar cells, electrical designs and welding processes that now are the baseline for all our major programs, including the James Webb Space Telescope and the Defence Weather Satellite System," said Tim Frei, vice president, system enhancements and product applications for Northrop Grumman Aerospace Systems. "Our depth of talent and the processes we developed enabled us to perfect the technology needed for spacecraft to perform under very harsh conditions."

Solar array performance is critical – if it fails, so does the mission. Two single-sided solar panels are MESSENGER's main source of electrical power. They are two-thirds mirrors and one-third solar cells. The mirrors reflect the sun's energy and keep the panels cooler. The panels also rotate away from the sun to get the required power and maintain an operating temperature of about 300 F.

Since its launch, MESSENGER has completed one swing past Earth, two Venus flybys and three Mercury flybys. By using the gravity of each planet to gain speed and alter its trajectory, MESSENGER was able to conserve the fuel it will need during its mission orbiting a planet that is only 29 million miles from the sun, about two thirds closer to the sun than Earth. At Mercury's equator, surface temperatures become hot enough to melt lead. The spacecraft's fast, elliptical orbit allows it to approach Mercury, gather data and swing out far into space to cool down.

MESSENGER is a NASA Discovery program spacecraft designed and built by the Johns Hopkins University Applied Physics Laboratory, Laurel, Md. The probe completed a six-and-a-half-year journey prior to its March 17 insertion into orbit around the planet closest to our sun. MESSENGER will orbit 730 times around Mercury for a year.

# Power Electronics

## New spin out to develop next generation of SiC semiconductors

The UK based firm, which was launched last week, aims to revolutionise silicon carbide power devices and has received investments of over £150,000.

Anvil Semiconductors, created by Warwick University's technology commercialisation company, Warwick Ventures, aims to develop smaller, more efficient power converters using innovative SiC power semiconductor switches.



**Figure: from L-R Peter Ward, CEO, Anvil Semiconductors; Phil Mawby, University of Warwick School of Engineering; Kevin Marks, Business Development Manager at Warwick Ventures; Stuart LeCornu, lead investor from Minerva.**

The company has received an investment of £25,000 from Midven's Early Advantage Fund, as

well as £125,000 investment from private investors Minerva, the Midlands network of entrepreneurs, venturers and angels. Since investment, the company has also been awarded a prestigious R&D grant from the Technology Strategy Board.

SiC devices are able to withstand higher voltages and currents and are 10 times faster than traditional silicon devices. However, they are also currently 10 times more expensive to produce, a factor which has prevented the material being widely adopted.

The semiconductors being developed by Anvil are expected to enable significant improvements in operating efficiency, size and cost when used in power converters such as those found in electric cars, photovoltaic cells and wind turbines. The market for these devices is estimated at \$25bn worldwide.

Anvil's technology has been developed by Peter Ward (Anvil CEO) and Phil Mawby's team at the University of Warwick's School of Engineering. Anvil will be using five patents licensed from the University to refine and commercialise the devices. The company will also be the first private company to use the £10m semiconductor clean room funded through the Science City Research Collaboration.

Mawby says, "Semiconductors have such a vast array of uses in electronic equipment. The technological advances we are introducing to their design have huge potential to reduce our overall energy consumption, through improving the efficiency of electric cars, renewable power generation and the Grid. Now Anvil gives us a route to get this technology to market."

Warwick Ventures' Business Development Manager, Kevin Marks adds, "Two factors have stopped the introduction of silicon carbide into the market place: the cost of the substrate and the production of a high quality switch. Anvil's technology offers potential solutions to both these barriers".

Andrew Muir, a director of Midven and Investment Director of the Early Advantage Fund, says, "Anvil builds on the impressive research track record of Phil Mawby and the substantial investment made in the Science City Cleanroom. Our investment, alongside the Minerva business angels, will support the progress of this business, which has great growth potential and the ability to become a world



leader”.

Anvil will be launching a further funding round later this year as the company moves towards producing prototype devices.

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## Siltronic jumps onboard imec's GaN-on-silicon research train

The organisations will jointly develop technology for next-generation gallium nitride power semiconductors and LEDs on 200 mm diameter silicon substrates. They aim to enhance properties and reduced production costs.

Siltronic AG and the Belgian nano-electronics research institute imec have concluded an agreement to collaborate on the development of silicon wafers with a GaN layer.

This partnership will be part of imec's GaN-on-silicon industrial affiliation program (IIAP) and aims to enable production of LEDs and next generation power semiconductors on 200 mm silicon wafers.

GaN is a very promising material; it combines superior electron mobility, high breakdown voltage and good thermal conductivity and is particularly suitable for optoelectronics and advanced power semiconductors.

These are used, for example, in wind power turbines, solar power systems, electric vehicles and energy-saving kitchen appliances. In comparison with conventional, silicon-based applications, structures with GaN/(Al)GaN layers evidence a very efficient switching behaviour.

However, GaN technology still needs further refinement to also be economically competitive. To achieve this, inexpensive and efficient production methods for epitaxial deposition of GaN/(Al)GaN structures on larger-diameter silicon wafers are very promising.

As a global provider of silicon wafers, Siltronic AG can draw on decades of experience in epitaxial deposition of materials on silicon substrates. Imec is a pioneer in the area of GaN deposition on silicon

substrates with diameters of 2-6 inches. Economies of scale in the production of 200 mm wafers could significantly reduce the manufacturing costs for GaN-based LEDs and power semiconductors.

In addition to Siltronic, other participants such as integrated device manufacturers, foundries, silicon compound producers and substrate manufacturers are also involved in this multinational research platform. Siltronic will actively use the facilities and technical resources of imec in Leuven, Belgium.

This coordinated on-site approach enables inter-company collaboration between all involved partners, while at the same time providing very early access to process and equipment technology for the next generation of LEDs and power semiconductors.

“We are delighted to welcome Siltronic into our research network,” said Rudi Cartuyvels, Vice President R&D Business Lines at imec. “Siltronic has an enormous amount of experience in epitaxial deposition on silicon wafers that will increase the momentum of our GaN program to deliver a manufacturable GaN technology on 200 mm silicon wafers.”

“Siltronic is already the world market leader for silicon wafers used to manufacture discrete and integrated power devices,” points out Rüdiger Schmolke, Senior Vice President Technology at Siltronic. “This research project will help us to further consolidate our leadership position in this market.”

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## Renesas reveals 1 GHz GaN PA for CATV applications

The gallium nitride power amplifier grown on a silicon substrate offers approximately double the output performance of similar gallium arsenide based products.

Renesas Electronics has announced the development of the MC-7802, a GaN power amplifier module for 1GHz CATV (cable television) systems.

Designed for use as a power amplifier for applications such as trunk amplifiers for CATV

systems, the MC-7802 achieves high output power and low distortion that are among the best in the industry today.



### ***Renesas GaN Power Amplifier Module for CATV Applications Using the 1 GHz Band, the MC-7802***

The MC-7802 module incorporates newly-developed GaN FETs that can be operated at higher frequencies and deliver higher output power than existing Renesas Electronics power amplifier module products based on GaAs. The MC-7802 provides approximately double the output performance while maintaining power consumption and distortion performance at the same levels as existing products.

This is achieved by optimising the matching circuits of the GaN FETs and other components for CATV applications. This enables manufacturers of CATV transmission equipment to roughly double output power without increasing energy consumption, so the coverage area of the CATV network overall can be expanded with no increase in power consumption.

The newly developed GaN FETs are fabricated on a silicon substrate instead of on a substrate made of SiC, the material typically used previously. The use of a silicon substrate rather than an expensive SiC substrate facilitates larger wafer sizes and will allow the MC-7802 to be more competitively priced.

Renesas Electronics regards the GaN FET as a key device and plans to expand its PA module product lineups for CATV to form a product family.

CATV power amplifier modules are mainly used in the trunk amplifiers of CATV systems, the optical node units of hybrid fibre coaxial (HFC) systems, and the final stages of booster power amplifiers

for common receiver units installed in multiunit dwellings such as apartment buildings. These power amplifier modules are semiconductor devices that amplify multiple channel signals to make up for transmission loss over the network.

Since they amplify terrestrial digital TV, CATV, and Internet signals, their better linearity (distortion performance) secure more stable data transfer, and improved signal quality. The high output power provides greater flexibility in system design and makes it easier to keep costs down, allowing the network to be expanded by extending transmission distances and increasing the number of branches.

With increasing digitisation in recent years, CATV systems have gone beyond the simple distribution of video content and now also offer hybrid services including Internet access and Internet telephony (VoIP), and the number of channels handled has proliferated. As a result, the use of systems employing the 1 GHz band is expected to grow.

However, although systems employing the 1 GHz band can transmit more channels than existing systems (which use the 770 MHz or 870 MHz band, depending on the region), the higher number of channels brings issues such as increased output power and distortion. In addition, demand is rising for high-frequency semiconductor devices with high output power, low distortion, and energy efficiency for use in amplifiers that maximise the transmission distance and number of branches in order to reduce the transmission cost. The MC-7802 addresses this market demand by providing low power consumption together with improved output linearity and distortion characteristics.

Renesas regards the new MC-7802 device as a strategic product that will enable the company to enlarge its share of the market for CATV power amplifier devices, and aggressive sales promotion is planned in Japan, North America, Europe and China.

Renesas plans to follow up on the new MC-7802 device by developing and commercialising a family of similar products with a variety of gain performances. The company also has plans to continue development work on products incorporating GaN FETs for high-frequency applications and to steadily expand its line-up of such products.

## Transphorm to reduce waste with \$25 million grant

The new financing will enable the firm to continue reducing power wastage with its gallium nitride power devices.

Transphorm, a company which hopes to redefine energy efficiency with the most efficient and compact power conversion technology, has completed a \$25 million Series D financing round with Quantum Strategic Partners.

This is a private investment fund managed by Soros Fund Management LLC, and existing investors Kleiner Perkins Caufield & Byers, Google Ventures, Foundation Capital and Lux Capital. This brings the total capital raised from all rounds to \$63 million.

Transphorm will use the funding to continue solving the multi-billion dollar power waste problem, which occurs whenever electricity from the grid is converted into usable electric power. Since the company launch in February 2011, Transphorm has successfully released what it says is the first complete solution to eliminating power waste, using its GaN based power conversion modules.

“This investment from our top-tier investor partners is a testament to the achievements of the Transphorm team commercialising a Total GaN solution for next-generation power conversion,” said Umesh Mishra, CEO of Transphorm. “Transphorm is sparking a revolution in energy efficiency, paving the way for the mass production of consumer, commercial and industrial technology products designed for optimum electrical efficiency.”

Transphorm’s Total GaN solution reduces power waste by 90 % and simplifies 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. In recent months Transphorm has increased its customer set by 50 % and expanded its operations by 30 % to accommodate demand.

“Transphorm will use the new funding to continue our expansion and scale up to meet growing customer demand for our products,” said Primit Parikh, President of Transphorm. “The Series D financing enables us to grow our facilities,

accelerate product development, and deepen engagement with customers. Above all, it allows us to execute rapidly on our customers’ roadmaps.”

The world’s power infrastructure must become radically more efficient to meet the energy and environmental challenges of the future. Inefficient electric power conversion results in lost energy that costs the United States economy \$40 billion a year and is equivalent to the output of 300 coal plants.

The Advanced Research Projects Agency-Energy (ARPA-E) awarded Transphorm \$2.95 million to invent beyond state-of-the-art, normally-off GaN switches while moving their GaN platform to low-cost silicon substrates.

“Through ARPA-E funding, innovation in next generation power electronics has put the U.S. in a leadership position with GaN-on-Si and motor control,” said Rajeev Ram, Program Director at ARPA-E. “Efficient electronically controlled motors can save over \$13 billion annually in the U.S. with enough energy savings to power 13 million homes.”

At the Applied Power Electronics Conference (APEC) in March 2011, Transphorm launched its first product: a power diode based on its patented, high-performance EZ GaN technology.

To demonstrate the performance advantage of its patented GaN based technology, Transphorm showcased at the APEC exhibition a Total GaN based, DC-to-DC Boost Converter running at more than 99 % efficiency. Shortly thereafter at the PCIM Europe Conference in May 2011, Transphorm unveiled its 600 V EZ-GaN transistor, which displaces silicon-based power conversion technology and reduces switching losses by up to 95 %.

At the PCIM, Transphorm also demonstrated a 100 KHz 3-phase 2 kW inverter, showing the highest efficiency in its class. Transphorm says it is currently the only company offering a Total GaN solution for highly compact and efficient electric power conversion.

## Skyworks unveils first stand-alone products for 3G and LTE

The company's new gallium nitride detectors incorporate a high off-state impedance transceiver and minimise loading other detectors connected to the input line.

Skyworks has increased its product portfolio by adding high dynamic range power detectors for smart phones and datacard

**Industry's First Stand-Alone,  
High-Dynamic Range Power Detectors  
for 3G and LTE Smart Phones and Datacards**



[www.skyworksinc.com](http://www.skyworksinc.com)

Skyworks' RF detectors address the market's need for small, stand-alone solutions that are compatible with various baseband architectures and accommodate multiple 3G and LTE band combinations.

In addition, these devices have been designed to work with the SKY7770X and SKY7772X series of 3G and 4G power amplifiers to expand the compatibility of the integrated daisy chain coupler for the majority of basebands and transceivers.

The detectors' small size (1.2 mm x 1.5 mm) minimises board space requirements, while their higher dynamic range increases power control and improves total radiated power performance. Their low current consumption enables both longer

standby and talk times, and their high off-state impedance level is particularly beneficial for today's demanding, high-end 3G smart phones.

"We are delighted to once again be at the forefront of technology innovation," said Gregory L. Waters, executive vice president and general manager of front-end solutions at Skyworks. "Skyworks' new power detectors are highly compatible with other solutions from our portfolio and allow us to offer our customers a full end-to-end solution for smart phones and data cards."

The SKY77002 is a stand-alone, high dynamic range power detector designed for use in smart phones and data cards in conjunction with Skyworks' power amplifiers in 3G and LTE applications. The detector is manufactured with Skyworks' GaN HBT process offering state-of-the-art reliability, temperature stability and ruggedness.

The SKY77002 detector circuit technology is optimally aligned for transceivers that require external detection for power control. Exceptional temperature and voltage compensation maintains accuracy over extreme operating conditions.

The detector presents high off-state impedance to the transceiver to minimise loading other detectors connected to the input line. The SKY77002 is packaged in the quad flat no-lead package and is fully compliant with current restriction of hazardous substances requirements.

Skyworks' new RF detectors are currently available.

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## Cree's 1200V SiC Schottky diodes offer more than value for money

The firm is looking to develop the next generation of power electronics and offer design engineers silicon carbide devices which have zero reverse recovery loss, temperature-independent switching losses and higher frequency operation.

Cree has revealed a new family of seven 1200V Z-Rec SiC Schottky diodes optimised for price and performance and available in a range of amperages and packages.

Cree is advancing the adoption of SiC power devices into mainstream power applications by introducing a comprehensive family of SiC diodes with a wide range of amperage ratings and package options.

“In order to develop the next generation of power electronics, design engineers are looking for the unique performance advantages of SiC Schottky diodes – zero reverse recovery losses, temperature-independent switching losses, higher frequency operation – all with a lower EMI signature,” said John Palmour, Cree co-founder and chief technology officer, Power and RF.

“This new family of diodes allows a higher current density and increased avalanche capability over previous generation SiC Schottky diodes with no penalty in performance. Cree’s recent innovations in device design and commitment to continuous process improvement are allowing us to offer significantly higher amperage ratings at lower cost per amp.”

Cree Z-Rec diodes feature zero reverse recovery, resulting in up to a 50% reduction in switching losses versus comparable silicon diodes. They also exhibit consistent switching performance across their entire temperature range, which simplifies circuit design and reduces the need for complex thermal management.

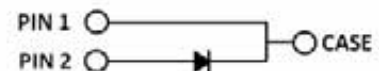
When used in conjunction with Cree’s recently-introduced 1200V SiC power MOSFETs, these SiC Schottky diodes enable the implementation of all-SiC power electronic circuits with the capability to operate at up to four times higher switching frequencies when compared to conventional silicon diodes and IGBTs.

This enables a reduction in the size, complexity and cost of inverter circuitry, while achieving extremely high system efficiency. Finally, this new family has the additional benefits of higher surge ratings and avalanche capabilities than the previous generation of SiC Schottky diodes, helping to increase overall system reliability.

These devices are ideal as boost diodes and anti-parallel diodes in solar inverters and 3-phase motor drive circuits, as well as in power factor correction boost circuits in power supplies and UPS

equipment. They can also be used in applications where engineers typically parallel many devices to address higher power requirements.

Devices now released are rated for 2A[C4D02120x], 5A[C4D05120x], 10A[C4D10120x], 20A[C4D20120x] and 40A[C4D40120x]. Dependent on amperage ratings, the parts are available in standard or fully-isolated TO-220 and standard TO-247 packages.



### **The C4D0212A SiC Schottky diode**

These new Z-Rec 1200V Schottky diodes are fully qualified and released for production use.

## **Cascade Microtech system speeds up time-to-market for power devices**

The unique Tesla probe systems with CT-3100/3200 Curve Tracers address high-voltage, high-power measurement requirements of silicon carbide and gallium nitride devices.

Cascade Microtech, an expert at enabling precision measurements of integrated circuits at the wafer level, has announced that Iwatsu Test Instruments Corporation will manufacture CT-3100/3200 Curve Tracers exclusively for Cascade Microtech to provide versatile wafer-level measurement for the growing power device market.

The curve tracer units strongly complement the high-voltage and high-current capabilities of Cascade Microtech’s Tesla probe systems to speed-up the device characterisation process and therefore time-to-market for power device manufacturers.

The market for power transistors will continue to post healthy gains through 2014, according

to IC Insights. Steady growth, combined with emerging energy standards and increasing power consumption and conservation efforts, demand additional performance capabilities. As such, pressure has been placed on device manufacturers to rapidly design and characterise new power devices to provide more efficiency.

Power device characterisation requires measuring performance across an entire operating region, often at hundreds of amperes and thousands of volts. High-performance requirements have created the need for innovations in curve tracer technology -- tools that have long been an industry standard for power device characterisation, but that no longer meet today's stringent and higher-power characterisation requirements.

The CT-3100/3200 Curve Tracers are designed specifically for measuring different types of high-power semiconductor devices such as SiC, GaN and/or IGBTs, super-junction MOSFETs, diodes and thyristors. Measurement productivity is enhanced by the built-in USB port and a LAN interface for remote control of the CT-3100/3200. Complementary to existing SMU-based instruments, the CT-3100/3200 Curve Tracers provide fast, accurate characterisation up to 3,000 V, 400 A, 4,000 W peak power and support a leakage mode with cursor resolution of 1 pA.

When used in combination with Cascade Microtech's Tesla probe system, design cycles can be significantly reduced from traditional package-level device characterisation methods that require high-power devices be cut from wafers, packaged and returned for test in custom fixtures. On-wafer characterisation methods reduce these lengthy measurement cycle times by eliminating the need for dicing and packaging steps. As a result, device developers can do more complete characterisations to improve quality and reduce time-to-yield.

"Integrated on-wafer measurement solutions for high-power device characterisation will greatly help customers to speed up their design cycle. No longer do they need to send the wafer for dicing and bonding in the package before devices can be tested accurately. Measurements can now be made at the wafer level," said Misao Saito, president of Iwatsu Test Instruments Corporation. "We are happy to partner exclusively with Cascade Microtech, one of the world's leading experts at wafer-level

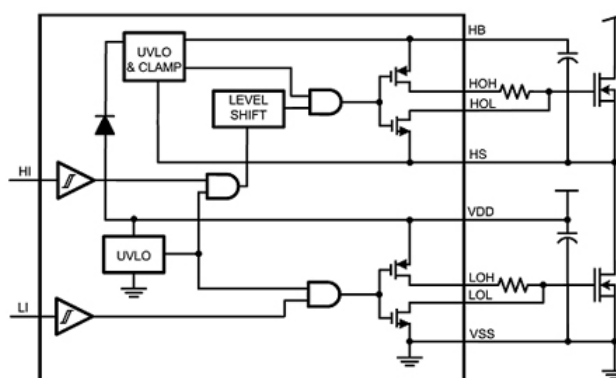
probing, to ensure our power device customers have accurate test information and advanced test capability, to reduce development time and cost."

"We are pleased to now offer Iwatsu curve tracers which, when paired with our Tesla system, will deliver an-integrated measurement solution for power device characterisation not previously offered in the market," said Michael Burger, president and CEO, Cascade Microtech. "Efficient on-wafer characterisation shortens the design cycle, improves product quality and provides our customers with faster time-to-market."

## National Semi reveals first 100V driver for e-mode GaN FETs

The highly-integrated gallium nitride half-bridge gate driver boosts power density and efficiency in high-voltage applications.

National Semiconductor has unveiled what it claims is the industry's first 100V half-bridge gate driver optimised for use with enhancement-mode GaN power FETs in high-voltage power converters. National's new LM5113 is a highly-integrated, high-side and low-side GaN FET driver that reduces component count by 75 % and shrinks printed circuit board (PCB) area by up to 85 % compared to discrete driver designs.



Designers of power bricks and communications infrastructure equipment require high power efficiency in the smallest form factor. Enhancement-mode GaN FETs enable new levels of efficiency and power density compared to standard MOSFETs due to their low on-resistance and gate charge

as well as their ultra-small footprint, but driving them reliably presents significant new challenges. National's LM5113 driver IC eliminates these challenges, enabling power designers to realise the benefits of GaN FETs in a variety of popular power topologies.

Meeting the stringent gate drive requirements of enhancement-mode GaN FETs requires multiple discrete devices and significant circuit and PCB design effort. National's LM5113 fully-integrated enhancement-mode GaN FET driver greatly reduces circuit and PCB design effort and delivers industry-best power density and efficiency.

"National's LM5113 bridge driver helps designers unleash the performance of eGaN FETs by simplifying the design," said Alex Lidow, co-founder and CEO for Efficient Power Conversion Corporation. "The LM5113 dramatically reduces component count, and paired with our eGaN FETs, enables a tremendous PCB area savings and higher level of power density versus equivalent MOSFET-based designs."

National's LM5113 is a 100V bridge driver for enhancement-mode GaN FETs. Using proprietary technology, the device regulates the high side floating bootstrap capacitor voltage at approximately 5.25V to optimally drive enhancement-mode GaN power FETs without exceeding the maximum gate-source voltage rating. The LM5113 also features independent sink and source outputs for flexibility of the turn-on strength with respect to the turn-off strength.

A low impedance pull down path of 0.5  $\Omega$  provides a fast, reliable turn-off mechanism for the low threshold voltage enhancement-mode GaN power FETs, helping maximize efficiency in high frequency power supply designs. The LM5113 features an integrated high-side bootstrap diode, further minimizing PCB real estate. The LM5113 also provides independent logic inputs for the high-side and low-side drivers, enabling flexibility for use in a variety of both isolated and non-isolated power supply topologies.

National's LM5113 is offered in a 10-pin 4 mm by 4 mm LLP package and cost \$1.65 each in quantities of 1,000. Samples are available now and production quantities will be available in September.

## Imec scientists impress at E-MRS and VLSI

Researchers based at the Belgian research institute have been acknowledged for their contributions to semiconductor technology.

At the European Materials Research Society (E-MRS) 2011 Spring Meeting, Liyang Zhang has received the Young Scientist Award for her paper 'Photoluminescence studies of polarization effects in InGaN/(In)GaN multiple quantum well structures', contributed to the Symposium on group III nitrides and their heterostructures for electronics and photonics.

In this work, the authors present the results of a study on the impact of polarisation on multiple quantum wells (MQWs) revealed by the optical performance by photoluminescence measurements. In addition to the traditional InGaN/GaN MQWs, they also demonstrate  $\text{In}_x\text{Ga}_{1-x}\text{N}/\text{In}_y\text{Ga}_{1-y}\text{N}$  MQWs. The MQWs were grown on sapphire substrates by MOVPE. Co-authors of the paper are K. Cheng, H. Liang, R. Lieten, M. Leys and G. Borghs.

The paper '1mA/ $\mu\text{m}$ -ION strained SiGe45%-IFQW pFETs with raised and embedded S/D' by Jerome Mitard *et al* from K.U.Leuven, has been selected as one of the technical highlights of the 2011 Symposium on VLSI Technology and Circuits. The paper reports the successful integration of a strained SiGe45% implant free quantum well pFET with embedded SiGe25%-source/drain. The results suggest that the SiGe-IFQW with embedded S/D is a viable device option for the 16nm technological node and beyond. The work was co-authored by researchers based at imec and K.U. Leuven.

## RFMD portfolio now features Ember ZigBee technology

The RF6555 FEM developed with Ember is targeting smart energy applications.

RF Micro Devices, a global designer and manufacturer of high-performance RF components and compound semiconductor technologies, has unveiled the highly integrated RF6555 ZigBee front

end module (FEM).

The RF6555 is optimised for smart energy/ advanced metering infrastructure (AMI) applications providing utilities and consumers more control over how they monitor and save energy. ZigBee is a global low power wireless networking standard for monitoring and control across a variety of applications, including energy management, safety and security, home automation, lighting, and electrical appliances.

The highly integrated RF6555 combines the power amplifier, harmonic transmit filtering, and low noise amplifier with bypass mode in a single 5mm x 5mm x 1mm package. It enables customers to shrink product footprint, accelerate product time-to-market, lower bill of material costs (BOM), and reduce power consumption for Smart Energy and Home Area Network (HAN) applications.

RFMD's RF6555 is ideally suited for battery operated smart grid and smart energy applications, such as smart meters, demand response, and HAN devices. The RF6555 is also suited for industrial and other wireless sensing and control applications requiring low power consumption, high performance, and proven reliability.

The RF6555 operates with Ember's EM351 and the EM357 in both system-on-chip (SoC) and network co-processor modes, as well as with Ember's EM250 SoC and EM260 network co-processor.

Bob Van Buskirk, president of RFMD's Multi-Market Products Group, said, "RFMD is pleased to collaborate with Ember to deliver highly integrated, high performance ZigBee solutions that reduce our customers' design cycle times, lower product BOM costs, and accelerate product time to market. Industry analysts forecast global smart energy deployments will continue to grow rapidly, with particular demand anticipated in low-power wireless networking technologies like ZigBee."

Ember's ZigBee networking systems which include chips, ZigBee protocol software and tools simplify the complexity of integrating embedded software, networking and RF for developing low power, wireless products in smart energy, connected home and other remote monitoring and control applications. Since its inception, Ember claims to have been the most deployed ZigBee platform in

the market.

The EM300 Series is Ember's next-generation ZigBee chip family, and the world's foremost ARM Cortex-M3 based ZigBee SoC, packing the industry's highest wireless networking performance and application code space into the lowest power-consuming chip set. Ember says the EM250 and EM260 are the most deployed family of ZigBee semiconductors. Ember's ZigBee semiconductors are renowned for delivering excellent RF performance, sensitivity and transmit power for long range, and 802.11 immunity.

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## Equipment and Materials

### AIN substrates can be cost efficient

Nitride Solutions is developing a manufacturing technology that hopes to deliver high-volume, low-cost aluminium nitride substrates with defect rates 10 times lower than substrates currently on the market.

With secured major financing commitments from Nebraska Angels and Aurora UV, Nitride Solutions, a developer of next-generation substrates for LEDs, lasers and power electronics, aims to transform the AIN substrate industry.

To date, Nitride has raised \$1.8M in a Series A preferred round. Nebraska and Aurora join lead investor Midwest Venture Alliance, in addition to Mid-America Angels and Manhattan Holdings in the round.

"Our investment group, the Midwest Venture Alliance, is looking to invest in solid management teams that are solving real market problems. Nitride Solutions represents just that," said Trish Brasted, president and CEO of Wichita Technology Corporation. "They have put together an experienced business and technical management team that is developing an industry-changing advanced material."

Nitride is developing a manufacturing technology that will deliver high-volume, low-cost AIN



substrates. With projected defect rates 10 times lower than substrates currently on the market, these substrates should improve the quality of existing LED, laser and electronic products, while also making possible whole new categories of UV devices.

The result will be improved white lighting for consumer and industrial uses, more efficient power systems in hybrid vehicles, sharper colour on flat-screen TVs, and better air and water purifiers. Nitride will use the funding to perfect the technology, and to begin manufacturing and sales in late 2011. "The number of biomedical and industrial applications of LED technology is rapidly growing," said Karen Linder, co-deal lead for Nebraska Angels in Lincoln. "Nitride Solutions' novel method of creating substrates on which these crystals can be grown will change the market. The technology is revolutionary, and the leadership team has the commercial experience and the scientific skills that will make the company successful."

"We expect to benefit with both high financial rewards and the satisfaction that we will have been part of the effort of applying hard science to alleviating some of the world's most vexing problems, including cheap access to pure water," said Muriel Taylor, president and CEO of Aurora UV in Santa Barbara.

Nitride is still seeking a small group of financial and strategic investors to finalise the round, which will stay open until September.



As a leading manufacturer of MOCVD equipment, Aixtron will provide one CRIUS II MOCVD system and one AIXG5HT MOCVD system at SINANO's facility to train its customers and potential customers' engineers on the usage of MOVCD systems. SINANO's process and maintenance engineers will also be trained by Aixtron for the system operations.

MOCVD is the most critical epitaxial growth equipment on the upstream chain of semiconductor lighting industry and requires high-level operation staff. By building the Aixtron - SINANO MOCVD Training Centre, SINANO and Aixtron will play advantages of each party's, for training the high-end industry professionals and to provide the talent supports for both Yangtze River Delta region and the national optoelectronics and photovoltaic industry development.

What's more, based on this cooperation, the two sides prepare to establish a MOCVD R&D centre, with a view to fundamentally improve China's MOCVD epitaxy technology and MOCVD equipment manufacturing capacity.

Yang Hui, director of SINANO and Wolfgang Breme, CFO of Aixtron attended the agreement signing ceremony.

## Aixtron – SINANO training centre established in China

The manufacturer of MOCVD equipment will provide one CRIUS II system and one AIXG5HT system at SINANO's facility to train its customers and potential customers' engineers.

Suzhou Institute of Nano-tech & Nano-bionics, Chinese Academy of Sciences (SINANO) signed an agreement on June 22 in Suzhou with Aixtron to co-establish the "Aixtron - SINANO MOCVD Training Centre" agreement.

## Bridgepoint backs acquisition of SPTS

The firm believes SPTS represents an attractive opportunity to acquire a market leader in the wafer fabrication equipment sector.

SPP Process Technology Systems (SPTS), a subsidiary of Sumitomo Precision Products ('SPP') and leading manufacturer of etch, deposition, and thermal processing equipment for the semiconductor industry has announced that Bridgepoint, a European private equity firm is backing a management acquisition of SPTS from SPP.

SPTS designs, develops and manufactures capital equipment that is used in the production of devices on semiconductor substrates. SPTS serves a number of end-markets including MEMS, power management, advanced packaging, high speed RF components, and LEDs on compound semiconductor substrates.

With over 500 employees in manufacturing, sales and service operations across 19 countries, SPTS serves the world's leading micro-device manufacturers through its main operations in Newport, Wales and San Jose, California. In 2010 it generated sales of \$217 million and Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA) of \$58 million.

SPTS President and CEO William Johnson said, "The investment by Bridgepoint in SPTS signifies the next stage in our evolution as a market leader in the MEMS, compound semiconductor, advanced packaging and power markets. SPP's support in the company has been invaluable, and the Board is grateful for the success enabled by SPP." "We are constantly looking to develop our capabilities to meet future customer needs and with Bridgepoint as a new investment partner, their financial and commercial expertise will be a key pillar to our expansion."

"I have been closely involved in the development of SPTS following the time with STS since its acquisition made by SPP in 1995. Consequently, I am very pleased with our decision to support the management team's plans to take SPTS forward," said Susumu Kaminaga, president, SPP.

"They have become important colleagues and I wish them well in their endeavours in the future. For SPP, this transaction allows us to focus on other areas of our business which offer attractive investment opportunities. However, we will continue to co-operate with SPTS, retaining a stake and working together with them through a joint venture for the Japanese market."

Bridgepoint believes SPTS represents an attractive opportunity to acquire a market leader in the wafer fabrication equipment sector. Chris Bell, a director at Bridgepoint, said, "SPTS has strong positions in every sector in which it operates, and a global customer base in end markets poised for long term growth. In addition, we have identified with management a number of initiatives to optimise its operational performance, including acquisitions in attractive niche markets and joint ventures, such as the BluGlass agreement."

Under the terms of the acquisition, its former parent SPP will continue to partner the business by taking a minority stake in the new business organisation. The company name will remain as SPTS.

Advisers involved in this transaction include: for vendor - BDO (corporate finance), Bingham (legal); for management - Osborne Clarke (legal), Ernst & Young (corporate finance); for Bridgepoint - Ernst & Young (transaction services), Travers Smith (legal), McKinsey, Prismaark and OC&C (market due diligence). The transaction is subject to standard competition clearances.

SPP Process Technology Systems was established in October 2009 as the vehicle for the merger of Surface Technology Systems and acquired assets of Aviza Technology. The company was a wholly-owned subsidiary of Sumitomo Precision Products Co., Ltd., and designs, manufactures, sells, and supports advanced semiconductor capital equipment and process technologies for the global semiconductor industry and related markets. These products are used in a variety of market segments, including R&D, data storage, MEMS and nanotechnology, advanced 3-D packaging, LEDs, and power integrated circuits for communications.

Bridgepoint is a European private equity firm focussing on the acquisition of companies valued up to €1 billion. With some €11 billion of capital raised to date, it typically focuses on acquiring well

managed companies in attractive sectors with the potential to grow organically or through acquisition. Although a generalist investor, Bridgepoint has developed expertise in the business services, consumer, financial services, healthcare, media, and industrial sectors. It has offices throughout Europe in Frankfurt, Helsinki, Istanbul, London, Luxembourg, Madrid, Milan, Paris and Stockholm.

Bridgepoint is currently investing a €4.8 billion fund, Bridgepoint Europe IV, which had its final closing in November 2008 and has made nine investments to date. Recent investments made by Bridgepoint include the acquisition of German specialty chemicals company CABB in March this year and of Foncia, the French leader in property management services, in June. See [www.bridgepoint.eu](http://www.bridgepoint.eu).

## Witec's True Surface Microscopy wins 2011 R&D100 Award

True Surface Microscopy provides optical or chemical properties at the surface of a sample and can be used to measure the topography of compound semiconductor materials.

WITec's "True Surface Microscopy" has been selected as a winner of the prestigious 2011 R&D 100 Award.

It honours the WITec innovation as one of the 100 most technologically significant developments of the year. True Surface Microscopy allows confocal Raman imaging guided by surface topography. The topographic coordinates measured from an integrated profilometer are used to perfectly follow the sample surface in confocal Raman imaging mode.



### **Figure. The instrument featuring the True Surface Microscopy Mode**

The result is an image revealing optical or chemical properties at the surface of the sample, even if this surface is very rough or heavily inclined. It is suited to imaging many materials such as compound semiconductors and graphene.

Previously in March 2011, True Surface Microscopy received the PITTCON 2011 Editors Gold Award.

"With True Surface Microscopy we have made another technological leap which will enable our customers to explore new avenues in their scientific field" says Olaf Hollricher, Managing Director Research & Development. "This second award further validates our claim of always providing cutting-edge innovations and is a great recognition of the success of our product strategy."

The internationally recognised award was established in 1963 and is selected by an independent panel of judges as well as the editors of R&D Magazine and is presented every year to outstanding innovations in industrial research and development.

In 2008 WITec received the R&D 100 Award for the automated confocal Raman and Atomic Force Microscope platform alpha500. The judges choose breakthrough products or processes that can contribute to changing people's lives or redefining current technology. Winners will be recognised at the R&D 100 Awards Banquet on 13 October 2011 in Orlando, Florida.

## Tiger Optics popularity high in monitoring gas mixtures

The U.S based company is producing more gas analysers to cope with the demand for its CW-CRDS laser technology in compound semiconductor manufacturing.

Tiger Optics, a manufacturer of laser-based instruments used to detect contaminants in pure gases, has said its devices are increasingly sought to monitor gas mixtures.

To meet demand, Tiger said it is deploying more

gas analysers from its HALO product line, one of the company's most versatile.



The development signals another milestone for the company, which holds exclusive rights to multiple, broad-based patents from Princeton University on Continuous Wave Cavity Ring-Down Spectroscopy (CW CRDS). Tiger analysers detect the presence of fugitive components down to the low parts-per-trillion level in a variety of gases.

Over the past decade, CW CRDS has advanced the analysis of many packaged pure gases, including inert gases, reactive gases (toxic gases, corrosives, and hydrides), and rare gases.

Mixed gas products are commonly used in calibration of chemical instruments, medical and healthcare facilities, laser applications, electronic manufacturing and metal welding. Each application has unique demands of precision in terms of the amounts of blended gases, as well as tolerance for impurities in the mixture.

“Water vapour is a common contaminant that can shorten the useful lifetime of packaged gas mixtures. Our HALO product line is a perfect fit for trace moisture analysis in quality control,” said Lisa Bergson, founder and chief executive of Tiger Optics.

Among the features that distinguish the HALO analysers are a fast response, high accuracy, wide detection range, and capacity to evaluate many base gases. The first HALO, introduced in 2006, was designed to offer the speed, specificity and reliability of the original Tiger tools at approximately

half the price and one-quarter the size. The device measures moisture in a range from 2 parts-per-billion to 20 parts-per-million.

In 2007, Tiger unveiled HALO+, designed to analyse moisture in gases down to ultra-low levels (0.4 ppb to 20 ppm) required in semiconductor fabrication plants.

The latest addition, the HALO-500-H2O, permits a facility's quality control lab to evaluate moisture levels over a very wide 20 ppb - 500 ppm range, encompassing expected moisture values in most gas mixtures. Even under conditions where high moisture samples are followed by sub ppm level samples, the HALO-H2O and HALO-500-H2O can achieve 95 % of a reading in less than 3 minutes, thereby assuring fast, highly accurate measurements and outstanding sample throughput in the lab.

Such accuracy is essential if gas mixtures are to be evaluated with certitude. Mixtures comprising multiple (two to 100-plus) components are used to set the reference point or scale of laboratory, research, and industrial instruments to accepted primary standards.

Meticulous blending to exact specification for each gas component is essential for high sensitivity and accurate measurements from calibrated equipment, such as detectors of environmental pollutants, monitors for breathing gases, and emissions analysers for industrial manufacturing like fuel and petrochemical production. With HALO analysers, moisture measurements are accurate to within 4 percent of each reading, thereby providing a great degree of confidence in the shelf life and stability of calibration mixtures.

A standard HALO analyser includes a family of six base gases (argon, helium, hydrogen, oxygen, nitrogen, and clean dry air). The HALO gas menu can be enhanced with other base gases, such as carbon monoxide, carbon dioxide, fluorocarbons and sulphur hexafluoride, as well as gas mixtures.

Options are also available for gas mixture samples that require compatible cell material (such as corrosion-resistant alloys) or specific operation settings (such as high/low flow or custom pressure range).

## Cascade Microtech system speeds up time-to-market for power devices

The unique Tesla probe systems with CT-3100/3200 Curve Tracers address high-voltage, high-power measurement requirements of silicon carbide and gallium nitride devices.

Cascade Microtech, an expert at enabling precision measurements of integrated circuits at the wafer level, has announced that Iwatsu Test Instruments Corporation will manufacture CT-3100/3200 Curve Tracers exclusively for Cascade Microtech to provide versatile wafer-level measurement for the growing power device market.

The curve tracer units strongly complement the high-voltage and high-current capabilities of Cascade Microtech's Tesla probe systems to speed-up the device characterisation process and therefore time-to-market for power device manufacturers.

The market for power transistors will continue to post healthy gains through 2014, according to IC Insights. Steady growth, combined with emerging energy standards and increasing power consumption and conservation efforts, demand additional performance capabilities. As such, pressure has been placed on device manufacturers to rapidly design and characterise new power devices to provide more efficiency.

Power device characterisation requires measuring performance across an entire operating region, often at hundreds of amperes and thousands of volts. High-performance requirements have created the need for innovations in curve tracer technology -- tools that have long been an industry standard for power device characterisation, but that no longer meet today's stringent and higher-power characterisation requirements.

The CT-3100/3200 Curve Tracers are designed specifically for measuring different types of high-power semiconductor devices such as SiC, GaN and/or IGBTs, super-junction MOSFETs, diodes and thyristors. Measurement productivity is enhanced by the built-in USB port and a LAN interface for remote control of the CT-3100/3200. Complementary

to existing SMU-based instruments, the CT-3100/3200 Curve Tracers provide fast, accurate characterisation up to 3,000 V, 400 A, 4,000 W peak power and support a leakage mode with cursor resolution of 1 pA.

When used in combination with Cascade Microtech's Tesla probe system, design cycles can be significantly reduced from traditional package-level device characterisation methods that require high-power devices be cut from wafers, packaged and returned for test in custom fixtures. On-wafer characterisation methods reduce these lengthy measurement cycle times by eliminating the need for dicing and packaging steps. As a result, device developers can do more complete characterisations to improve quality and reduce time-to-*yield*.

"Integrated on-wafer measurement solutions for high-power device characterisation will greatly help customers to speed up their design cycle. No longer do they need to send the wafer for dicing and bonding in the package before devices can be tested accurately. Measurements can now be made at the wafer level," said Misao Saito, president of Iwatsu Test Instruments Corporation. "We are happy to partner exclusively with Cascade Microtech, one of the world's leading experts at wafer-level probing, to ensure our power device customers have accurate test information and advanced test capability, to reduce development time and cost."

"We are pleased to now offer Iwatsu curve tracers which, when paired with our Tesla system, will deliver an-integrated measurement solution for power device characterisation not previously offered in the market," said Michael Burger, president and CEO, Cascade Microtech. "Efficient on-wafer characterisation shortens the design cycle, improves product quality and provides our customers with faster time-to-market."

## GT Solar appoints two new board members

Mary Petrovich and Robert Switz are experienced corporate executives, Appointed to GT Solar Board of Directors

GT Solar International, a global provider of sapphire and silicon crystalline growth systems and materials for the solar, LED and other specialty markets, has appointed Mary Petrovich and Robert E. Switz to its board of directors.

Petrovich and Switz have been appointed to serve until the 2011 Annual Meeting of Stockholders at which time they will stand for election.

The appointments fill the vacancies resulting from the resignations in November 2010 of Bradforth Forth and R. Chad Van Sweden, both with the GFI Energy Group of Oaktree Capital Management, previously a private equity investor in GT Solar.

The company also announced that Fusen E. Chen, a member of the board, notified the company of his decision not to stand for re-election following the completion of his current term which will end on the date of the company's annual shareholders meeting scheduled for August 24, 2011.

"We are grateful for the outstanding service and contributions of Fusen Chen as a GT board member over the last three years," said Matt Massengill, chairman of the board. "Fusen provided invaluable insight as we developed the technology strategy and roadmap that are being successfully deployed today.

"We are delighted with the additions of Mary Petrovich and Bob Switz to the GT Solar board," continued Massengill. "Both individuals are accomplished former CEOs of public companies who have created shareholder value and demonstrated excellent operational and leadership skills. In addition, they are both experienced directors on the boards of other public companies. The GT board will benefit from their insights and experience."

Petrovich has served as general manager of AxleTech International, a supplier of off-highway and specialty vehicle drive train systems and

components, since its acquisition by General Dynamics in December 2008. She served as chairman and chief executive officer of AxleTech International from 2001 through the December 2008 sale of the company. Petrovich is also a director of Woodward and Modine Manufacturing Company.

Switz served as a director, President and Chief Executive Officer of ADC Telecommunications from 2003 to 2010 and as its Chairman from 2008 to 2010. ADC Telecommunications was a supplier of network infrastructure products and services, which was acquired by Tyco International. Switz is also a director of Broadcom Corporation and Micron Technology.

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## Gore reduces cost of performing RF testing

The firm has added a rugged assembly specifically engineered for high throughput in production test applications in the wireless infrastructure market.

W. L. Gore & Associates, has added a rugged 18 GHz cable assembly to its GORE PHASEFLEX Microwave/RF Test Assemblies line.

This rugged cable assembly is specifically engineered for high throughput production test applications in the wireless infrastructure market. The increased durability of the assembly reduces total costs for testing because it lasts longer, decreasing the frequency of cable assembly replacements. Its stable performance ensures precise measurements and repeatability, which reduces the risk of testing errors and the need for time-consuming troubleshooting and system calibration.

In addition, the ergonomic design of this cable assembly eliminates the need to use a torque wrench to connect and disconnect accurately, which increases throughput on the manufacturing line.



Gore's new rugged cable assembly maintains the same reliable performance as all GORE PHASEFLEX Microwave/RF Test Assemblies. The robust connectors on these assemblies minimise failure by incorporating maximum strain relief at the point where the cable and connector meet. The assembly's internally ruggedised construction is more durable, delivering crush resistance of 187 pounds per linear inch (85 kg/cm).

Available in 1.0 and 1.5 metre lengths with both SMA and N-type male connectors, this cable assembly is easier for the operator to use because it is smaller and lighter weight, and it can be connected and disconnected manually. These assemblies withstand 100,000 flexures at a minimum bend radius of one inch. Additionally, the crush, torque, and kink-resistant construction also results in longer service life.

Like all GORE PHASEFLEX Microwave/RF Test Assemblies, this cable assembly is engineered to withstand the frequent torque and bending that is common to testing environments on the manufacturing floor.

According to Reneé Burba, GORE Microwave/RF Test Assemblies global product manager, cable assemblies have a significant impact on the total cost of testing in production environments. "Frequent troubleshooting, time-consuming recalibration, and retesting all have a direct impact on throughput in a manufacturing process, which in turn significantly increase costs."

"Also, having to use a torque wrench to connect and disconnect each product from the test equipment slows down the testing process," Burba explained. "After several customers voiced concerns about these issues, we engineered a small, durable microwave/RF cable assembly that reduces costs in

production testing by delivering consistently precise measurements in an easy-to-use construction. Using the same internally ruggedized construction as the high-frequency GORE PHASEFLEX Microwave/RF Test Assemblies enabled us to deliver the durability and reliable performance our customers expect."

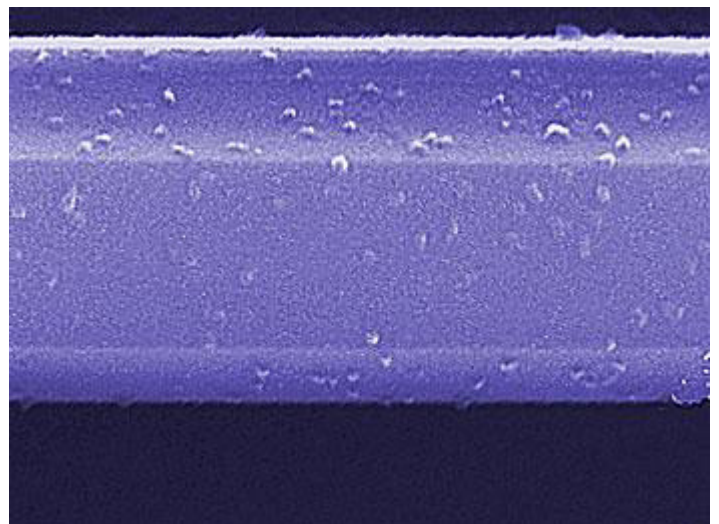
## Novel Devices

### GaN nanowires improve detection of volatile compounds

A gas sensor incorporating a single gallium nitride nanowire offers advantages over today's commercial gas sensors, including low-power room-temperature operation.

A team of researchers from the National Institute of Standards and Technology (NIST), George Mason University and the University of Maryland has made nano-sized sensors that detect volatile organic compounds.

These include harmful pollutants released from paints, cleaners, pesticides and other products. The latest innovation, which incorporates GaN nanowires, offers several advantages over today's commercial gas sensors, including low-power room-temperature operation and the ability to detect one or several compounds over a wide range of concentrations.



**Figure: SEM image of a gas sensor segment fabricated from a nanowire of GaN less than 500 nm across and coated with nanoclusters of titanium dioxide (TiO<sub>2</sub>). (Credit: NIST)**

This research proves that a gas sensor made of a single III-V nanowire and metal oxide nanoclusters can react to a specific organic compound. This work is the most recent of several efforts at NIST that takes advantage of the unique properties of nanowires and metal oxide elements for sensing dangerous substances.

Modern commercial gas sensors are made of thin, conductive films of metal oxides. When a volatile organic compound like benzene interacts with TiO<sub>2</sub>, for example, a reaction alters the current running through the film, triggering an alarm. While thin-film sensors are effective, many must operate at temperatures of 200° C (392° F) or higher.

Frequent heating can degrade the materials that make up the films and contacts, causing reliability problems. In addition, most thin-film sensors work within a narrow range; one might catch a small amount of toluene in the air, but fail to sniff out a massive release of the gas. The range of the new nanowire sensors runs from just 50 parts per billion up to 1 part per 100, or 1 % of the air in a room.

These new sensors, built using the same fabrication processes that are commonly used for silicon computer chips, operate using the same basic principle, but on a much smaller scale. The GaN wires are less than 500 nm across and less than 10 µm in length. Despite their microscopic size, the nanowires and TiO<sub>2</sub> nanoclusters are coated with have a high surface-to-volume ratio that makes them exquisitely sensitive.

“The electrical current flowing through our nanosensors is in the microamps range, while traditional sensors require milliamps,” explains NIST’s Abhishek Motayed. “So we’re sensing with a lot less power and energy. The nanosensors also offer greater reliability and smaller size. They’re so small that you can put them anywhere.”

Ultraviolet light, rather than heat, promotes the TiO<sub>2</sub> to react in the presence of a volatile organic compound. What’s more, each nanowire is a defect-free single crystal, rather than the conglomeration of crystal grains in thin-film sensors, so is less

prone to degradation. In reliability tests over the last year, the nano-sized sensors have not experienced failures.

While the team’s current experimental sensors are tuned to detect benzene as well as the similar volatile organic compounds toluene, ethylbenzene and xylene, their goal is to build a device that includes an array of nanowires and various metal oxide nanoclusters for analysing mixtures of compounds. They plan to collaborate with other NIST teams to combine their ultraviolet light approach with heat-induced nanowire sensing technologies.

The portion of this work conducted at George Mason University was funded by the National Science Foundation.

More details of this work is published in the paper, “Highly selective GaN-nanowire/TiO<sub>2</sub>-nanocluster hybrid sensors for detection of benzene and related environment pollutants” by G.S. Aluri, A. Motayed, A.V. Davydov, V.P. Oleshko, K.A. Bertness, N.A. Sanford and M.V. Rao in *Nanotechnology*, 22, 295503. DOI: 10.1088/0957-4484/22/29/295503