

# semiconductor TODAY

COMPOUNDS & ADVANCED SILICON

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## IEDM conference report

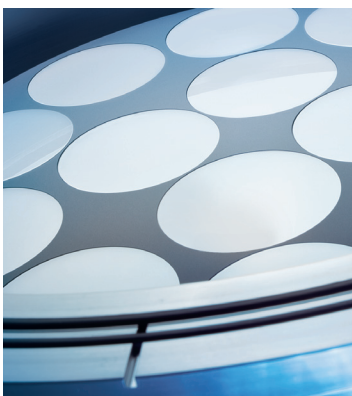
### THz pulses multiply GaAs transistor & PV potential



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Soitec to buy Altatech • Osram pilots 6" GaN-on-Si LED chips

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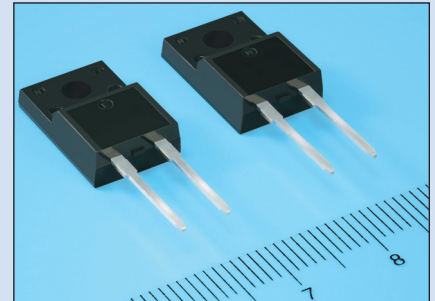


# contents

<b>News</b>	
<b>Markets</b>	<b>6</b>
GaN LED market falls 6% in 2011 • LED fab equipment spending to fall 18% in 2012 • GaAs IC market growth slows to 1% in 2011	
<b>Microelectronics</b>	<b>12</b>
RFMD revenue falls 19% as Skyworks grows 17% • Nocilis launches Si- and SiGeSnC-based epi foundry	
<b>Wide-bandgap electronics</b>	<b>22</b>
Renesas samples SiC devices integrating power conversion on-chip	
<b>Materials and processing equipment</b>	<b>28</b>
AXT setting up second China plant • Asahi Kasei buys Crystal IS • Soitec to buy Altatech; demos 4" and 6" GaN substrates with SEI • Albemarle launches Electronic Materials business unit	
<b>LEDs</b>	<b>42</b>
Osram pilots 6" GaN-on-Si • Epistar hits 216lm/W for warm-white	
<b>Optoelectronics: Photonics West</b>	<b>53</b>
First 300mW 980–780nm laser • 3S Photonics Group becomes 3SPGroup	
<b>Optical communications</b>	<b>60</b>
Oclaro samples 20G VCSEL • Optelian buys Versawave • Oclaro, Opnext & Emcore on Thai flood recovery: Oclaro down 28% year-on-year	
<b>Photovoltaics</b>	<b>65</b>
Semprius raises \$3m and AQT raises \$18.7m • First Solar boosts CdTe module efficiency to 14.4% • CIGS market to double by 2015	
<b>Technology focus: Photovoltaics</b>	<b>74</b>
Quantum well steps to efficient multi-junction solar cells	
<b>Technology focus: GaAs</b>	<b>76</b>
THz pulse boosts electron density in GaAs 1000-fold	
<b>Technology focus: LEDs</b>	<b>78</b>
First yellow-green and amber micro-LED arrays	
<b>Technology focus: UV LEDs</b>	<b>80</b>
Reflections on deep UV light extraction	
<b>Technology focus: III-Vs on silicon</b>	<b>82</b>
InGaAs buffer/channel structure boosts effective mobility 4.2x	
<b>Technology focus: III-Vs on silicon</b>	<b>84</b>
Creating high-performance nitride MOSFETs on silicon	
<b>Research review: Nitride transistors</b>	<b>86</b>
Digital etching for damage-free gate recess in nitride transistors	
<b>Technology focus: Nitride transistors</b>	<b>88</b>
Back-barrier enhancements to AlN/GaN HEMTs	
<b>Technology focus: Nitride transistors</b>	<b>90</b>
China creates its first high-performance InAlN HEMTs on sapphire	
<b>Conference report: IEDM (part 1)</b>	<b>92</b>
Speed and power from gallium nitride and silicon carbide	
<b>Suppliers' Directory</b>	<b>98</b>
<b>Event Calendar and Advertisers' Index</b>	<b>104</b>

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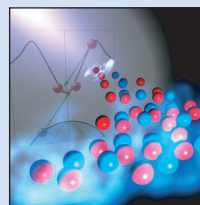
**p22** Renesas is sampling low-loss SiC power devices integrating power conversion circuit on-chip.



**p27** Naval Research Laboratory's Dr Brian Bennett, named a fellow of the American Physical Society.



**p68** First Solar staff hold the record 14.4%-efficient module, which has raised the record for CdTe PV modules from their prior record of 13.4%.



**Cover:** Illustration of how exposure to a picosecond terahertz electric field pulse induces an avalanche of electron-hole pairs in GaAs, boosting the exciton density 1000-fold. The findings by Koichiro Tanaka's lab at Kyoto University could lead to advances in high-speed transistors and high-efficiency solar cells. **p76**

# Supply & demand cycles

This issue sees the first in a two-part report on December's IEEE International Electron Devices Meeting, with this first part focusing on high-frequency and high-power research based on gallium nitride and silicon carbide (part 2 next issue will focus on gallium arsenide and III-Vs-on-silicon). In addition to IEDM, other articles this issue also cover nitride transistors, including nitride HEMTs on sapphire or silicon and nitride MOSFETs on silicon (page 84) as well as InGaAs MOSFETs on silicon (page 82).

GaN-on-silicon technology is also progressing further commercially in the LED sector, with news in January that Osram Opto Semiconductors has entered the pilot stage in fabricating prototype GaN-based blue and white LED chips on 150mm-diameter silicon wafers, with quality and performance matching that of GaN LEDs on sapphire substrates (page 50). Meanwhile, Soitec and Sumitomo Electric Industries have demonstrated 4" and 6" engineered GaN substrates (by applying Soitec's Smart Cut layer-transfer technology to SEI's bulk free-standing GaN substrates) and are currently installing pilot production lines (see page 39).

The economies of scale and low cost of silicon wafers are the big hope for driving adoption of LED solid-state lighting in the next year or so. However, while Chinese government subsidies have driven purchases of many MOCVD growth systems over the last year or so, more recent economic and financial uncertainty has delayed China's plans for LED lighting adoption, as noted on page 49 by LED maker SemiLEDs, which has transitioned its Taiwanese chip fabrication lines from 2" to 4", as well as started up its China joint venture exclusively at 4".

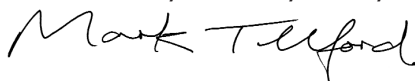
SemiLEDs' revenue has grown due to developing new, lower-price indoor lighting products, while Cree's revenues have grown 13% sequentially (see page 46). However, the latter is through last August's acquisition of Ruud Lighting; in contrast, Cree's revenue from LED products (components, chips and materials) fell slightly. Indeed, to bolster fab utilization and hence profit margin, Cree has slowed its transition from 100mm silicon carbide substrates to 150mm SiC, during the current over-capacity prior to the mass uptake of LED lighting and after the slowdown in demand for TV backlighting applications.

According to IMS Research, 60% growth in the packaged GaN LED market in 2010 was followed by a 6% fall in 2011 (as supply grew three times faster than demand) — see page 9. Consequently, following a 36% rise in 2011, LED manufacturing equipment spending will fall 18% in 2012, driven by a 40% drop for MOCVD systems, reckons SEMI (page 7).

However, while the equipment spending cycle is lagging behind the LED supply/demand cycle, IMS expects the GaN LED market to rebound by 5% in 2012 (driven by lighting revenue rising 30%, overtaking GaN LED revenue for TV backlighting a year earlier than expected) followed by double-digit growth in 2013 and 2014 as the lighting market accelerates. Over 2011–2016, IMS expects lighting LED revenue to grow more than 300% and units to grow more than 1500%, driving lighting's share of the GaN LED market from 21% to 49%. If so, then the pause in the equipment market this year should be followed by recovery next year.

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(e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers and LEDs in wireless and optical communications, etc).

#### Regular issues contain:

- news (funding, personnel, facilities, technology, applications and markets);
- feature articles (technology, markets, regional profiles);
- conference reports;
- event calendar and event previews;
- suppliers' directory.

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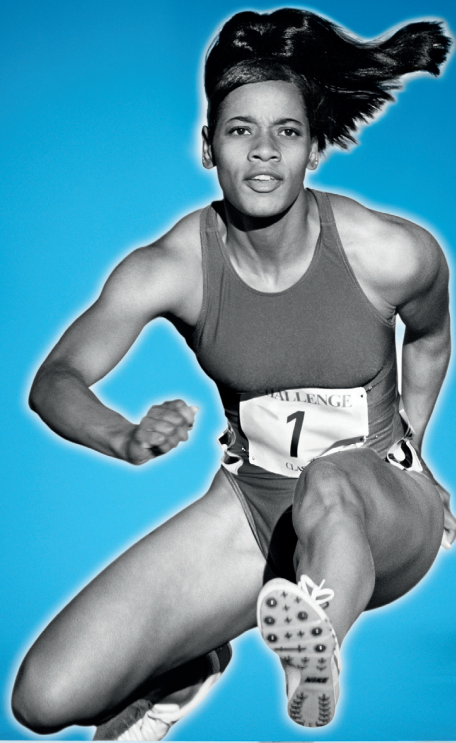
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# ALWAYS ONE STEP AHEAD



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**AIXTRON**



## HB-LED consumption to grow from \$10.77bn in 2011 to \$69.7bn in 2021

Global consumption of packaged HB-LEDs in 2011 was \$10.77bn, and is forecast to grow to \$69.7bn in 2021, according to ElectroniCast Consultants' report 'High Brightness Light Emitting Diodes Global Market Forecast & Analysis (2011–2021)', which covers HB-LEDs with a

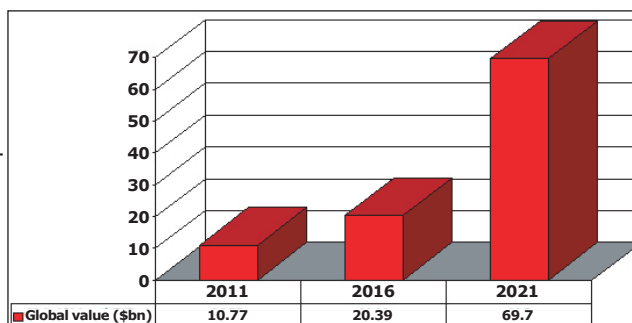
lumens/Watt efficiency rating of 30–70lm/W as well as HB-LEDs with a lumens/Watt rating of over 70lm/W.

Decreasing average selling prices (ASPs) are forecast to cause challenging growth patterns in consumption value (quantity x price) in some application segments. Some application categories are therefore forecast to decline in consumption value in the second half of the forecast period (2016–2021); however, the volumes (quantity/number of units) in all categories are forecast for positive growth throughout.

Use of HB-LEDs in Mobile/Portable Devices is forecast to remain a strong segment; however, organic LEDs (OLEDs) continue to take market share. The sector is relatively mature and it already has a substantial consumption value in 2012.

In terms of consumption value, the use of HB-LEDs in the Automotive/Vehicle category is forecast to multiply more than two-fold from 2011 to 2016.

The use of HB-LEDs in Stationary Signals (non-vehicle) is forecast to rise at an average growth rate of just 5.5% from 2011 to 2016. The consumption value is forecast to fall sharply due to price declines, as well as market saturation. However, in terms of volume (quantity/units), the segment is forecast to grow slightly during 2016–2021.



HB-LED consumption (in \$bn) from 2011 to 2021.

ElectroniCast's report also provides consumption data for packaged HB-LEDs used for Solid-State Lighting (General Lighting) stationary applications (area illumination), including interior and exterior decorative and functional lighting for residential, commercial and government areas (lighting for vehicles is included in a separate Automotive/Vehicle application category).

The use (consumption value) of HB-LEDs in the Signage/Professional Display application is forecast to rise at an average annual growth rate of 22.1% from 2011 to 2016 then at 35.9% from 2016 to 2021. Consumption of HB-LEDs in 'Other' or miscellaneous (non-specified) applications is forecast to reach \$710m in 2016, before falling during the second half of the forecast period.

The use of HB-LEDs in Consumer-Level TV/Desktop Monitor Back-lighting is forecast to maintain a strong market share (%) throughout the first-half of the forecast period, before slipping in market share during the second half due to saturation in many markets as well as an increase in competition from OLEDs. Also, the number of white packaged LEDs required in back-lighting units (BLUs) in consumer-level LCD-TVs (and desktop monitors) will fall, due to increased luminous efficacy and improvements in the supporting optics (components and packaging).

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

### IN BRIEF

## Lamp and luminaire shipments to exceed 500 million units in Asia-Pacific by 2021

Sales of LED lighting systems will rise rapidly over the next 10 years, especially after 2015, as unit shipments (including lamps and luminaires) will grow over 700% from 66 million in 2011 to 542 million in 2021, according to a report from Pike Research.

Sales of other forms of lighting (e.g. incandescent, T8/T5, and CFLs) will fall steadily.

"High upfront costs and a lack of customer awareness remain issues for the Asia Pacific LED market," says senior analyst Andy Bae. "But the news media has been touting recent price declines, and lighting manufacturers in the region are continuously expanding their product lineups to meet demand."

While energy-efficient products are expensive for many in the Asia Pacific, higher costs are being justified by higher efficacy and performance. Some countries have been early pioneers, so demand for LED products is growing in developed countries such as Japan and Korea. Moreover, regional and national government programs are promoting LED lighting.

Japan revealed its 21st Century Light Project more than a decade ago, then launched several LED subsidy and support programs. Taiwan established a Next Generation Light Source Technology Development & Supply Strategy. In China, Shenzhen for example plans to install LEDs in over 90% of public lighting applications, street lighting, and commercial spaces in the next decade.

These initiatives will serve as a key driver of the market in the coming decade, believes Pike.

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

# LED fab equipment spending to fall 18% in 2012

## MOCVD spending to fall 40%, but non-MOCVD to rise as LED makers optimize production lines and improve product designs

Following a massive 36% increase in equipment spending in 2011, worldwide LED manufacturing equipment spending is projected to decline 18% in 2012, according to the latest Opto/LED FabWatch and Forecast from global industry association Semiconductor Equipment and Materials International (SEMI). LED manufacturing capacity is expected to reach 2 million wafers in 2012 (4" equivalent per month), a 27% increase over 2011.

After several years of rapid capacity expansion driven by high-brightness light-emitting diodes (HB-LED) used in TV backlighting applications — reinforced by lucrative government incentives and economic development funding in China — a 40% decline in global metal-organic chemical vapor deposition (MOCVD) purchases in 2012 will reduce overall LED equipment spending for the first time in over five years, forecasts the report. However, spending for non-MOCVD equipment, particularly in lithography, etch, test and packaging equipment, will increase in 2012, as manufacturers optimize their production lines and improve their product designs.

While HB-LED demand continues to grow in solid-state lighting, HB-LEDs used in liquid-crystal display (LCD) TV backlighting units (about 40% of the total HB-LED market) failed to reach growth expectations in 2011. Total TV unit sales missed growth targets, and the penetration of LED backlighting as part of total LCD TV unit sales did not reach the levels many experts predicted. LEDs used in solid-state lighting, currently totaling about \$2.5bn,

may exceed \$30bn by 2020, according to many estimates.

"Similar to other microelectronics industries, LED manufacturing capacity and technology investments will vary year-over-year, but will correspond with the long-term demand driven by key applications; in LEDs, this will be primarily solid-state lighting," says Tom Morrow, executive VP, Emerging Markets Group, at SEMI. "Future equipment and capital spending will drive LED cost reduction through larger wafers, automation and dedicated equipment specifically designed to improve LED manufacturing yield and throughput," he adds.

Regional equipment spending shows China continuing to lead, with an expected \$719m planned for 2012, followed by Taiwan (\$321m), Japan (\$300m) and Korea (\$260m). Taiwan will continue to lead in capacity, at 25% of global LED capacity, followed by China at 22%. SEMI counted 29 new LED fabs in 2011. For 2012, it forecasts 16 new fabs coming online.

Looking at the back-end of the LED market, the 'Global Semiconductor Packaging Materials Outlook' published by SEMI and TechSearch Inc shows very strong growth in LED leadframe shipments. Following the 69% unit shipment growth in 2010, LED leadframe shipments are estimated to have risen by a further 10% in 2011. In 2012, shipments should reach almost 83 billion units. Data are based on shipments reported by 16 leadframe suppliers.

[www.semi.org](http://www.semi.org)

### Estimated LED leadframe units shipped (billions).

2008	2009	2010	2011F	2012F
35.7	39.5	66.9	73.6	82.7

### IN BRIEF

## Mobile broadband devices to reach 525 million by 2016

The mobile broadband device market will claim a global installed base of more than 525 million units by 2016, according to Strategy Analytics' report 'Mobile Broadband Devices: 5-Year Market Forecast for Embedded and External Modems', which shows steady growth for external modems over the forecast period.

Expansion will be driven by device costs, more flexible tariffs, a shift to LTE and growth in mobile hotspots for multiple devices, such as tablets and other consumer electronics, says the market research firm.

Embedded modems, however, will experience slower growth due to the higher cost of embedding cellular capabilities and the need for additional data services.

"Strategy Analytics anticipates continued growth in mobile broadband devices as operators improve user segmentation, such as flexible plans and content bundling all underpinned by LTE," comments report author Andrew Brown, director, Wireless Enterprise Strategies. "Mobile hotspots have been a highlight in this sector, typically enabling up to five devices at a time to connect anywhere on one data plan. The growth in the number and variety of Wi-Fi enabled devices has considerably increased the value proposition of these mobile hotspot devices," he adds.

The report includes forecasts of shipments of mobile broadband devices, both embedded and external, as well as sizing of the installed base of mobile broadband devices. Also included is further segmentation for embedded and external mobile WiMax devices.

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

# Low-cost direct LED backlights to reduce premium for LED-backlit LCD TVs

## Lower-than-expected LED penetration drives TV makers to attract cost-conscious consumers

Due to lower-than-expected consumer adoption of LED-backlit LCD TVs, TV makers have changed their strategy on direct LED-backlit TV to develop a product that uses less power and lowers costs by reducing the number of LEDs per TV set, according to the NPD DisplaySearch's 'Quarterly LED Backlight Report'. In turn, this also lowers brightness and moves away from the slim designs and higher picture quality that have been characteristic traits of LED-backlit LCD TVs.

"LED penetration in LCD TV was 7 points lower than our forecast a year ago, mainly due to high LED premiums," says senior VP Yoshio Tamura. "The premium for a LED backlight in a 32" LCD TV was 42% in Q4/2011, although it had been expected to fall to 27%," he adds. "Instead of high picture quality, set makers have chosen low-power consumption with a corresponding lower price as selling points for this new type of LED-backlit TV. This will increase its competitiveness with CCFL [cold-cathode fluorescent lamp]-backlit LCD TV and even CRT [cathode ray tube] TV."

The materials cost for direct LED backlights comes closer to that of CCFL backlights. NPD DisplaySearch estimates that for 32" LCD TVs, direct LED backlights cost 1.3–1.4 times CCFL backlights, as opposed to edge-lit LED backlights, which are estimated to cost more than twice as much as CCFL backlights. For 40" LCD TVs, the savings could be even greater, with low-cost direct backlights cutting nearly \$40 in material costs, which could result in as much as \$100 in savings at retail.

The cost savings come from using about half as many LEDs, as well as the replacement of light guide plates, optical film, and other materials

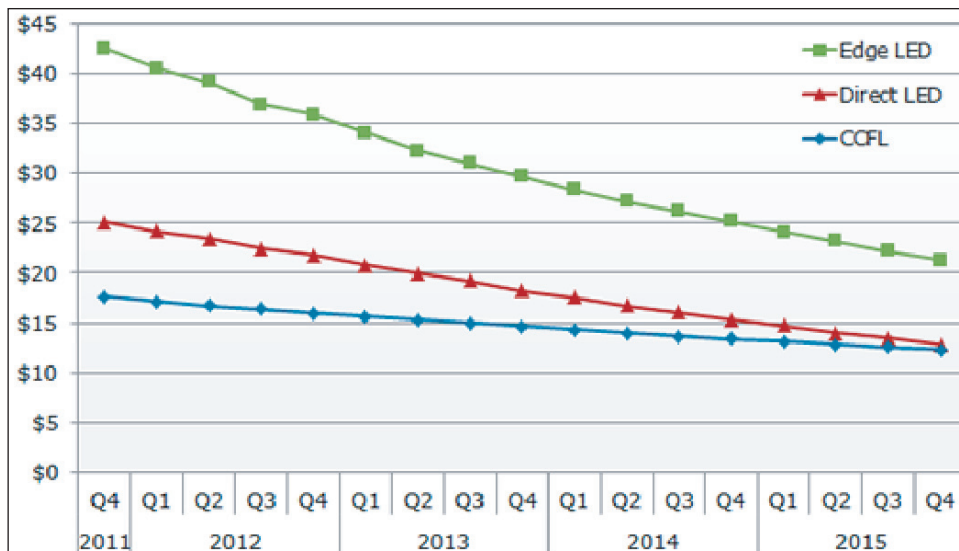


Figure 1: Backlight cost forecasts for 32" HD 60Hz LCD TV panel.

with lower-cost diffuser plates and lens structures on the LEDs. The reduction in LEDs and other materials lowers power consumption, but requires a thicker profile. Brightness is lowered to 300 nits from 450 nits for edge-lit LED or CCFL, and the lack of dimming reduces the contrast ratio and image quality.

Television set manufacturers have been adopting two-chip LED packages to reduce the number of packages and to reduce optical film usage. The number of LED packages used per set with direct backlights is therefore expected to be less than that of sets with edge backlights.

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

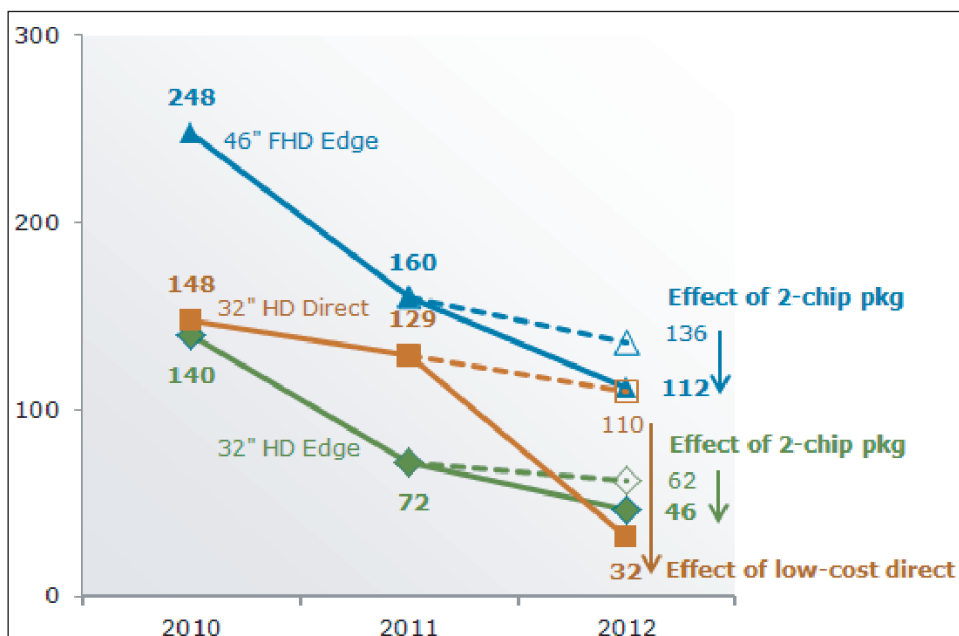


Figure 2: Forecast of LED packages per set for TVs. Source: NPD



# Packaged GaN LED market falls 6% in 2011 to \$8bn due to backlighting weakness

## Recovery from 2012 to 2015 to include double-digit growth in 2013–2014 as lighting accelerates

After 60% growth in 2010, the gallium nitride (GaN) LED market is now expected to fall 6% in 2011 to \$8bn, according to IMS Research's latest 'Quarterly GaN LED Supply and Demand', which tracks and forecasts all aspects of the LED market quarterly.

The decline can be attributed to the following:

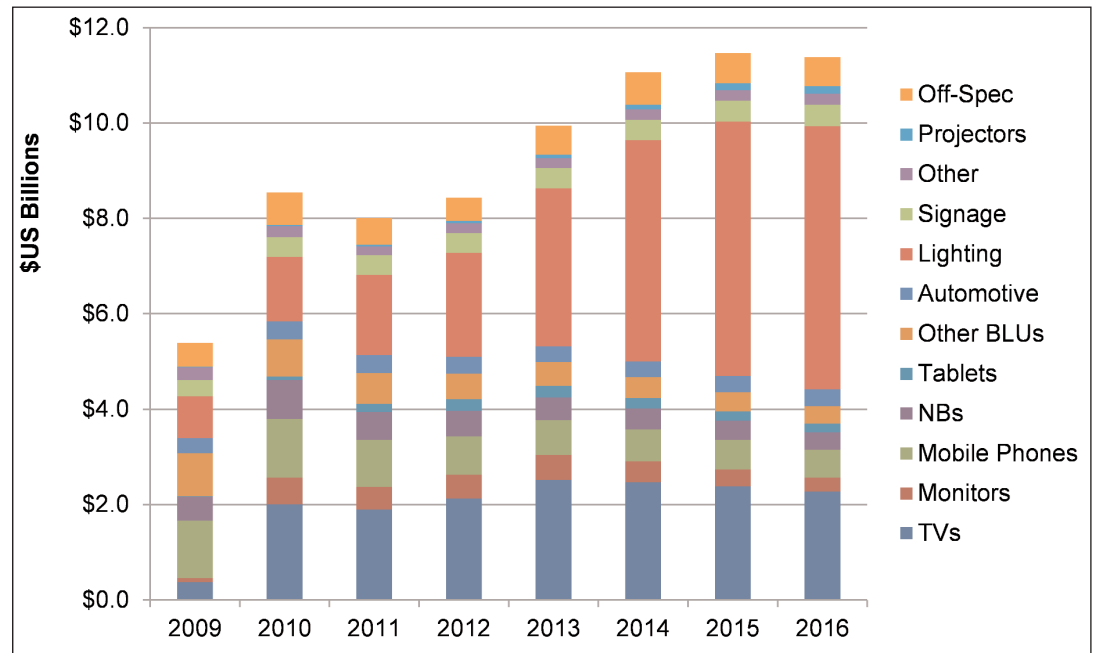
- A widening surplus resulted in significant pricing pressure as supply grew nearly three times faster than demand from 2010 to 2011, resulting in depressed LED factory utilization levels. The LED surplus rose from a relatively healthy 7% in 2010 to 45% in 2011 and is predicted to widen further in 2012.

- With both panel shipments and LED penetration below expectations and average LED prices for backlighting falling 34% on a volume-weighted average basis on depressed utilization, backlighting revenues fell 13% to \$4.8bn.

Average selling prices (ASPs) for certain backlighting markets were down as much as 45% in 2011, hence backlighting fell from 64% of GaN LED revenue in 2010 to 59% in 2011 and is likely to continue falling as the backlight markets become saturated and the lighting market accelerates.

- LED revenue for TVs is expected to fall 5% in 2011 to \$1.9bn as penetration is expected to reach only 39%, below the previous estimate of 43%.

However, the GaN LED market is expected to recover, enjoying annual growth each year from 2012 to 2015, including double-digit growth in 2013 and 2014 as the lighting market accelerates. High-



Packaged GaN LED market (2009–2016) by application; revenues by segment (\$bn).

lights include the following:

- The 2012 market is expected to grow 5% but remain below 2010 levels. Backlighting is expected to be flat due to slower unit growth and price reductions, while lighting is expected to rise 30% as LED lamp penetration jumps while prices continue to fall.

- Lighting revenue is expected to overtake TV revenue for GaN LEDs in 2012, a year earlier than previously predicted. This is due to the increasing LED lighting demand (as a result of lower pricing) while LED demand for TVs falls

**Lighting revenue is expected to overtake TV revenue for GaN LEDs in 2012, a year earlier than previously predicted. This is due to the increasing LED lighting demand while LED demand for TVs falls**

TVs falls (due to the lower-than-expected penetration) along with the use of low-cost direct LED backlights in developing markets.

- Compared with conventional edge backlights, low-cost direct LED backlights use about half the LED die area. This is due to significantly reducing the brightness specification, along with adopting a thicker form factor that allows wide-viewing-angle packages to be adopted, which further reduces the number of LEDs required. While the adoption of these new low-cost direct-type backlights will narrow the cost differential with CCFL LCD TVs, the thicker form factor and reduced brightness capability will narrow their appeal, says IMS.

- The lighting share of the GaN LED market is expected to surge from 21% in 2011 to 49% in 2016, with lighting LED revenue expected to grow more than 300% and units expected to grow more than 1500% over this period.

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

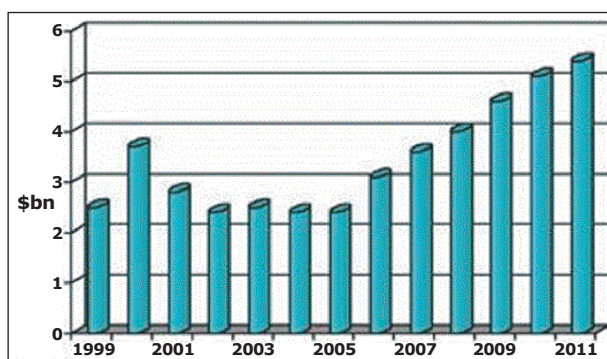
# GaAs IC market growth slows to 1% in 2011

## Wireless/WiFi recover to drive rebound to 8% growth in 2012

After growing 1.7% in 2009 then 36% in 2010, the gallium arsenide (GaAs) IC market grew just 1% in 2011, according to the 'The GaAs IC Market' from The Information Network (reported by Digitimes). The slowing growth was due to weak demand in wireless applications (cell phones and WiFi).

However, the wireless/WiFi market is expected to recover in 2012, so the GaAs IC market should rebound to 8% growth, forecasts the market research firm.

Multi-band 3G handsets often contain up to five power amplifiers (PAs), and GaAs makes up 100% of the market, which is nearly \$5bn. Also, the number of PAs per handset is growing due to increasingly complex 3G systems, global roaming support, and data roaming support. Pricing for PAs has increased from \$0.80 per handset to \$2.90 currently, and is projected to increase to over \$3.50 after long-term evolution (LTE) and advanced wireless services (AWS)



GaAs IC market (in \$bn) over 1999-2011.

spectrum emerge in advanced handsets in the marketplace, The Information Network notes.

But, while industrialized countries are using 3G networks, today's world is a mixture of 2G/2.5G and 3G networks. The vast majority of subscribers are on 2G-based networks, and this situation is predicted to remain for a number of years.

So, 2G handsets represent a sizable market, and contain just one PA. Because they are not as technologically advanced as 3G cell

phones (particularly smartphones), silicon is therefore making inroads into the GaAs domain. For 2011, only 90% of PAs were made in GaAs, whereas 5% were made in silicon CMOS and 5% in silicon LDMOS, estimates The Information Network.

Besides the technical dynamics, GaAs RFIC maker Skyworks Solutions

of Woburn, MA, USA has positioned itself in the market via its mid-2009 acquisition of CMOS PA supplier Axiom Microdevices of Irvine, CA. Also, in 2009 privately held Black Sand Technologies Inc of Austin, TX unveiled the world's first 3G CMOS RF PA. Other CMOS PA suppliers include Austin-based Javelin Semiconductor and Amalfi Semiconductor of Los Gatos, CA. Another firm working on CMOS PAs is ACCO Semiconductor of Sunnyvale, CA.

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

# GaN gaining traction in commercial applications

## Consumer market to grow to \$58m by 2015

Despite continuing dominance by military applications, the overall gallium nitride (GaN) device market will rise at a compound average annual growth rate (CAAGR) of nearly 29% to \$178m in 2015, as GaN technology is also seeing widespread deployment in commercial applications (led by cable TV and high-power electronics) which will grow from less than \$1m to nearly \$58m, according to the report 'GaN Microelectronics Market Update 2010-2015' released recently by market research firm Strategy Analytics.

The report covers GaN technology trends and challenges to wider deployment in military and commercial applications, as well as reviewing some of the centrally

funded programs from the USA, Europe and Japan.

"Military applications and government funding for semiconductor companies like TriQuint and Cree will continue to drive GaN development," comments Asif Anwar, director in the Strategy Analytics Strategic Technologies Practice. "Additionally, the overall GaN market will expand with demand for commercial applications," he adds.

The percentage of total GaN revenue derived from military applications will shrink from 98% in 2010 to 67% in 2015, forecasts Strategy Analytics. Meanwhile, revenue growth rates for GaN devices in wireless infrastructure, high-power electronics and CATV/VSAT (very small aperture terminals) will all exceed 100%.

"Driven by performance advantages like efficiency, power dissipation and operating temperature, GaN is finally starting to generate interest in commercial market applications," notes Eric Higham, director of the Strategy Analytics GaAs and Compound Semiconductor Technologies Service.

"GaN developments by device manufacturers like RFMD and Nitronex (for CATV applications) and International Rectifier and EPC (for power converter applications) are displacing other technologies," Higham adds. "Operators and equipment manufacturers are recognizing the operating cost advantage that GaN can provide," he concludes.

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

# GaN could save US mobile operators \$2bn annually

## Remote radio heads switched from LDMOS to GaN power amplifiers

RFHIC Corp of Suwon, South Korea, which makes GaN- and GaAs-based active RF & microwave components and hybrid modules for telecom and broadcast markets, reckons that the USA's four largest mobile network operators could collectively save \$20bn over the next ten years by using GaN technology in their wireless infrastructure.

As consumer demand increases in the wireless industry (driven by with exploding video data needs), wireless infrastructure is struggling to keep pace. Many mobile operators in the US market have hastily been deploying 4G capabilities (particularly LTE). Progression from 3G to LTE/4G networks demands additional infrastructure, with remote radio heads (RRHs) complementing existing macro base-stations.

With energy, land and installation costs at a premium, mobile network operators have begun to realize savings by switching LDMOS-based RRHs to more energy-efficient GaN-based RRHs, says RFHIC. Analyst estimates that each of the

carriers spends about \$0.5bn annually on powering its infrastructure. GaN-based base-stations — including macro base-station, RRH, pico, mini, microcell and other small-cell systems — can save significant cost for mobile network operators.

While LDMOS is the mainstay of the telecom industry, recent price drops of GaN-based amplifiers have placed it on a par with LDMOS-based RRH systems' price. GaN's technological advantage remains in its wider bandwidth coverage (allowing future application upgrades) and, most importantly, in its efficiency. With more than 35 million watts of GaN-powered RRHs rolled out to LTE providers already in the USA and Asia, GaN technology is just starting to take hold in the market. Due to the efficiency of GaN power amplifiers, these carriers can not only save billions of dollars of operating costs over the lifespan of the RRH systems but also be greener by reducing carbon dioxide emissions significantly, says RFHIC. Analyst estimates that wireless car-

riers in the USA alone can save more than \$2bn per year on operating costs, primarily from energy savings on their wireless infrastructure by simply switching from LDMOS to GaN power amplifiers.

Moreover, GaN's efficiency enables RRH designers to make systems smaller by reducing the heat-sink size and power supply requirement. This translates directly to lower installation and RRH space rental expenses for carriers. Also, overall reliability affects the carriers' bottom lines by producing more reliable LTE services to end users, and by cutting maintenance expenses, says RFHIC. Furthermore, carriers can save on future upgrades, as GaN-based RRHs can support multi-band, multi-mode, and multi-carrier technology, the firm concludes.

RFHIC has already produced RRH solutions for Sprint, NTT Docomo, LG Telecom, and SK Telecom, and expects to deliver 500,000 GaN power amplifiers for LTE roll-outs in 2012 (equivalent to over 135MW).

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

## Tablet market passes 15.5 million shipments in Q3/2011

Global consumer tablet shipments hit a record 15.5 million units in third-quarter 2011, up from 4.5 million in Q3/2010, according to the latest Tablet Tracking report from Futuresource Consulting.

The update highlights significant industry growth across the three key territories, demonstrating that a product with little consumer demand prior to development and launch can experience a massive upsurge in approval, proving that an unsurpassed reputation, expert technological development and streamlined marketing activities can quickly turn an item into a 'must have' product.

The USA leads the way in tablet adoption, accounting for 46% of global ownership, and exceeding an installed base of 24 million devices

at the end of Q3. Europe has seen a slower uptake (4.2 million shipments in Q3 compared to 7.1 million in the USA), but this still represents over 300% growth year-on-year.

In terms of brand positioning, Apple continues to dominate the global market. This is certainly true in the USA, where it accounts for over 70% of unit shipments, although Samsung, HP and Acer are beginning to gain some traction. Europe is more fragmented, with Apple still on top but with other brands shining through, although the competitive landscape varies country by country.

Looking to the immediate future, the emergence of major sporting events in 2012 is expected to fuel a rise in the uptake of tablets as consumers demand connection while

away from home to view TV content or keep on track of results. The associated size and features of the tablet mean that consumers can enjoy higher-quality viewing compared to that of a smartphone.

Long-term prospects for the tablet industry are positive, reckons Futuresource Consulting, with strong growth throughout the forecast period to 2015, driven by a widening array of mobile content for tablets including apps, declining prices making the product widely available to an increased user-base and product replacement as consumers update and modernize. Multiple ownership per household will also drive market growth as advances are made in the range of uses and applications available.

[www.futuresource-consulting.com](http://www.futuresource-consulting.com)



## RFMD's quarterly revenue falls 19% year-on-year China 2G decline offsets 3G/4G growth outpacing smart-phone market

For its fiscal third-quarter 2012 (to end-December 2011), RF Micro Devices Inc of Greensboro, NC, USA has reported revenue of \$225.4m, down 19.2% on \$278.8m a year ago and 7.5% on \$243.8m last quarter (and 9.8% below the \$250m that was forecast in early November). Both Nokia and Samsung comprised over 10% of revenue each.

Multi-Market Products Group (MPG) revenue was \$45.6m, down 13% (more than the projected 10%) on last quarter's \$52.4m, reflecting broad weakness in end markets. Cellular Products Group (CPG) revenue was \$179.8m, down 6% on \$191m last quarter.

China represented over a third of total revenue, but 2G product demand did not materialize as expected for the traditional lunar New Year ramp. Also, while 3G demand in China grew 50% sequentially, it fell short of customers' forecasts. This offset global market share gains in smart-phones (with sales of 3G/4G components rising to over 55% of RFMD's total cellular revenue, outpacing smart-phone market growth). With sales to Nokia falling, RFMD continued to diversify its customer base, with about 100% year-on-year revenue growth at Foxconn, HTC, Huawei, Motorola and Research In Motion.

"Our share is still relatively small at these accounts, giving RFMD significant runway for growth," says president & CEO Bob Bruggeworth.

The demand short-fall led to an unplanned mid-quarter drop in fab and assembly plant utilization (to lessen investment in inventory and mitigate future inventory risk), driving a disproportionate impact to gross margin. On a non-GAAP basis, after rising from 38.7% a year ago, gross margin has fallen from 39.1% to 30.2%. However, 2-3 percentage points of this drop is due to a rise in inventory reserves.

Net income has fallen further, from \$52.6m a year ago and

\$31.1m last quarter to \$5.1m. Despite this, operating cash flow was \$46.2m (up from \$38.4m last quarter). After capital expenditure of \$8.7m, free cash flow was \$37.5m (up from \$30.6m). Also during the quarter, RFMD repurchased about 2.3 million shares of common stock and retired \$6m principal amount of convertible debt. Overall, total cash, cash equivalents and short-term investments rose from \$276.6m to \$295.4m.

"RFMD's growth drivers are very much intact, led by industry-leading new products and the release of exciting new product categories, like RFMD's antenna control solutions," says Bruggeworth.

CPG continued to ramp its high-efficiency 3G/4G power amplifiers (PAs) across a broad range of leading smart-phone makers. It also ramped PowerSmart products with an additional base-band supplier and is engaged with leading LTE base-band suppliers to deliver PowerSmart LTE to their customers. In addition, CPG secured a major PA design win on a reference design for the 3G entry market. Also, shipments of switch and signal conditioning products surpassed \$25m, in support of Foxconn, HTC, Samsung, LG, Research In Motion and others.

MPG released a broad range of new products during the quarter, including 15 high-frequency MMICs operating at 6-27GHz for microwave backhaul (five customers have already designed two or more into their next-generation platforms). RFMD also secured major GaN-based design wins and started volume shipments of high-power GaN-based components to a major defense radar manufacturer.

"In the March 2012 quarter [fiscal Q4], we anticipate sales of 3G/4G components will continue to increase as a percentage of CPG revenue [to two-thirds], and we expect MPG will outperform its underlying markets," says Bruggeworth. RFMD

expects further market share gains in smart-phones, but a greater-than-seasonal decline in sales to cellular handset makers in China, due to the impact of the lunar New Year on order visibility and the projected impact of channel inventory.

Also, three customers (one a top-tier handset maker in China and two top-tier infrastructure customers) are transitioning to inventory hubs during the March quarter. "This creates a one-time impact to revenue [of \$4-5m], as the normal 2-3 weeks of inventory the customer carries must get absorbed in RFMD's inventory hub," notes chief financial officer Dean Priddy.

Nevertheless, based on the demand environment (including sales to Nokia declining further), RFMD expects revenue to fall to \$185m (down 13% on \$213.3m a year ago). Despite this, gross margin should improve by 200-300 basis points as inventory levels are reduced. RFMD expects to generate positive free cash flow.

"Our visibility into China will improve after the Lunar New Year holiday," believes Bruggeworth. "We have begun to see signs of stabilization in customer order activity, and we believe RFMD will return to growth in the June 2012 quarter." Gross margin should return to historical levels, believes Priddy.

RFMD's 3G growth drivers in China are very much intact in wideband CDMA, in TD-SCDMA and TD-LTE. "The China market will transition to 3G, and RFMD is very well positioned to capitalize," says Bruggeworth. "Key 3G/4G drivers (PowerSmart, high-efficiency PAs, switch-based products, antenna control solutions) grew in the December quarter, continue to gain key design wins, and will grow considerably during 2012," he adds. "MPG will recover as the macro environment improves, and new products and technologies will deliver revenue growth."

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

## RFMD expands portfolio of 2.4GHz front-end modules for ZigBee/HAN

RF Micro Devices has launched the RFFM6201, a 2.4GHz-band single-chip Zigbee front-end module (FEM) featuring an integrated power amplifier, low-noise amplifier and diversity switch.

The RFFM6201 delivers what is claimed to be industry-leading current consumption (170mA at rated power) and high-power performance (+23dBm) for home area networking (HAN)/smart energy applications. ZigBee Smart Energy is the leading standard for home area networks used by smart grid programs to boost energy management and efficiency in homes worldwide. The energy-efficient RFFM6201 is pin-for-pin compatible with RFMD's RF6555 and offers 5dB higher output power, enabling users to increase power output and range without requiring changes in product layout.

"RFMD's expanding FEM portfolio supports our customers' rapid ZigBee product launches while reducing component count, size, cost, and power consumption," says Rohan Houlden, general manager

of RFMD's Wireless Connectivity business unit. "RFMD's RFFM6201 ZigBee FEM is specifically optimized for smart energy applications, including smart meters, energy usage control, or 'demand response', and HAN devices," he adds.

"Beyond Smart Energy, the RFFM6201 is also suited for industrial, wireless sensing, and control applications requiring low power, high performance and assured reliability."

At the 2012 Consumer Electronics Show (CES) in Las Vegas (10-13 January), RFMD showcased its ZigBee and smart energy solutions in the ZigBee Alliance Pavilion.

RFMD says its ZigBee portfolio supports a wide range of smart energy, HAN, and machine-to-machine (M2M) applications, and its products are featured on many third-party chipsets and reference designs. The RF6555, for example, is mated with multiple reference designs and is optimized for battery-operated solutions, enabling low 70mA current consumption for ZigBee and other 2.4GHz applications.

## RFMD launches high-power front-end modules for 802.11b/g/n WiFi 2.4-2.5GHz CPE applications

RF Micro Devices has launched the RF5605 and RFFM420x family of high-power, front end modules (FEMs), designed specifically for IEEE 802.11b/g/n WiFi 2.4-2.5GHz customer premises equipment (CPE) applications.

Applications for the RFFM4200, RFFM4201, RFFM4202 and RFFM4203 FEMs include access points/gateways, WiFi-enabled set-top boxes, data cards and terminals, and spread-spectrum and MMDS systems.

Each device has an integrated three-stage linear power amplifier, Tx harmonic filtering, and SPDT

switch. Operating from a single 5V supply, output power is 27.5dBm (< 2.5% EVM) and gain is 35dB (typical) across the frequency band.

The 1X1 MIMO-architecture modules also have a fully matched input and output for a 50Ω system and incorporate matching networks optimized for linear output power and efficiency. With mirrored pin-out options, the modules align with any chipset or configuration used for WiFi designs.

Housed in a 6mm x 6mm laminate, pricing begins at \$4.67 each for 100 pieces.

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

### IN BRIEF

#### Lenovo honors RFMD with 2011 Best Supplier Award

Lenovo Mobile Internet and Digital Home Business Group (MIDH) — the subsidiary of Lenovo responsible for creating mobile Internet-focused devices (including tablets and smartphones, as well as devices for new categories like cloud computing, smart TV and the digital home) — has honored RF Micro Devices Inc of Greensboro, NC, USA with its 2011 Best Supplier Award.

"RFMD is greatly honored to receive this award from Lenovo in recognition of RFMD's local product development and customer support, our record for reliable on-time delivery, and our commitment to product and technology leadership," says RFMD president & CEO Bob Bruggeworth. "RFMD is especially proud to support Lenovo broadly across our entire cellular product portfolio, and we look forward to expanding our relationship with Lenovo in calendar 2012 as new 2G feature phones and 3G/4G smartphones are introduced," he adds.

RFMD currently has more than ten products in volume production in support of Lenovo MIDH, and anticipates significant expansion in 2012, with about 20 products expected in production by the March quarter. Its product portfolio for Lenovo includes 2G transmit modules, WEDGE and WGPRES power amplifiers and transmit modules, TD-SCDMA power amplifiers, TD/EDGE multi-mode power amplifiers, 3G switches, and 3G power amplifiers, including its family of ultra-high-efficiency 3G/4G power amplifiers.

In the September 2011 quarter, RFMD started shipping multiple ultra-high-efficiency 3G/4G power amplifiers in support of the Lenovo A60 dual-SIM 3G smartphone.

## IN BRIEF

## Anadigics ships production volumes of HELP3E PAs for Samsung's Galaxy Nexus smartphone

Anadigics is shipping production volumes of its AWC6323 dual-band High-Efficiency-at-Low-Power (HELP3E) power amplifiers (PAs) to Samsung Electronics for its new Galaxy Nexus smartphone.

The feature-packed Nexus has a slim case containing a 4.65" high-definition display, 5 megapixel camera, and 1.2GHz dual-core processor. Available via Verizon Wireless, the Nexus is also the first smartphone to use the new Android 4.0 Ice Cream Sandwich operating system.

"The selection of Anadigics' dual-band power amplifier for the flagship Galaxy Nexus from Samsung demonstrates the strength of the relationship forged between Anadigics and Samsung," says president & CEO Ron Michels. "Samsung Electronics remains at the forefront of the mobile digital lifestyle by continually innovating and evolving the smartphone... Our goal is to support Samsung through each successive generation of mobile connectivity".

HELP3E PAs use Anadigics' exclusive InGaP-Plus technology to achieve optimal power-added efficiencies (PAEs) across low- and mid-range output power levels (with three mode states) and to low quiescent currents of 4mA. Anadigics also claims best-in-class linearity at maximum output power.

In a single package with a 3mm by 5mm footprint, the compact HELP3E dual-band devices contain two independent PAs, an integrated voltage regulator, and an integrated RF coupler. This level of integration reduces PCB space by 25% compared with current-generation dual-band solutions, Anadigics says.

## TriQuint recognized for excellence by Raytheon for fourth consecutive year

At its 2011 SAS Supplier Excellence Award (SEA) recognition event, Raytheon Company has honored RF component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA for the fourth consecutive year, for exceptional performance in supporting Raytheon's Space and Airborne Systems (SAS) business.

Winning suppliers represent less than 1% of the SAS supply base. Only 39 companies that supply Raytheon SAS received awards.

Winning firms were chosen for meeting demanding standards in quality and delivery performance, customer satisfaction, total business and financial health. Evaluations from Raytheon buyers and material program managers who interact with TriQuint every day were also part of the selection process.

"TriQuint's Defense team is focused on service, quality and highly reliable solutions for phased array radar chipsets and other critical programs," says James L. Klein, TriQuint's VP & general manager for Defense Products and Foundry Services. "Our ISO/AS9100 foundry continually strives to offer the best technology in the industry in order to enable customers' leading-edge applications," he adds.



**From left to right: Janet Duffey, Raytheon VP for SAS Supply Chain Management; Tony Balistreri, TriQuint marketing director; James L. Klein, TriQuint VP & general manager of Defense Products and Foundry Services; and Bob Lindeman, Raytheon VP for SAS Mission Assurance.**

TriQuint GaN, GaAs and SAW/BAW technologies have made it a leading supplier of RF system components and foundry services to Raytheon and other defense/aerospace contractors. It supports multiple GaN process and manufacturing development programs funded by DARPA as well as US Air Force, Army and Naval labs. Integrated assembly capabilities and MMICs continue to expand its global market reach. TriQuint is a Category 1A Department of Defense (DoD)-accredited 'Trusted Foundry' for GaAs/GaN.

[www.triquint.com/defense](http://www.triquint.com/defense)

## Anadigics receives 2011 Best Comprehensive Performance Supplier Award from ZTE

Wireless communications equipment and network provider ZTE Corp of Shenzhen, China has awarded RF and mixed-signal semiconductor maker Anadigics Inc of Warren, NJ, USA its 2011 Best Comprehensive Performance Award for its "commitment to technological leadership, quality excellence, and superior service". Anadigics supplies ZTE with 3G and 4G power amplifiers.

"Through a combination of industry-leading products, outstanding

applications support, and impeccable quality, we were able to surpass the performance of more than 1000 suppliers to receive the award," says Michael Canonico, Anadigics' senior VP of worldwide sales. "Anadigics views this event as another milestone in our successful relationship, and we look forward to continue working closely with the talented team at ZTE," he adds.

[www.zte.com.cn](http://www.zte.com.cn)  
[www.anadigics.com](http://www.anadigics.com)



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# Skyworks' 17% year-on-year revenue growth beats guidance

## Synergy from AATI acquisition to aid margin recovery in June quarter

For its fiscal first-quarter 2012 (to end-December 2011), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures linear products, power amplifiers, front-end modules and radio solutions for handset and infrastructure equipment) has reported revenue of \$393.7m, down 2% on last quarter's record \$402.3m but up 17% on \$335.1m a year ago (and exceeding guidance of \$390m). The 10%-customers were Foxconn, Samsung and Nokia. Of total revenue, 70% was for handsets and 30% for high-performance analog (HPA) products.

During the quarter, Skyworks ramped GPS low-noise amplifiers across leading smart-phone OEMs; started volume production of advanced antenna switch modules (ASMs) for China's Huawei Technologies; was awarded TDD-LTE base-station switch design wins at Ericsson; supported leading tablets, gaming consoles and LED TVs with connectivity solutions; captured wireless networking sockets within General Electric's smart appliances (including washers, dryers, refrigerators, dishwashers and ovens); and secured designs within Medtronic's next-generation heart monitor/pacemaker and 2-way radio applications. The firm also received the 2011 Global Partnership award from Chinese telecom equipment firm ZTE.

On a non-GAAP basis, gross margin has fallen from 44.7% last quarter to 44.3%. Operating expenses have been cut back slightly from \$70.3m to \$69.3m. Net income was \$96.2m, down from \$103.8m last quarter but up from \$84.7m a year ago.

Cash flow from operations was \$77m (well below last quarter's record \$122.8m). Capital expenditure has been reduced again, from

\$33m a year ago and \$15.3m last quarter to just \$6.4m (compared with depreciation of \$17.3m). Free cash flow was hence \$70.8m (down from last quarter's \$108m, but well above \$41m a year ago).

During the quarter, Skyworks repurchased 750,000 shares of its common stock and \$9m of its convertible debt. Overall, cash and cash equivalents rose from \$410.8m to \$446.5m (almost back to the \$450m of a year ago).

"Skyworks' solid performance against the current economic backdrop is being driven by our expanding positions in adjacent analog semiconductor markets, global demand for mobile internet applications and strong operational execution," says president & CEO David J. Aldrich. "More specifically, we are capitalizing on new opportunities in medical, automotive, smart energy and home automation markets while capturing additional content and share within LTE smart-phones, e-readers, tablets and LED TVs... while the economic climate has created challenges in some of our segments, we saw a healthy holiday season demand across all categories of mobile Internet devices," he adds. "As a result, Skyworks' ongoing diversification and scale are positioning us to deliver above-market growth and, ultimately, create greater competitive advantages."

**We are capitalizing on new opportunities in medical, automotive, smart energy and home automation markets while capturing additional content and share within LTE smart-phones, e-readers, tablets and LED TVs**

After the close of the quarter (on 10 January), Skyworks completed its acquisition of Advanced Analogic Technologies Inc (AATI) of Santa Clara, CA for about \$200m in net cash. AnalogicTech is an analog semiconductor firm focused on energy-efficient devices for the application-specific power management needs of feature-rich consumer electronic devices (such as mobile handsets, digital cameras, tablets, notebooks, TV and LCD displays) as well as devices for computing, industrial, medical and communications applications. "We elected to pursue an all-cash structure of this transaction in order to avoid issuing equity," says VP & chief financial officer Donald W. Palette. Skyworks also retired its remaining \$17m of outstanding debt.

"Based on our diverse customer and market base as well as share gains, we are planning to outperform our addressable markets in the seasonally low March quarter," says Palette. Specifically, for fiscal second-quarter 2012 Skyworks expects revenue of \$360m, including \$14m from a partial-quarter contribution from AATI (for which the full December-quarter revenue was \$15.7m). "While we are forecasting AATI to be neutral to second fiscal quarter earnings, we expect the acquisition to be accretive for fiscal year 2012," says Palette.

Due to the seasonally lower revenue base, gross margin should fall to 43-43.5%. However, this should improve in fiscal Q3 (to end-June) as sequential revenue growth resumes and as Skyworks realizes synergies associated with the AATI acquisition. Including AATI, operating expenses should rise to \$74-75m. "CapEx should remain below depreciation levels until fiscal second-half 2012 as we increase volumes," notes Palette.

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

## Skyworks completes tender offer for remaining AATI shares

Skyworks Solutions has completed the tender offer by its subsidiary PowerCo Acquisition Corp for all the outstanding shares of common stock of Advanced Analogic Technologies Incorporated (AATI) of Santa Clara, CA for \$5.80 per share (paid in cash, without interest and subject to any required withholdings of taxes).

AnalogicTech is an analog semiconductor firm focused on enabling energy-efficient devices for the application-specific power management needs of feature-rich consumer electronic devices (e.g. mobile handsets, digital cameras, tablets, notebooks, TV and LCD displays) and devices in a range of computing, industrial, medical and communications applications. The firm also licenses device, process, package, and application-related technologies. Assets include design centers in Santa Clara and Shanghai, plus Asia-based operations and logistics.

A total of 42,861,222 shares of AATI's common stock was tendered (including 5,096,232 delivered pursuant to guaranteed delivery procedures). Assuming all shares tendered pursuant to guaranteed delivery procedures are delivered, 96.7% of all outstanding shares have been tendered (or 85.2% excluding guaranteed delivery shares).

To complete the acquisition of 100% of AATI's common stock, Skyworks will effect — without prior notice to, or any action by, any other AATI stockholder — a short-form merger in which PowerCo Acquisition Corp will merge with and into AATI, with AATI surviving the merger and continuing as a wholly owned subsidiary of Skyworks.

PowerCo Acquisition Corp has hence notified AATI of its intent to exercise its option under the merger agreement to purchase sufficient newly issued AATI shares to ensure ownership of at least 90% of the outstanding AATI shares to complete the short-form merger.

Each of the remaining untendered shares of AATI stock (other than shares as to which appraisal rights are properly demanded and perfected under Delaware law, if any) will be converted into the right to receive the same \$5.80 per share as was paid to AATI stockholders pursuant to the tender offer.

Following the merger, instructions will be mailed to AATI stockholders that did not tender their shares, outlining the steps to be taken to obtain the merger consideration. Subsequent to the merger, AATI's common stock no longer be traded on the NASDAQ Stock Market.

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

## Global Partnership Award from ZTE

Skyworks Solutions has received the 2011 Global Partnership Award from ZTE Corp for excellence in performance and worldwide cooperation. Skyworks was the only RF firm honored with this achievement.

As a global provider of telecoms equipment and network solutions, ZTE leverages multiple Skyworks' products including EDGE and WCDMA/LTE front-end solutions for data cards and USB modems, TD-SCDMA and CDMA solutions for

handsets, as well as antenna switch modules for several smart phone platforms. ZTE also uses several custom high-performance analog solutions from Skyworks for infrastructure and WLAN applications.

"Skyworks' commitment to customer satisfaction and working closely together as a partner has helped ZTE achieve our growth goals and deliver best-in-class solutions to customers in 140 countries around the globe," says ZTE.

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

## IN BRIEF

### GigOptix launches surface-mountable microwave filters

III-V-based semiconductor and optical components supplier GigOptix Inc of San Jose, CA, USA has launched a line of microwave filters for use in point-to-point wireless backhaul, EW (electronic warfare), radar, test & measurement equipment applications.

Available in a number of frequency ranges including 26, 38 and 42GHz (with frequency customization available), the microwave filters are now in production and shipping to tier-1 telecom suppliers.

Key features include:

- small factor surface-mounted technology (SMT) solution providing superior and consistent performance over traditional larger PCB print implementations;
- lower insertion loss (typically better than 3dB);
- excellent rejection (typically better than 20dB); and
- ability to support either band-pass or band-stop implementations.

"With the increasing pressures on our customers to accelerate time to market and reduce system size, our microwave filters enable customers to not only simplify their microwave system implementations but also reduce size using our small-factor SMT device that provides superior performance at a competitive price," claims Padraig O'Mathuna, general manager & VP of the RF Microwave product line.

"Moreover, our filters can be customized to enable customers to further optimize their system performance if required."

The microwave filters are available in a 7mm x 7mm QFN package and are designed to be fully compatible with industry-standard SMT processes. Production samples are available now.

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



## IN BRIEF

## Microsemi receives Strategic Partner award from FiberHome

Microsemi Corp of Aliso Viejo, CA, USA, a provider of semiconductor solutions differentiated by power, security, reliability and performance, has received FiberHome Telecommunication's 'Strategic Partner' award for the second consecutive year, in recognition of its outstanding product quality, customer service, technical support and for meeting product delivery schedules.

FiberHome Telecommunication Co Ltd is one of China's largest providers of fiber-optic and communications equipment. Microsemi received the award in December at FiberHome's 2011 supplier conference in Wuhan, China.

"Receiving this prestigious award illustrates our commitment to developing innovative solutions that provide our customers with a competitive edge, backed by superior service and support," says Rick Goerner, Microsemi's senior VP of worldwide sales. "I want to commend the Microsemi team for their continued hard work and dedication," he adds.

"Microsemi shares our devotion to continuously delivering high quality in all areas of operation," says FiberHome VP He Jianming. "We look forward to further strengthening our relationship with Microsemi in the future."

Microsemi's communications portfolio includes: network and timing solutions; voice-over-IP, FTTX and DSL products; wireless LAN and RF integrated circuits; and power management, conversion and delivery devices. The firm also offers sense and control solutions, as well as Power over Ethernet (PoE) integrated circuits and midspans.

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

## Microsemi launches SiGe platform for 4G RF front-end module development

Microsemi of Aliso Viejo, CA, USA has announced its technology platform for 4G RF front-end modules (FEMs) based on silicon germanium (SiGe) technology. The firm is already developing next-generation IEEE 802.11ac wireless local-area network (WLAN) FEMs on the new platform. IEEE 802.11ac is now being referred to as fifth-generation WiFi (or 5G WiFi) by the industry, notes Microsemi.

The new platform integrates multiple filters, switches, low-noise amplifiers (LNAs) and power amplifiers onto a single monolithic SiGe die, and supports multiple input/multiple output (MIMO) functionality. The high level of integration allows substantial reductions in cost and printed circuit board footprint (key considerations when designing devices such as smartphones and tablets).

"Microsemi has developed what we believe to be the world's first silicon germanium-based, single-chip RF front-end module platform capable of meeting the stringent requirements of 4G applications while still offering space and cost savings," says Darcy Poulin, director of product engineering.

According to ABI Research, IEEE 802.11ac shipments will increase significantly in 2013, with 802.11ac emerging as the dominant Wi-Fi protocol by 2014. Industry research firm In-Stat estimates

that nearly 350 million routers, client devices and attached modems with 802.11ac will ship annually by 2015, up from about 1 million units in 2012.

"The first-of-its-kind digital tuning capability we have designed will reduce future development times and customization efforts as we engage our baseband partners," says senior VP Paul Pickle. "In addition, the performance achieved will enable Microsemi to drive innovation into the latest wireless LAN standard, IEEE 802.11ac, as well as the next-generation 4G mobile standard," he adds.

Microsemi's RF front-end-module includes two fully functional 2.5GHz IEEE 802.16 power amplifiers, two transmit/receive switches, two LNAs, two baluns, harmonic and noise shaping filters, and a digital interface for control and tuning. Its performance meets the strict 802.16 mask and EVM requirements at an output power of 24dBm in a 5mm x 5.6mm package.

The firm's next-generation wireless LAN dual-band FEM will be able to integrate highly linear 802.11ac-compliant 2.4GHz and 5GHz PAs, 2.4 and 5GHz bypassable LNAs, switches, filters, a diplexer and an I2C digital interface into a 3mm x 4mm QFN package.

Microsemi has previously shipped over 200 million RFICs globally, mainly for the wireless LAN market.

## Folsom facility AS9100:2009 Rev C certified

Microsemi's RF Integrated Solutions (RFIS) facility in Folsom, CA has achieved compliance with new AS9100:2009 (Rev C) quality system requirements for aviation, space and defense markets, which has increased focus on program and risk management, intensive supply chain management controls, and facility-wide continuous improvement activities that include

on-time delivery and product conformity measurement processes.

The AS9100 standard is an additional requirement that requires a facility to first be compliant with the ISO 9001:2008 quality management standards for systems and processes. The quality system assessment was conducted by Det Norske Veritas Inc (DNV), an ANAB-certified third-party registrar.

## Nocilis launches Si- and SiGeSnC-based epi foundry

Nocilis Materials AB of Kista, near Stockholm, Sweden — which was spun off from the Royal Institute of Technology (KTH) in 2011 — is launching its foundry service to provide silicon-based materials worldwide.

Founded by Dr Henry Radamson and entrepreneur Bo Hammarlund MSc and based on expertise built up over many years of research and technical studies in silicon processing and device fabrication, Nocilis provides epitaxy of advanced silicon germanium tin carbon (Si-Ge-Sn-C) alloys for both electronic and photonic applications. Applications include niches in infrared (IR) and terahertz (THz) uncooled detectors and thermoelectric structures based on group IV materials. Nocilis claims to be the first dedicated foundry for supplying advanced Si-based compound materials.

The epitaxial growth technique used by Nocilis is reduced-pressure chemical vapor deposition (RPCVD), and the epitaxial layers provided (on 4", 6" and 8" substrates) are:

- P-, As- and B-doped Si and SiGeSnC layers (with doping levels of  $10^{15}$ – $10^{19}$ cm<sup>-3</sup> in Si, but dependent on the specific material design for Si alloys);
- selective epitaxy of doped and undoped SiGeC layers on patterned substrates;
- multilayer structures (superlattices) of Si-or Ge-based materials;
- Ge (unstrained) on Si;
- compressive- and tensile-strained SiGe layers;
- strained Si on relaxed SiGe layers; and
- tensile-strained Ge layers (on-going).

Nocilis says that further services can be provided for material characterization of epitaxial films, including:

- high-resolution scanning electron microscopy (HRSEM), in both planar and cross-sectional view; and
- high-resolution x-ray diffraction (HRXRD).



In addition, analyses techniques including reciprocal lattice mapping (RLM), grazing angle measurement, strain measurement and layer profiling over the substrate area can provide information on the interfacial roughness, composition and strain (in-plane and perpendicular to the plane).

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

**Pictured left: Co-founders Dr Henry Radamson (right) and CEO Bo Hammarlund (left).**

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## SEMATECH and Dainippon Screen collaborate to develop abrupt, ultra-shallow junction formation

### Sub-14nm silicon and non-silicon high-mobility materials targeted

International semiconductor manufacturers' research consortium SEMATECH of Albany, NY, USA has entered into a partnership with Japan-based semiconductor equipment maker Dainippon Screen Mfg Co Ltd to accelerate development and commercialization of advanced semiconductor doping technology. SEMATECH and Dainippon Screen will collaborate on techniques for monolayer doping and activation methods that are compatible with ultra-shallow junctions for planar and non-planar device technologies (e.g. FinFETs, nanowires, memories) in silicon and non-silicon high-mobility materials.

To achieve faster transistor speeds and lower power dissipation, device fabrication will require solutions to minimize leakage resulting from process damage and electrostatic

control. Ultra-shallow, abrupt, damage-free junctions with high active dopant concentrations are essential for better off-state leakage control in highly scaled nano-electronics. With the advent of non-planar device architectures and high-mobility compound semiconductors, doping conformality and minimal lattice damage are increasingly important, and cooperative research is needed to meet the demands of the International Technology Roadmap for Semiconductors (ITRS). A defect-free and conformal doping alternative — monolayer doping — will be investigated and then developed for commercial use.

"This alliance could be a key driver for improving annealing processes and address associated defect issues for manufacturers to continue scaling of CMOS devices,"

says Tadahiro Suhara, president of the Semiconductor Equipment Company at Dainippon Screen.

"This partnership with Screen is a key component of our overall strategy to develop critical infrastructure needed for major industry transitions," says SEMATECH's president & CEO Dan Armbrust. "Innovative process technologies like monolayer doping are essential to enable transitions to non-planar and to non-silicon high-mobility channels, while minimizing processing-induced damage, cost and complexity," he adds. "SEMATECH and Screen will combine our strengths and technical insights to bring innovative solutions for next-generation device manufacturers."

[www.screen.co.jp](http://www.screen.co.jp)

[www.sematech.org](http://www.sematech.org)

## NXP's SiGe LNA enhances reception and range of NorthVu's indoor digital TV antenna

NXP Semiconductors N.V. of Eindhoven, Netherlands and NorthVu Systems Inc of Ottawa, Canada have collaborated to bring to market the smallest high-performance indoor digital TV antenna. It is claimed that the NorthVu NV20 Pro is 40% smaller than comparable products while delivering superior reception and range, enabling consumers to enjoy digital HD broadcast TV (over-the-air or digital terrestrial TV).

At just 8.1" x 5.25" x 1.85", the NV20 Pro receives digital 1080p HD TV signals directly off-air, and it features an integrated low-noise amplifier (LNA) based on NXP's BFU760F silicon-germanium (SiGe) low-noise transistor, enhancing the quality and reliability of the signals.

The BFU760F is a member of NXP's family of bipolar SiGe and SiGe:C LNA devices, which offer what is

claimed to be exceptional RF noise figure versus gain performance, while drawing very low current. This performance allows for better signal reception at low power and enables RF receivers to operate more robustly in noisy environments. They also have the advantage of better ESD robustness over competing GaAs LNA solutions, NXP adds.

NorthVu incorporated NXP's low-noise transistor technology into the NV20 Pro to increase signal range to 35 miles and improve overall picture reception. Optimized to receive VHF, UHF and digital FM signals, users can receive a wide selection of digital broadcast TV channels on a device that is compact and discrete

"This product is a great validation of our expertise in the small-signal, low-current requirements of wide-

band applications," says Erick Olsen, marketing director for RF small signal at NXP. "The combination of NorthVu Systems' patent-pending technology with our industry-proven LNA solution has delivered a high-performance digital TV antenna in an industry-first compact form-factor. The exceptional performance parameters of the BFU760F — such as ruggedness, reliability, low noise and high level of integration — make it an ideal solution for this type of innovative RF product," he adds.

"NXP also did a great job of supporting us throughout the development of the NV20 Pro, quickly delivering multiple amplifier design iterations as we fine-tuned the design specifications for the product," comments president Spenser Williams.

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

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



## Javelin adds to Band 1 CMOS PAs with 3G Band II PA

Javelin Semiconductor Inc of Austin, TX, USA recently unveiled its JAV5502 3G Band II power amplifier (PA), the newest member of its CMOS PA product family. Samples are available now, with volume shipments beginning in March.

Based on the patented architecture of Javelin's Band I PAs, the JAV5502 brings low power consumption, low noise, high performance and high reliability to Band II applications targeting American markets and world phones. Like all members of Javelin's PA family, the JAV5502 is offered in an industry-standard 3mm x 3mm package and is software-compatible with all 3G baseband platforms, simplifying adoption into a broad range of wireless applications including smartphones, tablets, e-readers, WCDMA modules and modems.

"Our Band I PAs are gaining broad acceptance in smartphones for Asian and European markets, and adding the JAV5502 to our portfolio



**Javelin's family of 3G CMOS power amplifiers.**

will accelerate this transition," reckons president & CEO Brad Fluke. "Customers recognize the inherent supply assurances of Javelin's CMOS implementation, plus their products' battery life and performance is improved by Javelin's low power consumption and ultra-low noise," he adds.

Javelin claims that its PAs, measured in actual handsets, have achieved excellent linearity and the best noise performance of any 3G PA currently on the market, which

improves overall handset performance by minimizing interference with other 3G, GSM, GPS, WLAN and Bluetooth radios in smartphones. The firm also claims that its PAs feature the highest ESD rating in the industry (passing 3kV on all pins), enabling higher manufacturing yields. In addition, with CMOS integration, the JAV5502 is the first PA to support a MIPI digital interface for advanced features including power control.

Javelin holds 16 patents on its architecture, and claims to be the first firm to produce a 3G PA in standard CMOS that meets or exceeds all stringent industry performance and reliability standards. The JAV5502 integrates complete circuitry for power regulation, PA bias, input and output matching, and power control. It also requires no custom software development, enabling a simple design-in process.

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

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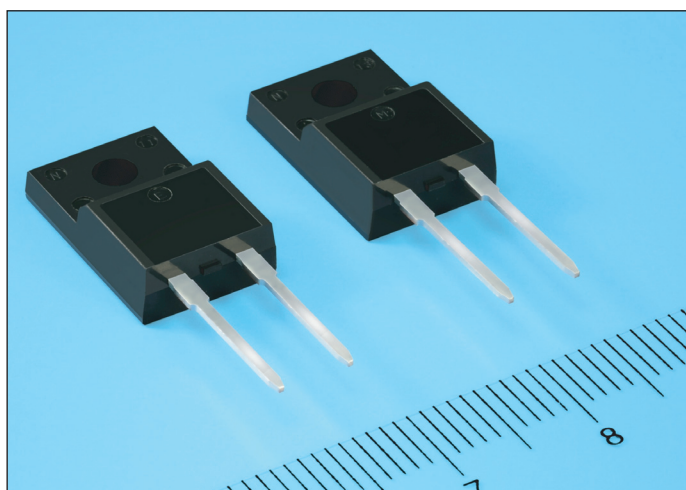
# Renesas samples low-loss SiC power devices integrating power conversion circuit on-chip

Tokyo-based Renesas Electronics has developed the RJS6005TDPP Schottky barrier diode (SBD), which uses silicon carbide (which the firm considers to have great potential for use in power semiconductor devices).

The new SiC Schottky barrier diode suits use in high-output electronic systems such as air conditioners, communication base-stations, and solar power arrays. It also incorporates technology (developed jointly by Renesas and Hitachi Ltd) that contributes to reducing power consumption by about 40% compared with Renesas' existing power devices based on conventional silicon (Si).

Recently, driven by environmental concerns, demand has grown for more efficient power supply circuits in many types of systems, particularly regarding power conversion in products using power switching circuits or inverter circuits enabling precise motor control (such as air conditioners, communication base-stations, PC servers, and solar power arrays). The diodes used in these power converter circuits therefore need to provide faster switching speeds and low-voltage operation. Renesas developed the new SiC SBD to address these demands.

The new SiC Schottky barrier diode has a reverse recovery time (the time required to recover to the prescribed current value after switching to the off state) of 15ns (standard value: measuring conditions  $I_F = 15A$ ,  $di/dt = 300A/\mu s$ ). This is about 40% faster than that of existing silicon-based Renesas products (enabling faster switching speed and reducing power loss by about 40%). In addition, the reverse recovery time does not degrade when the temperature rises, which enables consistently low switching loss when the device is operating in high-temperature environments.



**Renesas' low-loss SiC power devices.**

The new SiC-SBD has a voltage rating (forward voltage,  $V_F$ ) of only 1.5V, which is lower than that of existing Si fast-trigger diode products. In addition, the temperature dependency of this characteristic is small, ensuring that a stable forward voltage can be obtained even under high-temperature conditions, so more compact heat dispersion measures can be used.

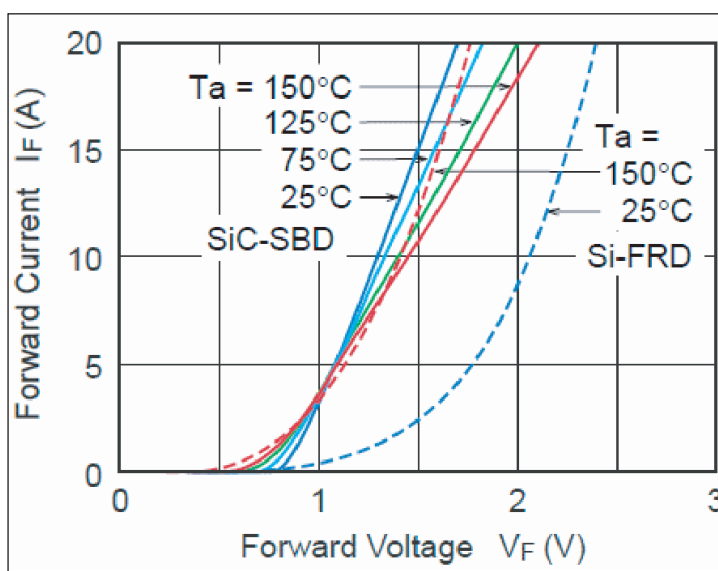
The RJS6005TDPP uses a package equivalent to the industry-standard fully molded TO-220, with which it is also pin compatible, so it can easily be used as a replacement for conventional silicon diodes on

existing printed circuit boards.

Renesas has a line-up of 3–30A power devices (with voltage tolerance of 600V) designed to meet the need for better energy efficiency in high-output systems such as air conditioners, communication base-stations and solar power arrays.

Also, plans call for the introduction of a series with a voltage tolerance of 1200V.

Renesas aims to provide solutions combining MCUs (microcontroller units) and analog & power devices, and also to become the leading power device supplier. The firm plans to enhance its kit solutions and compound semiconductor devices, with the new high-voltage SiC-SBD power devices at the core, supplemented by peripheral power supply control ICs, high-performance IGBTs (insulated gate bipolar transistor), high-voltage super-junction MOSFETs, and photocouplers.



**Temperature dependence of the forward voltage of the RJS6005TDPP Schottky barrier diode.**

Samples of the RJS6005TDPP are available now, priced at \$5 per unit. Mass production is scheduled to begin in March and is expected to reach a volume of 100,000 units per month by August.

Pricing and availability are subject to change without notice.

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

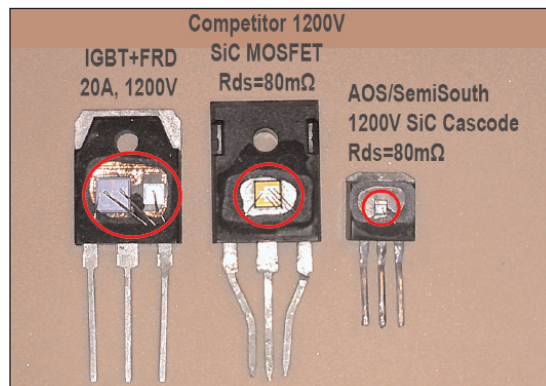
# Alpha and Omega Semiconductor and SemiSouth demonstrate 1200V Si/SiC stack-cascode MOSFETs

Power semiconductor designer Alpha and Omega Semiconductor Ltd (AOS) of Sunnyvale, CA, USA and SemiSouth Laboratories Inc of Starkville, MS, USA (which designs and manufactures silicon carbide devices for high-power, high-efficiency, harsh-environment power management and conversion applications) have jointly demonstrated UniSiC, a 1200V, 90m $\Omega$  MOSFET in a TO262 package, to meet the growing need for energy-efficient switching devices for high-performance power conversion applications in the alternative energy, industrial and consumer segments. The firms claim exceptional figures-of-merit and reduction in form factor for the 1200V MOSFET device.

AOS says that it continues to execute its strategy to be a full-service power solution provider by extending its portfolio of AlphaMOS MOSFETs and AlphaIGBT silicon devices with the new 1200V MOSFET.

The UniSiC device is formed by stacking a low-voltage Si MOSFET atop a normally-on SiC JFET (from SemiSouth). The low-voltage MOSFET is specially engineered to allow optimal operation of the composite device with clean switching, and low Rdson and gate charge. It is intended to provide great ease of use (working with standard drive circuitry) and to drastically improve circuit efficiencies over the whole range of load current.

The UniSiC MOSFET provides what is claimed to be unprecedentedly low Rdson and gate charge Qg, an excellent body diode with virtually no stored charge, and a low diode forward voltage drop. The device may be used similarly to a conventional MOSFET or IGBT, with standard gate drives, and is engineered so it can be switched over a wide speed range (as fast as a super-



**Die sizes of a 1200V IGBT with co-packaged diode, a competitor 1200V SiC MOSFET, and AOS' UniSiC stack-cascode device.**

junction MOSFET or as slow as an IGBT). The device has what are claimed to be far superior characteristics compared to existing IGBTs, silicon power MOSFETs or even the best competitive SiC 1200V MOSFET. In addition, the small die size shows the potential for future miniaturization of power circuits, given how much it cuts conduction and switching losses.

"Using the superb characteristics of SiC JFETs for high-voltage applications, and solving the switching problems that have plagued cascode devices in the past, AOS is in a position to offer the power electronics community a dream switch," claims Dr Anup Bhalla, VP of High-Voltage Discretes at AOS. "The devices can be used like conventional discrete IGBTs and FETs using the same gate drives, allowing the user to realize huge efficiency gains without too much re-engineering," he adds.

"First released in 2008, we have seen our JFET products gain rapid adoption in the market, and this first-ever stack-cascode demonstration from AOS really takes the performance and ease of use to the next level," says SemiSouth's president & chief technology officer Dr Jeff Casady.

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

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

## IN BRIEF

### Low-profile SiC MOSFET modules with multiple circuit topologies

Powerex Inc of Youngwood, PA, USA has launched two split dual silicon carbide (SiC) MOSFET modules (QJD1210010 and QJD1210011) designed for use in high-frequency power applications.

Created with a low profile and multiple circuit topologies (including independent, dual, in parallel, common collector, and common emitter), each module consists of two MOSFET SiC transistors, with each transistor having a reverse-connected Zero Recovery free-wheel SiC Schottky diode made by Cree Inc of Durham, NC. All components and interconnects are isolated from the heat-sinking baseplate, offering simplified system assembly and thermal management.

Rated at 100A/1200V, the modules incorporate two individual switches, each featuring a junction temperature of 175°C, low internal inductance and capacitance, and what is claimed to be industry leading  $R_{DS(on)}$ . As well as having high power density, this allows high-speed switching with low switching losses and low drive requirements. The isolated baseplates are copper on the QJD1210010 and (for extended thermal cycle life) AlSiC on the QJD1210011.

The modules can be used in high-frequency applications including: energy-saving power systems (such as fans, pumps and consumer appliances); high-frequency-type power systems (such as UPS, high-speed motor drives, induction heating, welding and robotics); and high-temperature power systems (e.g. power electronics in electric vehicle and aviation systems).

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



# TriQuint begins Phase II of 'NEXT' program

RF front-end product and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has begun work on Phase II of the Defense Advanced Research Projects Agency (DARPA) multi-year Nitride Electronic NeXt-Generation Technology (NEXT) program as a prime contractor. The firm has received \$12.67m in support of the NEXT contract to date.

NEXT was created by DARPA to research and develop devices suitable for complex, high-dynamic-range mixed-signal circuits for future defense/aerospace applications. Phase II of the program is contracted to last 18 months.

TriQuint is already exploring and bringing to market derivative devices made possible by breakthroughs demonstrated in Phase I. "NEXT devices provide game-changing technology for substantially improving performance in applications like phased array radar and communi-

cations," says James L. Klein, TriQuint VP & general manager for Defense Products and Foundry Services. "The devices developed under 'NEXT' open up applications for lower-voltage GaN-based products, which achieve power densities at least four times higher than GaAs devices," he adds.

At the 2011 GOMACTech conference in Orlando, FL last March, the team of TriQuint senior fellow Dr Paul Saunier (who leads the NEXT program as principal investigator) reported a cut-off frequency ( $f_T$ ) of more than 240GHz in a GaN circuit ('State-of-the-Art E/D GaN Technology Based on an InAlN/AlN/GaN Heterostructure'), which was twice that of the previous record of 120GHz.

DARPA's NEXT Phase I concentrated on fabricating very high-frequency devices and meeting defined yield metrics. Phase II will concentrate on process development in the pursuit of increased

yields while pushing the operating frequency to 400GHz. Phase III will seek to extend the operating frequency to 500GHz with still higher yields and reduced circuit size. NEXT research also focuses on highly scaled enhancement-depletion (E/D)-mode GaN mixed-signal devices, similar to those used in gallium arsenide E/D MMICs. TriQuint says it creates the latter with integrated digital control functionality and power handling for greater efficiency and cost-effectiveness.

Beyond NEXT, TriQuint is working on enhancement-mode power switching devices that are needed for ultra-high-efficiency DC-DC converters integrated with RF amplifiers for radar, communications and electronic warfare (EW) systems. The technology is enabling greater sensitivity, while reducing prime power and cost, says the firm.

[www.triquint.com/defense](http://www.triquint.com/defense)

[www.darpa.mil/MTO](http://www.darpa.mil/MTO)

## Agilent announces availability of Mitsubishi Electric's nonlinear RF model library for ADS

Agilent Technologies Inc of Santa Clara, CA, USA says that the latest model library for Mitsubishi Electric's nonlinear GaAs and GaN RF devices is now available for use with Agilent's Advanced Design System (ADS) electronic design automation (EDA) software for communications applications.

The upgraded library works seamlessly with ADS 2009 Update 1, as well as prior ADS releases. ADS2011 and future versions will also be supported. The model can be obtained by contacting Mitsubishi Electric.

The new ADS model library includes high-power GaN HEMT and low-noise HEMT devices that are commonly used in base-station and direct-broadcast satellite receivers as well as other radio communications equipment. The library helps

designers better explore design alternatives in order to meet demanding performance specifications with a cost-effective solution.

The library includes an ADS symbol for schematic capture, a simulation model that includes parasitic effects. It also covers a broad variety of body sizes and part values that enable sweeps and optimizations.

"Collaborating with a recognized world leader in design software allows Mitsubishi Electric to support and leverage its high-power and low-noise HEMT device offering," says Takao Ishida, manager of the wireless communication device application engineering section at Mitsubishi Electric's High Frequency and Optical Device Works. "We are very pleased to offer our design kit to help support ADS users," he adds.

"The combination of ADS and the Mitsubishi Electric library gives our mutual customers a powerful, integrated design solution for a fast and efficient RF design flow," says Juergen Hartung, foundry program manager of Agilent's EESof EDA organization. "Our customers are now able to enjoy the industry's most comprehensive multi-technology design platform with the breadth of simulation capability in ADS, including yield optimization, DFM tools and the Momentum 3-D planar EM simulator."

Users can generate X-parameter models of their circuit-level designs directly from ADS. X-parameters provide fast and accurate behavioral modeling, vital to designing high-performance RF modules and RF system-in-package components.

[www.agilent.com/find/eesof-ads](http://www.agilent.com/find/eesof-ads)



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## **IQE reports year-on-year growth in revenue and profits**

### **Strong first-half 2011 outweighs second-half inventory corrections**

In a trading update for full-year 2011, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that it expects revenue to exceed £75m, up on 2010's £73m.

Earnings before interest, tax, depreciation and amortization (EBITDA) is expected to increase from last year's record £12.6m to at least £13.7m. Net debt is expected to be less than £4m.

"2011 has been another positive year for the group, with increased sales and profits to record levels, despite challenging supply chain and macro-economic conditions," says chief executive Dr Drew Nelson. "Our core business of wireless-related products for all forms of mobile communications is performing as expected, whilst new and emerging products for consumer, industrial and defence applications are generating demand across all our key markets," he adds.

Sales grew rapidly in first-half 2011, driven by strong double-digit growth in the wireless and optoelectronics divisions. Growth in wireless sales reflected the increasing adoption and sophistication of portable devices such as smartphones and tablets using gallium arsenide, and the increasing adoption of gallium nitride technology in high-power wireless applications such as radar and infrastructure, says IQE. Growth in optoelectronic sales was

driven by a wide variety of applications including consumer, industrial and high-efficiency solar power applications.

As announced in October, second-half 2011 sales were adversely affected by inventory corrections in the supply chain related to market share swings amongst a couple of IQE's key customers. These inventory corrections have unwound as expected, and should be fully resolved by the end of first-quarter 2012.

IQE says that its long-standing strategy to qualify multiple products with multiple customers across the entire supply chain went some way toward offsetting the impact of the shifts in market share. As further qualifications complete, the future impact of market share shifts will continue to diminish, the firm says.

New product qualifications have progressed well, with significant milestones now achieved, IQE notes. The firm has qualified its BiHEMT product with one of the top three Japanese mobile chip makers, which has recently announced a major expansion programme in the smartphone market. Sales under this qualification have started to ramp, and this customer is expected to move into IQE's 'top 10' during second-half 2012.

IQE is also in the final stages of qualification of BiHEMT products

with two of the leading wireless chip manufacturers globally and expects to ramp into production during second-quarter 2012. In addition, the firm is qualifying a number of next-generation wireless products with a significant number of customers.

Business is also being driven by increasing demand across IQE's other core markets including advanced semiconductor materials for optoelectronic products, which continued to enjoy strong growth driven by a range of existing and emerging end-market applications that are expected to account for an increased proportion of IQE's full-year 2012 revenue.

"We have added to our manufacturing capacity during the year and expect to benefit strongly from some significant operational achievements including best-in-class quality improvements to our products," says Nelson. "This will enable improved customer output and increased throughput from our own production tools and lead to continued improvements in operational and financial metrics," he adds.

"The board remains confident that IQE is well positioned to build further on its robust business model and powerful market position to deliver strong growth in 2012 and beyond," Nelson concludes.

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

## **Tegal sells nanolayer deposition technology portfolio; Cu barrier and low-k dielectric patents still under auction**

Tegal Corp of Petaluma, CA, USA has awarded patents to multiple bidders for three of the four bid lots of its nanolayer deposition technology (NLD) patent portfolio, which was offered for sale last September for a total of about \$4m. To date, about \$3.6m has been received.

Tegal sold over 30 patents from the NLD portfolio — which includes over

35 US and international patents in pulsed chemical vapor deposition (CVD), plasma-enhanced atomic-layer deposition (ALD) and NLD.

In March 2010, Tegal sold its legacy thin-film etch and physical vapor deposition (PVD) product lines to OEM Group Inc of Gilbert, AZ, USA, and in February 2011 it sold its deep reactive ion etch (DRIE)

assets to SPTS Technologies Ltd of Newport, Wales, UK.

Discussions are ongoing for Lot 4 of the portfolio, which applies to copper barrier and low-k dielectric technology. Interest is coming mainly from IC device makers, whereas interest in Lots 1 to 3 was driven by equipment makers, says Tegal.

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



## AXT to establish second substrate-making plant in China

### \$12.5m investment in constructing Tianjin plant over next two years

AXT Inc of Fremont, CA, USA, which makes gallium arsenide, indium phosphide and germanium substrate and raw materials, has agreed with the Administrative Commission of Tianjin Economy and Technology Development Zone to establish a second manufacturing facility in Tianjin, China. The arrangement provides AXT with land use rights for about 32 acres of industrial land in Yixian Scientific and Industrial Park to construct a compound semiconductor substrate manufacturing facility that would be completed in phases by 2017.

AXT has committed to a \$12.5m investment in the construction of the facility over the next two years in exchange for land use rights,

enterprise and individual income tax rebates, employee hiring and development subsidies, and other benefits. The facility should provide AXT with substantial substrate manufacturing capacity expansion, complementing its current 190,000ft<sup>2</sup> facility in Beijing.

"We are very pleased for the opportunity to begin planning our future expansion in such a vibrant and dynamic area of China," says CEO Morris Young. "While our current facility in Beijing continues to provide us with ample capacity to grow our business for the next 18–24 months, we believe that a second manufacturing facility in Tianjin will provide us with additional capacity for many years to

come, particularly in light of positive trends in the demand for wireless devices, the proliferation of LEDs, and the adoption of photovoltaic technology," he adds.

"The positive financial considerations of this arrangement, coupled with what we believe to be our longer-term capacity needs, provide compelling incentives to proceed with our expansion plans at this time," continues Young. "This arrangement allows us to begin planning for growth and redundancy in our business in a measured and incremental way that is suitable both to the current economic conditions and the sizeable opportunity ahead."

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

## NRL's Bennett made American Physical Society fellow

Dr Brian Bennett, a scientist at the US Naval Research Laboratory (NRL), has been named a Fellow of the American Physical Society (APS) in recognition of his "pioneering contributions to the epitaxial growth, characterization, and design of narrow-bandgap semiconductor heterostructures".

Bennett has made key contributions in materials physics over the last two decades. Earlier work included highly cited contributions on electro-optical effects in silicon and III-V compounds as well as self-assembled quantum dots. His main focus over the last several years has been in the design, growth and characterization of antimonide-based heterostructures for application to high-frequency, low-power electronics.

The Naval Research Laboratory claims that Bennett's research (in collaboration with J. Brad Boos and colleagues) has established it as the world leader in this field. His efforts on the design and epitaxial growth of high-electron mobility transistors based on indium arsenide quantum wells and



**Bennett transfers samples into an MBE system prior to growth of InAs quantum wells for high-speed, low-power-consumption transistors.**

antimonide barriers helped to develop a technology that was transferred to industry, leading to the production of low-noise amplifiers operating at ultra-low power for US Department of Defense (DoD) applications.

Bennett received his bachelor's degree (1984), master's degree (1985) and doctorate (1992) all from the Massachusetts Institute of Technology. He served as a military officer in the US Air Force's Solid-State Sciences Division from 1984 to 1988. He has been at NRL since

1992 and currently serves in the Electronics Science and Technology Division as head of the Nanotechnology Section, which includes 12 PhD scientists working on topics including graphene, carbon nanotubes, quantum wires, atomic layer deposition (ALD), and plasmonics. Results of his research have been reported in over 160 archival journal publications and cited over 5000 times. He also holds ten US patents, and has served as an organizer and/or committee member of Electronic Materials Conference since 2000.

Bennett has previously been recognized with an NRL Technology Transfer Award in 2001; an NRL Group Achievement Award in 2004 for transition of Sb-based HEMT technology developed at NRL to Northrop-Grumman Space Technology; an NRL Edison Patent Award in 1998 and 2009; an NRL Berman Publication Award in 1998, 2000, and 2008; and a Navy Top Scientist/Engineer of the Year Award (one of 18 out of 35,000 eligible) in 2009.

[www.nrl.navy.mil](http://www.nrl.navy.mil)

## Albemarle launches Electronic Materials business unit

### TMA and TMI to join TMG metal-organic in new PureGrowth portfolio

Specialty chemical manufacturer Albemarle Corp of Baton Rouge, LA, USA has announced the formation of its Electronic Materials business unit. The new business unit, which is a subgroup of Albemarle's Performance Catalyst Solutions (PCS) division (formerly the Polyolefin and Chemical Catalyst division until November 2011), provides electronic-grade metal organics to the LED, compound semiconductor, and solar panel markets.

"As a producer of metal organics for over half a century, Albemarle has built a solid reputation on chemical expertise and experience," says Amy Motto, VP of Albemarle's PCS division. "With the launch of our Electronic Materials business unit, Albemarle will bring the same high level of quality and competence to the LED and solar markets."

Albemarle's Electronic Materials business has already begun selling commercial quantities of ultra-high-purity trimethylgallium (TMG) and triethylgallium (TEG) under its new PureGrowth brand name. The portfolio will be expanded to include ultra-high-purity trimethylaluminum (TMA) by early 2012 and trimethyl indium (TMI) by mid 2012, likewise for use in MOCVD processing (e.g. in the manufacturing of LED chips for applications such as backlighting in displays and light bulbs).

**By expanding into the electronic-grade metal organic arena, Albemarle will be able to provide a robust portfolio of complementary products and services**

The Electronic Materials business is built upon Albemarle's existing competencies in the electronics industry. In addition to the PureGrowth portfolio, Albemarle is currently selling diethyl zinc (DEZ) to the solar panel industry and will expand its offerings to include dimethyl zinc (DMZ) in the near future.

"By expanding into the electronic-grade metal organic arena, Albemarle will be able to provide a robust portfolio of complementary products and services used throughout the electronics industry," says Jenny Hebert, global product manager for Electronic Materials. "Albemarle will also benefit from a number of R&D and distribution synergies shared by its various business units," she adds.

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

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# SMG Indium Resources raises \$7.5m in private placement

New York's SMG Indium Resources (SMGI) has entered into a definitive purchase agreement to issue 2 million shares of its common stock at \$3.75 per share in a private placement offering to entities affiliated with Raging Capital Management LLC. Of the \$7.5m gross proceeds, SMGI expects to use 85% to buy and stockpile indium and 15% for general corporate purposes.

"Our largest shareholder, Raging Capital Management LLC, continues to believe in our corporate vision and has decided to increase its investment," says CEO Alan C. Benjamin. "We have agreed to issue common stock at a 10% premium to the closing bid price and essentially at parity to our net market value (NMV) which was last reported on our website on 31 December 2011 at \$3.76 per share," he adds. 'NMV' is defined as the number of kilograms of indium held at any given point multiplied by the spot price for indium as published by Metal Bul-

letin PLC, plus cash and other company assets, less any liabilities.

"The supply/demand fundamentals of the indium market are very compelling, and we are excited to be shareholders in what we believe is the world's largest strategic stockpile of the metal [outside China]," says Raging Capital Management's chairman & chief investment officer William C. Martin. "The company has successfully acquired an additional 25 metric tons of indium since the initial public offering [in May 2011, which raised \$24m]."

Primary production is constrained by both physical occurrence (produced as a by-product of industrial metal smelting) and by geographic occurrence (over 50% of production and 70% of reserves are in China). Production has been stagnant for five years and has not been rising to meet demand.


**Production has been stagnant for five years and has not been rising**

Last year, the US Department of Energy's first Critical Materials Strategy report found that four clean energy technologies used materials at risk of supply disruptions in the next five years. The supply of five rare-earth elements and indium were assessed as being most critical in the short term.

SMGI believes the indium market is in a structural supply deficit. However, economic uncertainty, generated by the fiscal crisis in Europe, has led display makers to draw down inventories, even as end-user sales of TVs, tablets and cell phones have continued to grow. This has resulted in lower-than-expected demand for LCD-driven raw materials, and the price of indium has fallen to \$570 per kg. Although the price can always drop further amidst uncertainty, SMGI believes this level represents an excellent opportunity to further increase its stockpile.


[www.smg-indium.com](http://www.smg-indium.com)

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## IN BRIEF

## USCi using Aixtron reactor to develop next-gen SiC devices

United Silicon Carbide Inc (USCi) of Princeton, NJ, USA is to develop the next generation of SiC devices using an Aixtron VP2400 Hot-Wall CVD reactor. The system was received in fourth-quarter 2011 and will be delivered in third-quarter 2012.

USCi specializes in the development of SiC devices including Schottky barrier diodes, junction field-effect transistors (JFETs), bipolar junction transistors (BJTs), solid-state circuit breakers, power modules, and custom SiC integrated circuits.

"Having evaluated the market for SiC epitaxy equipment, and based upon our success with merchant SiC epitaxy vendors utilizing similar tools, we have selected the Aixtron VP2400HW system for the superior quality of both n- and p-type SiC epitaxial layers," says USCi's director of engineering Dr John Hostetler. "The versatility of the 2400 system will enable USCi to rapidly develop novel device designs. The system's ability to achieve high growth rates make it an ideal platform to develop our next generation high-voltage (5–15kV) SiC devices with thicknesses in excess of 100µm," he adds. "Aixtron Planetary Reactors are becoming the standard for high-volume SiC device production, and our ownership of a 2400 will greatly facilitate our production process transfer to our merchant epitaxial wafer partners," Hostetler continues.

"SiC Planetary Reactor technology has continued to evolve over the past 10 years," says Dr Frank Wischmeyer, VP & managing director of Aixtron AB, Sweden. "Our extensive experience and know-how in the SiC deposition process is evident in the current design."

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

## Aixtron installs CNT and graphene deposition system at Portugal's INESC

Aixtron's support team for Europe has installed and commissioned another Black Magic carbon nano-material deposition system at INESC Microsistemas e Nanotecnologias (INESC MN) in Lisbon, Portugal.

"My current research is focused on the controlled fabrication of CNTs [carbon nanotubes] and related nanostructures for electronic applications," says Dr Sara Vieira, principal investigator of the CNT research group at INESC MN.

"The Black Magic system has already proved itself to be indispensable for our current work. Our activities are centered on nanofabricated field-emission sources, and the system is capable of depositing aligned CNTs with the desired field-emission characteristics," she adds. "The system, with its flexible process window and plasma capabilities, has enabled us to fabricate single-, double- or multi-walled carbon nanotubes."

"It is ergonomic, easy to use and reproducible in so many respects and, most importantly, it is also capable of growing graphene, which also has many potential uses in future nanoelectronics," Vieira says. "The system provides my group with the ability to independently produce high-quality material and the opportunity to initiate new joint projects with other institutions requiring such CNTs and related devices."

INESC MN is a private, non-profit R&D institute created in 2002 from the Solid State Technology group of INESC. It operates a Class 10/100 cleanroom with optical and electron-beam lithography, allowing nanoscale device fabrication. It is dedicated to R&D in strategic technological areas of micro- and nano-technologies as well as the application of such technologies to electronic, biological and biomedical devices.

[www.inesc-mn.pt](http://www.inesc-mn.pt)

## Finland's University of Oulu orders Aixtron Black Magic system for CNT devices

A local Aixtron Europe support team has installed and commissioned a Black Magic 1x2"-wafer carbon nanotube deposition system at the Microelectronics and Materials Physics Laboratories at the University of Oulu in Finland.

The system will be used for the low-temperature synthesis of aligned carbon nanotubes/nanowires on templates for applications such as integrated CNT devices for electronics, mechanical components in sensors/ actuators, and scaffolds for catalytic membranes.

"We selected this system because of its process flexibility and versatility," says Oulu. "The system has a well established global customer base and Aixtron has demonstrated a lot of experience in CVD processing of carbon nanomaterials," it adds. "We will

be using the system not only for development projects but also for the education of doctoral students... we have to have a robust, easy-to-use system that delivers reproducible growth of different types of nanotubes for various applications."

Oulu is one of the largest universities in Finland engaged in multi-disciplinary basic research and academic education. Its Microelectronics and Materials Physics Laboratories have activities in micro- and nano-system technologies, with a particular focus on materials, devices and their manufacturing technologies. Research is driven by the need to enhance the performance of electronic, photonic and telecom devices.

[www.ee.oulu.fi/research/miklab](http://www.ee.oulu.fi/research/miklab)  
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## IN BRIEF

## SSEC adds industry veterans to boost sales force in critical regions

Solid State Equipment LLC (SSEC) of Horsham, PA, USA, which makes single-wafer wet processing equipment, has added two industry sales veterans to fuel its growth in currently under-addressed markets. Jim Murphy and Kojitsu Goto (KG) will assist in expanding SSEC's presence in their respective areas.

Murphy will be responsible for Strategic Accounts on a global basis, including coordinating the early adaption of 450mm silicon wafers. "Jim comes with extensive industry experience and has a solid track record of accomplishment," says John Voltz, director of Field Operations. "We expect Jim to expand our presence at IDMs (integrated device manufacturers) with the same success we are enjoying with foundries," he adds.

Goto is assuming the role of Country Manager for Japan and Korea – markets that represent an high percentage of capital expenditures for the types of equipment manufactured at SSEC.

"These are challenging and highly competitive markets with large global companies and small local companies vying for the business," says Voltz. "Considering KG's past success, we are confident his perseverance will get us traction in these markets to help us grow," he adds.

"They [Murphy and Goto] add bench strength to our existing sales force and support the increasing number of customers that are choosing SSEC," Voltz concludes.

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

## CVD Equipment's orders grow 44%

CVD Equipment Corp of Ronkonkoma, NY, USA received \$36m in new orders for 2011, up 44% on 2010's \$25m.

For the SDC (Stainless Design Concepts) division (which makes ultra-high-purity gas and chemical delivery systems), orders rose 78%, due mainly to further penetration of R&D market expansion worldwide.

Orders for the CVD/FN (chemical vapor deposition/First Nano) division of production and research systems rose 45% to \$30.5m, as it continues to benefit from increased interest in energy generation, energy savings and nanotechnology fields and from the need to scale up production facilities with customized CVD equipment. The firm expects that this demand will continue in 2012.

The CVD/First Nano Division consists of the CVD product group (which builds equipment for custom CVD processes) and the First Nano product group (which makes EasyTube equipment for growing nanowire, nanotube and thin-film materials) as well as an Application Laboratory (where it develops processes and solutions for commercializing emerging technology

in the nano/solar fields and develops/optimizes custom material manufacturing processes).

"Quotation levels remain strong and we continue to find new opportunities for the application of our custom CVD solutions in addition to applications in the manufacturing of solar cells, grapheme films, carbon nanotubes, silicon nanowires and other nano materials," says president & CEO Leonard Rosenbaum. "Using our Application Laboratory, we continue to perfect and expand the multiple areas where our process solutions can be applied. The aerospace, medical, solar and nanotechnology markets offer us significant worldwide growth opportunities for technologies that deliver favorable cost and performance benefits," he adds.

"Our strategy of accelerating commercialization of tomorrow's technologies is being recognized by technology innovators with the financial acumen and resources to help accelerate the transition of nano materials from R&D into volume production," says Karlheinz Strobl, VP of business development.

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

## Plasma-Therm named finalist for 2011 Manufacturer of the Year Award

At the Annual Manufacturers' Summit and Global Marketplace in Orlando, FL on 1 December, plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA was named a finalist for the 2011 Manufacturer of the Year Award, an honor recognizing a commitment to excellence in the manufacturing business.

A total of 16 finalists were chosen in four categories for the award. Each firm was evaluated on its commitment to their business, their customers and their employees. The areas of focus included: leadership, strategic planning, customer and market focus, measurement,

analysis and knowledge management, workforce focus, and process management.

"This achievement recognizes the hard work and dedication of our entire team," says Plasma-Therm's director of operations Scott Craver. "The preparation for the judging process, analysis and evaluation of our business processes uncovered unexpected benefits," he adds. "Not only did it identify the positive things we are doing, it also highlighted the areas where we need improvement; this will help us provide even greater value to our customers."

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



# Riber's revenue grows 40% to €29m in 2011

## MBE sources quadruple to €12.1m, but systems driving orders for 2012

For fourth-quarter 2011, Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported revenue of €10.5m, almost doubling from Q3/2011's €5.5m. This took full-year 2011 revenue to €29m, up 40% on 2010's €20.7m (and up from last July's forecast of 35% growth to €27–29m). Of total revenue, 52% came from Asia-Pacific, 32% from Europe and 16% from North America.

Cells and sources revenue drove growth in 2011, almost quadrupling (up 292%, from €3.1m in 2010 to €12.1m). This reflected the delivery of major investment orders aimed at setting up organic light-emitting diode (OLED) screen production lines, says Riber.

MBE system sales rose 4% from €11.1m in 2010 to €11.5m, indicating the good level of sales to compound semiconductor firms and research centers. In 2011, 10 MBE systems were delivered, including three production systems.

Services and accessories revenue has fallen 18% from €6.5m to €5.4m, set against a slowdown in

the North American market.

Riber says that Q4/2011 saw a dynamic level of commercial development, receiving orders for nine MBE systems (one production system and eight research systems). This growth has been achieved due specifically to the continued strengthening of positions in Europe and China.

As of end-2011, the order book was €19.4m, up 12% on €17.3m a year ago. This comprises primarily 15 MBE systems (two production systems and 13 research systems), with only one due to be delivered after 2012. The systems order book totaled €17.4m, up 31% on €13.3m a year ago.

The cells and sources order book was down significantly (€0.6m, down 74% on €2.2m a year ago) following the completion of investments in generation 5? OLED production lines. Riber is currently preparing its range of next-generation cells for future investment steps. The services and accessories order book was €1.4m, down 19% on €1.8m a year ago.

Riber will report full-year 2011 earnings on 29 March.

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

## Plasma-Therm awarded five-star rating by VLSIresearch

Plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA has been awarded the five-star rating from market research firm VLSIresearch, representing the top performers among semiconductor equipment companies.

The five-star rating recognizes firms that received the highest ratings from their customers and

performed exceptionally across all rating categories, including customer service, organizational performance and equipment performance.

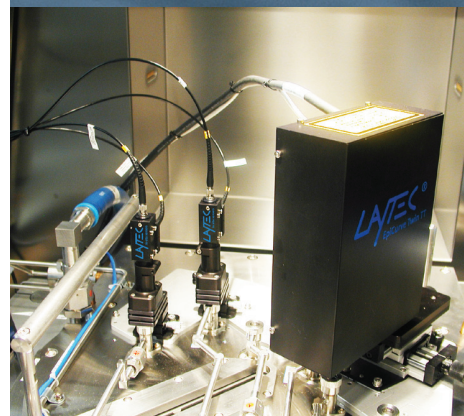
"Accomplishing this superior rating is testament to Plasma-Therm's hard work and dedication in our immediate market," says Rich Gauldin, Plasma-Therm's director of Customer Focus.

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

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## AIP sells MFC manufacturer Brooks Instrument and process tool, gas & chemical delivery module maker Ichor

New York-based American Industrial Partners (a middle-market private equity group focused on acquiring and improving North American-based industrial businesses) has sold both Brooks Instrument and Ichor Systems.

Acquired by AIP from Emerson Electric Co in December 2007, Brooks Instrument of Hatfield, PA, USA is a provider of low-flow and pressure/vacuum analytical instruments to end markets including industrial, chemical, life science, oil/gas, microelectronics, LED, and alternative energy.

Brooks has about 800 staff at 18 locations in 13 countries. Its products are used to regulate the flow rates of gases and liquids in laboratory and process environments, and include thermal mass flow controllers (used in MOCVD systems), variable area meters, coriolis and ultrasonic flow meters, and capacitance diaphragm gauges. Brooks serves over 9000 customers in 75 countries, with an installed base of over 1.5 million instruments.

"Our team is primarily comprised of engineers and operators who support management in achieving the growth objectives for their business," says AIP partner Eric Baroyan. "By acquiring and commercializing intellectual property, supporting new product development, developing efficient manufacturing processes, optimizing procurement, and consolidating a global manufacturing footprint, Brooks more than doubled revenue and tripled EBITDA during our investment period," he notes.

"It was the support and commitment of the entire American Industrial Partners team that enabled us to achieve the step change in product offerings, operating efficiency, and financial performance over the last few years," says Brooks' CEO Clark Hale. "We look forward to continued growth under new ownership.

Acquired by AIP in October 2009 at the trough of the semiconductor equipment market, Ichor Systems of Tualatin, OR, USA is a designer and maker of process tools and gas and chemical delivery modules for original equipment manufacturers in the semiconductor, alternative energy, LED, data storage, and flat-panel display industries.

Ichor has about 540 staff globally, at operations in the USA (Oregon, Texas, New York, Massachusetts and Colorado), Malaysia and Singapore. Its gas and fluid management products and systems are used to produce microelectronic semiconductor chips, solar panels, LEDs, superconductor wire and thin-film magnetic heads. Since its inception in 1999, the firm has established strategic relationships with OEMs, collaborating on system design and serving as an outsourced manufacturer for complex subsystems.

"During our ownership of Ichor, management — working closely with American Industrial Partners — rapidly effected an agenda of operating improvements such as diversification of the core business into new markets including LED lighting and data storage as well as our relocation of operations to Singapore and Malaysia," says AIP associate Joel Stanwood. "American Industrial Partners is primarily comprised of engineers and operators who support management in achieving growth objectives for their business. In our Ichor investment, we not only achieved significant gains through lean manufacturing and low-cost country sourcing, but also executed a transforming add-on acquisition [of Precision Flow Technologies of Saugerties, NY] and helped Ichor establish an impressive pipeline of new revenue opportunities," he adds.

"American Industrial Partners had both a unique insight into the semi industry at its 2009 trough and the deep technical skills to successfully work with management to execute

numerous operational enhancements," notes Ichor's chairman & CEO David Shimmon. "Ichor has diversified into entirely new product markets and developed industry-leading operational capabilities in Asia," he adds. "The Ichor team greatly values American Industrial Partners' contribution to the success of the company... we look forward to continued growth."

AIP has sold Ichor to San Francisco-based Francisco Partners, a global private equity firm focused on investments in technology and technology-enabled services businesses. Francisco Partners pursues structured investments in technology firms, targeting investments in private companies, public companies and divisions of public companies (with transaction values from \$25m to over \$1bn).

"We see a real opportunity for Ichor Systems to build upon its operational strengths, global workforce and deep industry relationships to drive growth," says Andrew Kowal, a partner at Francisco and head of its semiconductor and hardware investment activities. "Francisco Partners brings significant experience from more than a decade of investments in the semiconductor and related industries, and we will work closely with Ichor Systems' management team to capitalize on these opportunities," he adds.

"We plan to build upon Ichor Systems' successes and will provide the resources needed to expand the company's market leadership," says Francisco Partners' managing partner Dipanjan Deb.

"We have found the truly unique partner who brings historical investment experience in our specific market, a rich network, and strong expertise in the semiconductor, LED, and technology markets broadly," says Ichor's CEO David Shimmon.

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

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

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



# Soitec agrees to buy Altatech

## Acquisition to speed development roadmap for LEDs and CPV systems

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers (as well as III-V epiwafers through its Picogiga International division), has entered into a letter of intent to acquire, by the end of January, all of the outstanding shares of Altatech Semiconductor of Montbonnot Saint Martin, near Grenoble, France, which makes wafer inspection and analysis, liquid-vaporization chemical vapor deposition (CVD) and nanoprining equipment. Earlier this month, Altatech also launched its first product designed specifically for detecting, classifying and characterizing defects on wafers used in manufacturing LEDs.

The acquisition of Altatech should enable Soitec to accelerate its development roadmap in electro-luminescent diodes, as well as in

concentrating photovoltaic (CPV) systems (especially Plug&Sun mini-trackers systems, which Soitec launched on 13 December).

For the purposes of this transaction, Altatech's base value was set to €15m, in line with the independent appraisal carried out at Soitec's request by Oddo Corporate Finance.

The acquisition will be financed partly in cash and partly using Soitec stock. Selling shareholders will be bound by certain holding requirements for the portion of the purchase price to be paid in Soitec stock. BNP Paribas

**Altatech should enable Soitec to accelerate its development roadmap in electro-luminescent diodes, as well as in CPV systems**

Exane was mandated by Soitec to implement its share buy-back program, as approved by shareholders during the combined ordinary and extraordinary meetings on 24 June, and to purchase on the market the Soitec stock to be allotted to the Altatech selling shareholders as consideration for their shares.

As a result of the personal interest held by Soitec's chairman & CEO André-Jacques Auberton-Hervé in the capital of Altatech (whose supervisory board he chairs), the transaction was carried out by Soitec's finance department and the Audit Committee of the board of directors. The transaction was approved by Soitec's board on 15 November. Auberton-Hervé neither deliberated nor voted on the transaction.

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

[www.altatech-sc.com](http://www.altatech-sc.com)

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## China's Wuhan National Laboratory for Optoelectronics signs off Vistec e-beam lithography system

Vistec Lithography B.V. of Best, The Netherlands says that its EBPG5000pES electron-beam lithography system has been signed off by Wuhan National Laboratory for Optoelectronics (WNLO) at the Huazhong University of Science and Technology (HUST), a national key university in Wuhan, China.

Co-established by the Ministry of Education, Hubei Provincial Government and Wuhan Municipal Government, WNLO is one of China's first five national labs. It is managed by HUST and in collaboration with Wuhan Research Institute of Posts and Telecommunications (WRI), Wuhan Institute of Physics and Mathematics (WIPM) affiliated to the Chinese Academy of Sciences (CAS), and Huazhong Institute of

Optoelectronic Technology (HIOT).

The EBPG5000pES e-beam lithography system should enable WNLO to further strengthen its position in photonics and optoelectronics R&D. "The EBPG5000pES facilitates us to achieve all the lithography challenges we are facing in our research," says professor Jinsong Xia, director of the Optoelectronic Micro & Nano Fabrication and Characterization Facility (OMFC) at WNLO. "In respect to application support and service we know that we can count on the Vistec team as our strategic partner," professor Xia adds.

The EBPG5000pES is a high-end lithography tool based on a proven system architecture. With its flexible electron-optical column and high-brightness TFE (thermal field emis-

sion) source, allowing 50kV and 100kV operation, it provides a spot size down to <2.2nm, enabling nano-lithography structures smaller than 8nm to be generated routinely. The system incorporates an interactive graphical user interface (GUI) that provides ease of use for diverse, multi-user, university-type environments, says Vistec.

"The electron-beam lithography system at WNLO is the first operational Vistec EBPG5000pES in the People's Republic of China, which opens up great opportunities to a sustainable business development for Vistec in that region," believes Vistec Lithography's managing director Erwin Mueller.

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## EVG collaborating with Eulitha on low-cost nanopatterning for HB-LEDs

### PHABLE UV litho technology to be integrated with EVG's automated mask aligner

EV Group (EVG) of St Florian, Austria, a supplier of wafer bonding and lithography equipment for the MEMS (micro-electro-mechanical system), nanotechnology and semiconductor markets, has signed a joint-development and licensing agreement with Eulitha AG (a spin-off of the Paul Scherrer Institute in Villigen, Switzerland that produces nanostructures using lithography techniques).

Eulitha's PHABLE mask-based ultraviolet (UV) photolithography technology will be integrated with EVG's automated mask aligner product platform, with the goal of developing a low-cost-of-ownership (CoO) nanopatterning solution to enable the production of high-brightness LEDs (HB-LEDs). With demonstration capabilities in place already, the first products are expected to ship later this year.

According to LED market research firm Strategies Unlimited, the market for high-brightness LEDs is expected to grow from \$11.2bn in 2010 to \$16.2bn in 2014, driven by applications such as TV backlighting, mobile devices and increasingly by lighting. To meet this increased demand, LED manufacturers need new manufacturing solutions that can increase the lighting efficiency of their products while keeping manufacturing costs down. Through their joint-development agreement, EV Group and Eulitha aim to explore new manufacturing technologies that support LED manufacturers' cost and technology requirements.

Combining Eulitha's full-field exposure technology with EVG's mask alignment platform provides low-cost, automated fabrication of photonic nanostructures over large areas, and supports the production of energy-efficient LEDs, solar cells and liquid-crystal displays, say the firms. It combines the low cost,

ease-of-use and non-contact capabilities of proximity lithography with sub-micron resolution, making it suitable for use in patterning sapphire substrates in order to enhance the light extraction (and hence efficiency) of LEDs. EVG plans to offer a PHABLE-enabled EVG620 system as an extension to its existing mask alignment system platform, giving a wider choice of configuration options.

"We look forward to working with EV Group to greatly accelerate commercialization of PHABLE through the integration of this novel technology with EVG's industry-leading mask aligner platform," says Eulitha's CEO Harun Solak. "The synergies of our respective technologies have great potential to provide the resolution and volume-production capabilities of lithography steppers at a fraction of the cost, enabling LED, optics and photonics manufacturers with extremely tight cost constraints the opportunity to extend their technology roadmaps to higher levels of performance," he adds.

"Eulitha's expertise in nanofabrication makes them an ideal partner to collaborate with on new patterning solutions for the LED industry," comments Hermann Waltl, EVG's executive sales and customer support director.

**Combining Eulitha's full-field exposure technology with EVG's mask alignment platform provides low-cost, automated fabrication of photonic nanostructures over large areas,**

[www.eulitha.com](http://www.eulitha.com)  
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# Asahi Kasei acquires Crystal IS

## Product engineering and manufacturing expertise of GaAs Hall sensor maker to speed commercialization of AlN UVC LEDs

On 28 December, Japan-based diversified industrial enterprise Asahi Kasei Group acquired Crystal IS Inc of Green Island, NY, USA, which develops single-crystal aluminum nitride (AlN) substrates and ultraviolet light-emitting diodes (UVC LEDs) based on them.

The Asahi Kasei Group is currently advancing 'For Tomorrow' projects in the fields of the environment & energy, residential living, and health care, for the creation of new businesses under its 'For Tomorrow 2015' mid-term management initiative. A key focus of the Environment & Energy for Tomorrow project is the development of technology to create new business with compound semiconductor devices that complement Asahi Kasei's established gallium arsenide (GaAs)-based Hall-effect devices, infrared sensors, and magnetic resistance devices.

Since being spun off from Rensselaer Polytechnic Institute (RPI) in Troy, NY, USA in 1997, Crystal IS has been working in development mode for more than ten years, with a history of early support from RPI as well as continued support from both regional and US government. Venture funding in 2004 and 2006 from ARCH Venture Partners, Lux Capital, the Credit Suisse/New York State Common Retirement Fund and Harris & Harris Group, helped the firm to scale up development.

As one element of its Environment and Energy for Tomorrow project, in July 2010 Asahi Kasei purchased shares in Crystal IS, and the two firms began the joint development of process technology for manufacturing AlN substrates. Recent collaborative and strategic support from Asahi Kasei Group as well as China's San'an Optoelectronics Company Ltd propelled it to its current level of operation. Crystal IS currently has 25 staff.

Crystal IS had been exploring its options for commercializing the AlN-based UV LEDs that it had developed, which feature exceptionally short wavelength as well as what's claimed to be world-leading efficiency and service life. As well as having high thermal conductivity and excellent tolerance to high voltage, AlN absorbs and emits short-wavelength UV light, which has a bactericidal effect. UV LEDs featuring smaller size, lighter weight, longer service life and energy conservation can therefore facilitate the development of portable disinfection equipment and other new applications. However, difficulty in growing AlN in pure crystal form has hindered high-volume commercial production.

Crystal IS' technology was judged to be a good fit with Asahi Kasei's thin-film device technology, which can provide a base for the further expansion of compound semiconductor operations, while both firms share a common vision for the development of the UV LED sector. Asahi Kasei adds that the acquisition enables combination of the technologies of Asahi Kasei and Crystal IS, as well as marking its entry into the UV LED market and providing a foundation for further developments in energy-conserving devices.

Asahi Kasei reckons that having Crystal IS as a subsidiary will enable not only the early commercialization of technology to grow single-crystal AlN substrates but also, through a combination of the two firms' technologies, the early commercialization of UV LED devices which are expected to meet growing demand. "The advances in solid-state UVC technology accomplished by Crystal IS will allow for clean and safe disinfection to be introduced into water, air and surface applications in multiple markets," says Masafumi Nakao,

general manager of Asahi Kasei's Advanced Devices and Sensor Systems Development Center. In addition, further developments will be explored for the application of AlN technology to other energy-conserving devices.

Crystal IS reckons that, while continuing to be based in New York State, as a subsidiary of Asahi Kasei it will be able to accelerate commercialization of its UVC LEDs, leveraging Asahi Kasei's strength's in product engineering and manufacturing excellence. The company will organize around its respective strengths, with R&D fundamentals and entrepreneurial business development managed from Crystal IS, and product engineering and manufacturing excellence being led by Asahi Kasei.

"Our record LED performance in development has brought interest from global customers and we are eager to create a high-quality product to meet their needs," says Crystal IS' CEO & president Dr Steven Berger. "We recognize Asahi Kasei Group's strength as a successful developer and manufacturer of compound semiconductor devices and are confident that their support will ensure a timely and quality launch of our UVC LED business in the global marketplace," he adds.

"I am pleased that this groundbreaking technology platform is moving forward into the next phase of growth," comments Crystal IS' co-founder & chief technology officer Leo Schowalter. "We are pleased to be part of a growing high-tech area focused on advanced materials, life science, cleantech and energy," he adds. "We will continue our tradition of innovation and excellence, while also accelerating global business growth with our new owner."

[www.crystal-is.com](http://www.crystal-is.com)

[www.asahi-kasei.co.jp](http://www.asahi-kasei.co.jp)

## Soitec and SEI demo 4" and 6" GaN engineered substrates Pilot production lines installed to enable wider market adoption

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers (and III-V epiwafers via its Picogiga International division), and Tokyo-based compound semiconductor materials provider Sumitomo Electric Industries Ltd (SEI) have passed a milestone in their strategic joint development program started in December 2010 by demonstrating 4" and 6" engineered gallium nitride substrates and launching pilot production lines to enable wider market adoption.

Produced by transferring ultra-thin high-quality GaN layers from a single GaN wafer to produce multiple engineered GaN substrates, they are suited to manufacturing high-brightness LEDs for lighting and power-efficient controllers for the electric vehicles and energy markets.

Leveraging SEI's manufacturing technology for GaN wafers and

Soitec's Smart Cut layer-transfer technology, the strategic alliance project had originally produced 2" wafers. With the demonstration of scalability, the partners are now proceeding with the next step to invest and establish pilot production lines in Bernin and in Itami, Japan (initially fabricating 4" wafers, with 6" production quickly following to support customers demand.

SEI will manufacture bulk free-standing GaN substrates in Japan for shipment to France, where Soitec will apply its Smart Cut layer-transfer process to generate the final engineered wafers with the same thermal expansion coefficient as GaN wafers. The resulting wafers have low defect density, enabling the manufacturing of devices at lower cost than bulk GaN wafers, the firms say.

"Our partnership's successful demonstration of 4" and 6" engi-

neered GaN substrates' scalability is a critical milestone, accomplished by applying very strong innovative capabilities from both sides," comments Frédéric Dupont, VP of Soitec's Specialty Electronics business unit. "The advanced substrates we are developing will allow the introduction of a new materials platform with novel and advanced functionalities," he adds.

"With layer-transfer technology's production readiness now proven for larger wafers, the substrates can be made even more cost effectively for large-volume production," notes Yoshiaki Miura, general manager of Sumitomo Electric's Compound Semiconductor Materials Division. "We look forward to continuing our successful collaboration with Soitec to fulfill the requirements of the LED and energy markets."

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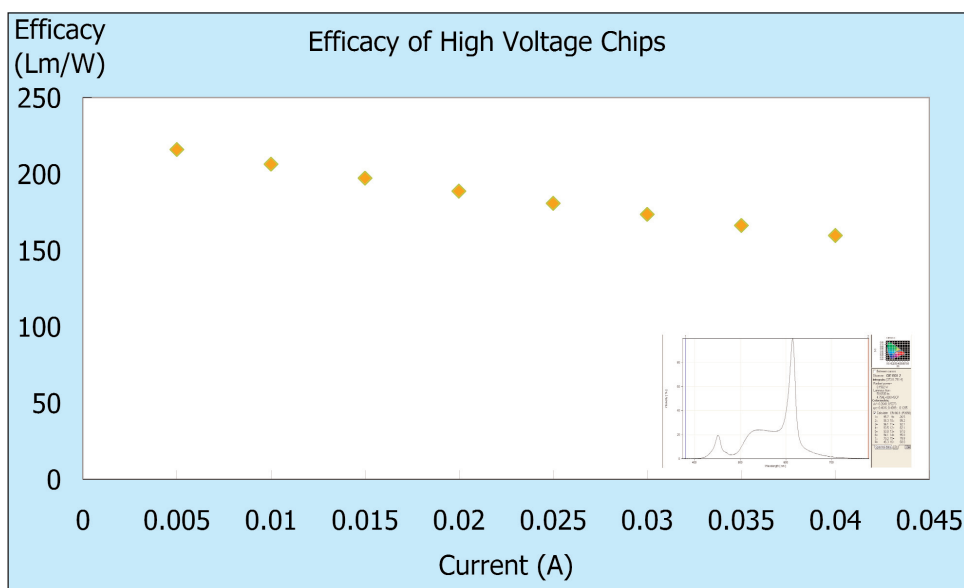


# Epistar reports record 216lm/W warm-white LED with high-voltage chipset

Efficacy up to 216lm/W at 5mA current and CRI of 87 and CCT of 2700K

Taiwan's largest LED chipmaker Epistar Corp of Hsinchu, Taiwan has reported what it claims is record luminous efficacy for a warm-white LED with a high-voltage chipset. Efficacy is 216lm/W at an operating current of 5mA and a color rendering index (CRI) of 87 Ra at a correlated color temperature (CCT) of 2700K. Operating under a typical driving current of 15mA (or about 1W equivalent), luminous efficacy was 197 lm/W.

Epistar says that its latest record adopts several technologies in high-voltage chips. These include a novel substrate transfer process, lower MQW (multi-quantum well) light absorption, a fine structure for increasing photon extraction efficiency, improvements in current spreading uniformity, and an improved MQW structure with high internal quantum efficiency (IQE) as well as lower forward voltage.



Luminous efficacy of high-voltage warm-white LED versus drive current.

Epistar says that the higher-performance warm-white HV (high-voltage) chipset is suitable for retrofit, professional lighting, and luminaires applications.

The firm adds that it will continue

to develop more advanced technologies to enhance product performance, as well as working closely with downstream customers to provide better LED lighting solutions to the market.

## Epistar launches 100, 120 and 150lm/W LED chipsets for warm-white lighting

Epistar has launched three LED chipset products — 'Standard Set', 'Premium Set' and 'Deluxe Set' — with packaged luminous efficiencies of 100, 120 and 150lm/W, respectively. All chipsets have a color rendering index (CRI) of >85 and correlated color temperature (CCT) of 2700–3000K.

The 100lm/W Standard Set has a low-voltage chip platform (V10S for blue and AX12 for red) with recommended operating current of 30mA per chip and three chips in one package (3528 PLCC), yielding output of 0.27W and 27lm. Targeting final system efficiency of more than 65lm/W, the Standard Set is intended to provide a 40W bulb and T8 tube replacement.

The 120lm/W Premium Set has two versions: a low-voltage chip platform (V11A for blue and AX12 for red) with recommended operating current of 30mA per chip and a 3528 PLCC package (with three chips in one package), yielding output of 0.26W and 31lm; and a high-voltage chip platform (HV45B for blue and HA40 for red) with recommended operating current of 20mA per chip and four chips in one package (5050/6565 ceramic or 7090 PLCC), yielding output of 3W and 360lm. Targeting final system efficiency of more than 80lm/W, the Premium Set emphasizes high package efficiency with affordable cost for 60W bulb and high-performance T5 tube replacement.

The 150lm/W Deluxe Set has a high-voltage chip platform (FV60 for blue and HA40 for red) with recommended operating current of 20mA per chip and four chips in one package (5050/6565 ceramic or 7090 PLCC), yielding output of 2.7W and 405lm. Targeting final system efficiency of more than 100lm/W, the Deluxe Set emphasizes high efficiency with fair cost for 75W up bulb replacement, high-performance PAR, and the downlight markets.

Epistar says that, while dedicating itself to higher lm/W luminous efficacy, it is also committed to delivering competitive lumen per dollar value.

[www.epistar.com.tw](http://www.epistar.com.tw)

## LED maker Bridgelux closes in on 100% revenue growth in 2011

LED chip and lighting array maker Bridgelux Inc of Livermore, CA, USA (which claims to be the only vertically integrated maker of LED solid-state light sources specifically for the lighting industry) reckons that market conditions and its recent achievements have positioned it for additional growth in 2012. The firm's revenue grew as much as 792% from fiscal 2006 to 2010, and additional 100% year-on-year growth is expected by the end of 2011. The firm adds that, in the past year, it raised \$76m in additional funding, added several noteworthy customers, introduced innovative products and technology, and received numerous industry awards.

The LED luminaire market is poised for dramatic expansion, with analysts predicting compound annual growth rate (CAGR) of 40% through 2015 (according to IMS Research's report 'The World Market for Lamps & Luminaires in General & Exterior Lighting' released last July). Recognizing its potential, prominent financial and strategic investors have invested \$76m in Bridgelux in the past year.

"We're seeing significant increases in adoption and demand for LED lighting in many sectors and regions," says CEO Bill Watkins. "In fact, we've experienced a 300% unit volume growth in LED array sales in the past year alone, dramatically increasing our market share while also delivering well over 100 million high-power LED chips to enable new and innovative product designs," he adds. "Going forward, Bridgelux is extremely well positioned to meet rising demand: we're well funded, have some of the industry's most innovative technologies and product designs, and have established strong strategic partnerships."

Retail and hospitality are among the most promising near-term sectors for the LED lighting market, with a forecasted CAGR (from 2010 to 2015) of 59% for retail and 54% for hospitality, reckons IMS. Geographically speaking, Europe in particular has great market potential, with analysts estimating a CAGR of 101% (from 2009 to 2015). Bridgelux recently expanded its customer base in all of these sectors, adding to both its hospitality and retail customer base with installations at The Sheraton Hotel at D-Cube City in Seoul, Intersport Austria in Klagenfurt, the Dior fragrance booth at the 'Galeries Lafayette' in Paris, Coop Adriatica stores in Italy, and more than 40 Manor department store locations throughout Europe (with several more installations scheduled for first-quarter 2012).

In August, Bridgelux extended its performance and manufacturability of GaN LEDs on silicon substrates when it broke its previous industry record for lumen per Watt luminous efficacy for gallium nitride on silicon (GaN-on-Si) LEDs.

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



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# Triode probe of efficiency droop in nitride semiconductor light emitters

Researchers conclude limited hole-injection is a major cause of fall-off

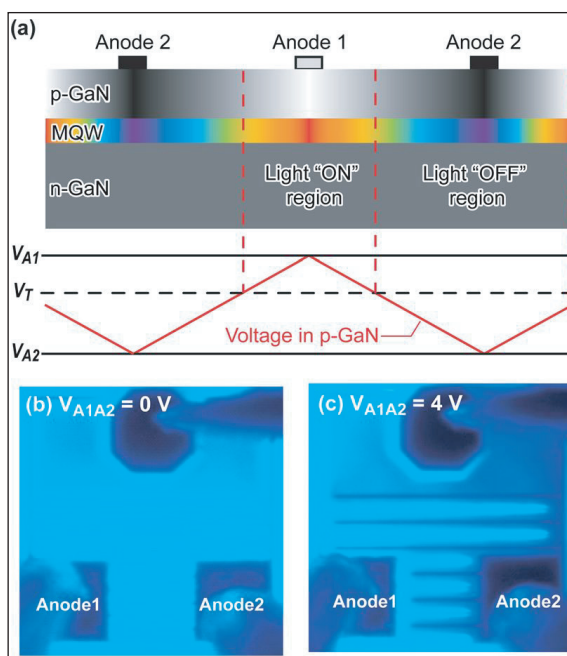
Researchers in South Korea and USA have used nitride semiconductor light-emitting triode structures (LETs) to investigate the effect of hole injection on light output [Sun-yong Hwang et al, Appl. Phys. Lett., vol99, p181115, 2011]. The work was carried out by South Korea's Pohang University of Science and Technology (POSTECH) and Rensselaer Polytechnic Institute (RPI) of Troy, NY, USA.

Hole injection is known to be particularly poor in nitride semiconductor LEDs and has been blamed for the 'efficiency droop' effect by some groups. 'Efficiency droop' describes the fall-off in efficiency of nitride LEDs as the injection current is increased. Many other causes have been suggested for the effect, including device heating, Auger recombination, delocalization of carriers from indium-rich low-defect-density regions, and electron leakage.

The POSTECH/RPI structure (Figure 1) consists of two anodes and a cathode. The anodes consisted of inter-digitated metal structures on the p-type contact layer. The connection to the n-type layer formed the cathode.

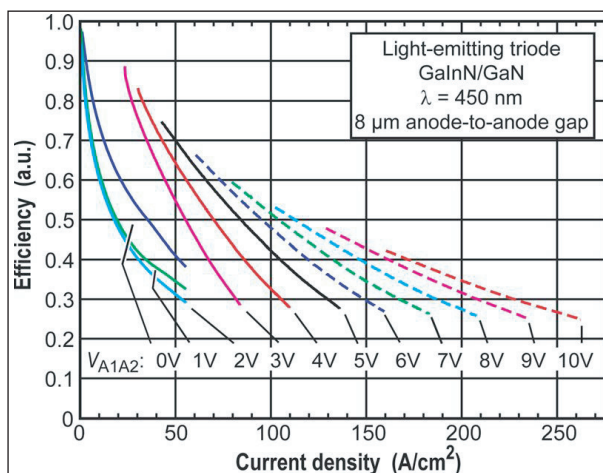
The two anodes are used to accelerate the holes in the p-type layers, giving them kinetic energy. The extra kinetic energy raises the effective temperature of the holes above that of the crystal lattice, easing their passage over the hole barrier of the electron-blocking layer (EBL). The electric field between the 8 $\mu\text{m}$ -spaced anodes can reach  $\sim 10^4\text{V/cm}$  at moderate bias.

The POSTECH/RPI researchers used a typical blue (450nm wavelength) LED structure grown on c-plane sapphire using MOCVD. The active layer consisted of a 6-period multi-quantum well (MQW) with 3nm undoped GaInN in the wells and 9nm n-GaN barriers. The electron-blocking layer consisted of  $\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$ .



**Figure 1. (a) Effective area modulation of the active region of an LET with a linear voltage variation approximation. Top view of the lit-up LETs under different anode-to-anode voltages: (b) 0V and (c) 4V.**

The LET consisted of a mesa produced through inductively coupled plasma (ICP) etch and deposition and annealing of ohmic contacts (n-type/cathode, titanium/aluminum/titanium/gold; p-type/anodes 1 and 2, nickel:zinc/silver).



**Figure 2. Efficiency vs drive current density for LETs under different anode-to-anode biases, as corrected for effective area modulation (EAM) of light emission.**

Efficiency measurements were carried out with increasing bias between the anodes ( $V_{A1A2}$ ). Although the droop decreases with increasing anode bias, the peak efficiency also declines. The researchers explain this result as being due to the reduced area of light emission due to different anode potentials placing only part of the device above the threshold voltage of 2.86V, giving 1mA current from the n-type layer for the particular structure used (Figure 1).

By correcting for the reduced effective area modulation (EAM) of light emission, the researchers give a series of curves showing increased efficiency against current density with increasing bias between the anodes (Figure 2). The increased

efficiency is attributed to higher hole injection enabled by the LET structure. The researchers also note that higher bias leads to a slower decline in efficiency with increasing current density, concluding: "This trend indicates that the

limited hole-injection efficiency is one of the major causes of the efficiency droop in GaN-based LEDs."

Financial support for the work came from South Korea's Industrial Technology Development Program funded by the Ministry of Knowledge Economy (MKE) and Priority Research Centers Program of the National Research Foundation of Korea (NRF).

<http://link.aip.org/link/doi/10.1063/1.3658388>

Author: Mike Cooke



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## IN BRIEF

## Seoul Semiconductor registers 10,000 LED patents domestically and internationally

South Korea's Seoul Semiconductor Co Ltd – which is the world's fourth largest LED supplier, according to market research firm Strategies Unlimited – says that it has applied, registered and secured more than 10,000 patents for LEDs.

The LED maker says that, to strengthen its LED technology and increase its number of patents, it invests 10-20% of its annual revenue in R&D, including funding of an affiliate company. It holds a patent portfolio across a broad range of technologies and processes, including material, design, manufacturing and methodology. Most notably, it holds patent rights for Acrich, a semiconductor light source that uses a multi-cell architecture (and the first commercially produced AC LED), as well as patent rights for deep UV LED technology, which Seoul Semiconductor expects to be commonly used in the future.

"With the large number of patents and cross-licenses with major LED corporations, Seoul Semiconductor has achieved technical independence and offers customers distinctive solutions not available elsewhere," claims Seoul Semiconductor vice president Brian Wilcox. "R&D is our future, and patents heighten our competitiveness," he adds. "Starting this year, we expect increased business activity from our innovative LED lighting solution, Acrich2 [launched last December], as it goes into production."

[www.seoulsemicon.com/en](http://www.seoulsemicon.com/en)

## Lumileds launches LUXEON M for outdoor and industrial LED lighting

Philips Lumileds of San Jose, CA, USA has launched the LUXEON M, an illumination-grade LED designed specifically to simplify solution design, reduce costs, and provide the optic control and quality of light required by outdoor lighting applications as well as high-bay and low-bay lighting solutions.

"LUXEON M performance fundamentally lowers the cost and design complexity for a wide range of applications in the outdoor and industrial markets and equips lighting fixture designers with a source that allows them to meet the ever increasing demands of customers and regulators," says VP of marketing Rahul Bammi.

LUXEON M is released with three correlated color temperatures (CCTs) of 3000K, 4000K and 5700K, each with a minimum color rendering index (CRI) of 70. Each part is hot tested and specified at 85°C and delivers 'Freedom From Binning'.

Initial specifications for LUXEON M include:

- luminous flux of more than 900lm at 700mA and 85°C junction temperature;



- luminous efficacy greater than 120lm/W at 350mA and 85°C junction temperature; and
- a 12V/8W package on AIN substrate.

Using its latest die and phosphor technologies, Lumileds reckons that LUXEON M will deliver the industry's best lumen/\$ that can be realized using low-cost, readily available drivers, optics and boards for design simplicity.

The new LUXEON LED will be exhibited at the Strategies in Light 2012 event in Santa Clara, CA (7-9 February). LUXEON M LEDs will be broadly available in second-quarter 2012.

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

## Lumileds appoints Pierre Yves Lesaichere as CEO as Michael Holt retires

Philips Lumileds has appointed Pierre Yves Lesaichere as CEO, succeeding Michael C. Holt and reporting directly to Philips Lighting's acting CEO Frans van Houten.

"Pierre Yves' tremendous experience at NXP Semiconductors, most recently as senior VP & general manager of the business lines Microcontrollers & Logic, make him uniquely qualified to lead Philips Lumileds into the new world of lighting," says van Houten. "Pierre Yves will drive Philips Lumileds performance and actively shape the fast-changing LED illumination market," he adds.

"I also thank Mike Holt, Lumileds'



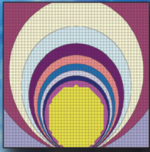
first CEO, who for more than a decade has led the company as it invented and introduced high-power LEDs and opened entirely new lighting segments," van Houten continues. "Mike is retiring to enjoy more time with his family".

Lesachere joins Lumileds with more than two decades of experience in the semiconductor and component industry. He lives in Silicon Valley and speaks multiple languages including French and Japanese.



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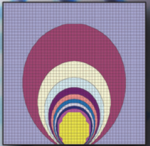
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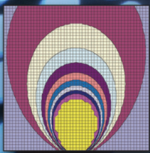
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## Cree's 13% quarterly growth driven by lighting acquisition

### Conversion to 150mm wafers delayed to optimize near-term utilization of 100mm capacity

For its fiscal second-quarter 2012 (ended 25 December 2011), Cree Inc of Durham, NC, USA has reported revenue of \$304.1m, up 18% on \$257m a year ago and 13% on \$269m last quarter, but at the low end of the targeted \$300–320m.

Compared with last quarter, revenue from LED Products (components, chips and materials) fell by \$2.6m to \$194.2m due to a challenging competitive environment (as slightly higher XLamp LED component sales were offset by lower high-brightness LED and chip sales). Power & RF sales fell by \$6m to \$14.2m. In particular, Power device sales fell mainly due to continued weakness in solar inverter demand, while RF device sales fell due to a delay in a military program (primarily a timing issue).

Growth was driven by Lighting Product revenue (indoor & outdoor LED lighting products plus traditional lighting systems) rising by \$44m (85%) from \$51.7m to \$95.7m. However, as well as double-digit organic growth in both indoor & outdoor products, this included the first whole quarter of sales from subsidiary Ruud Lighting of Racine, WI, USA (acquired about a month before the end of fiscal Q1/2012).

"The current business environment has reinforced the value of our market leadership position in LEDs and lighting as well as the power of having truly innovative products that change the market and drive adoption," says chairman & CEO Chuck Swoboda.

During the quarter, Cree introduced: the next-generation XLamp XB-D LED (which doubles the lumens-per-dollar of lighting-class LEDs); high-voltage XLamp XT-E and XM-L LEDs (which enable the use of more efficient, smaller drivers to lower cost for compact lighting applications); and the LMH2 LED module family (which features Cree TrueWhite technology and delivers 80lm/W

system efficacy combined with a color rendering index of over 90). Cree also licensed remote phosphor patents to five LED lighting makers through its recently launched remote phosphor licensing program.

Also during the quarter, Cree transferred CR troffer production to Racine (which should provide cost leverage starting in fiscal Q3) and also transitioned all lighting-related customer service activities to Racine (which will provide a common interface for indoor and outdoor products, and should improve Cree's ability to respond to customer requests). Cree has announced a 208,000ft<sup>2</sup> facility expansion at Ruud.

"Our second-quarter results

demonstrated the strength in our expanded lighting product line, with strong growth in sales of both indoor and outdoor products," says Swoboda.

"While the business environment remains challenging, our results demonstrate that our strategy is working."

On a non-GAAP basis, operating expenses rose from \$67.9m to \$76m, with R&D expenditure up \$1.3m and SG&A (selling, general & administrative) expenditure up \$7m (\$2.5m less than targeted, due mainly to lower-than-expected selling expenses and legal fees).

Gross margin has fallen further, from 47.7% a year ago and 37.4% last quarter to 35.3% (below the targeted 37–38%). This is due to lower LED margins (from increased pricing pressure and factory utilization of just 60% due to a \$17m reduction in WIP, as finished goods inventory was reduced across product lines). This offset the progress

on yield improvement and cost-reduction programs. Indoor and outdoor lighting product margins improved, driven mainly by cost reductions. Power & RF margins fell due to lower factory utilization.

"We continue to take a conservative approach on factory starts to reduce inventory while also trying to maintain flexibility to respond to short lead-time expectations in the market," says Swoboda. As a result, inventory declined by \$16.3m to \$187.4m. "While this increases short-term margin pressure, it puts the factory in a better position to realize cost reduction and respond to future demand," he adds.

Net income was \$28.7m, down from \$60.7m a year ago but up slightly on \$28.1m last quarter (although below the expected \$29–33m). Cash from operations of \$81m minus capital expenditure of \$23m (down from \$34m last quarter) yielded free cash flow of \$58m. Due to the solid profitability, improvements in working capital and reduced capital spending, cash and investments rose by \$55m during the quarter to \$687.2m.

"With the productivity and yield improvements that we have made over the last several quarters, we're spending a fraction on CapEx versus previous years as our current LED chip factory has the capability to increase output 60–70% from current levels with minimal incremental investments," says Swoboda.

"We continue to qualify additional products on 150mm wafers but have slowed the rate of transition to take advantage of existing excess [100mm] capacity," says Swoboda. "With some additional investment in 150mm tooling and equipment, our current LED chip factories should be able to increase output by another 100%," he adds. "In total, we have the ability to more than triple LED chip produc-

**We have slowed the rate of transition to take advantage of existing excess [100mm] capacity**

► tion output from current levels, and are well positioned to support significant growth in LED lighting over the next 12–24 months.”

LED orders are tracking behind last quarter, as customers and distributors are trying to minimize their inventory and utilize short lead-times. “We saw a similar pattern in our fiscal Q3 each of the last two years for LED products, as the Chinese New Year holiday effectively reduced demand in the beginning of the quarter before a strong rebound post-Chinese New Year,” notes Swoboda. “We’re currently targeting a good second half of the quarter, once again driven by end demand, which will be a significant variable for the quarter,” he adds.

Lighting order backlog is slightly ahead of last quarter. “This is a typically slower quarter for outdoor products due to lack of installations in the winter months,” says Swoboda. “We see a strong pipeline of new projects for both indoor and outdoor products, and target overall growth in Q3, as we remain very encouraged by the success of this product line and our ability to drive adoption in the market,” he adds.

For its fiscal third-quarter 2012 (ending 25 March), Cree targets

revenue of \$290–310m, with single-digit growth in lighting (driven by strong growth in indoor sales, with flat to seasonally lower outdoor sales); LED product sales down a few percent (which includes XLamp LED sales flat to down a few percent, plus seasonally lower high-brightness LED chip and material sales); and flat Power and RF sales. Gross margin should be level at 35–36%, as cost-reductions are offset by the competitive pricing environment in the LED product line and low factory utilization. Operating expenses are expected to rise by \$3–4m, including selling expenses rising by \$1–2m (mainly higher commissions, due to increased sales of lighting products through lighting agent channels, as well as new-product introductions) and G&A expenses rising by \$1m (due mainly to the timing of patent-related litigation). Net income should be \$21–29m.

“Our future business outlook remains very optimistic based on our belief that innovation drives payback, payback drives LED lighting adoption, and adoption expands the market for both Cree and our customers,” concludes Swoboda.

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

## Cree licenses remote phosphor patents

Cree has granted five LED lighting manufacturers’ licenses to select Cree patents through its remote phosphor licensing program (launched in August). Cree says that, by making fundamental remote phosphor patents available through license, it is further enabling LED lighting adoption by facilitating the development of LED lights combining remote phosphor optical elements with blue LEDs.

“Cree is committed to the development of innovative, energy-efficient LED lighting technology, and this program provides access to important technology developed by Cree,” says George Brandes, director of intellectual property

licensing. “The remote phosphor licensing program is designed to provide rights under the relevant Cree patents that our LED customers need to develop and commercialize leading-edge LED luminaires and bulbs,” he adds.

Initial licensees to Cree’s remote phosphor patents include lighting innovators Aurora Energie Corp, Horner APG, Ledzworld Technology, Vexica Technology, and WyndSOR Lighting LLC. Cree is currently in discussions with other companies to license the remote phosphor patents, and aims to sign additional licensing agreements in the coming months. Details of the royalty-bearing licenses were not disclosed.

## IN BRIEF

### Sharp launches 2nd generation of 10W Mini Zeni LED arrays

Sharp has launched the second generation of its 10W Mini Zeni white-light LED arrays, which have 47% higher luminous efficacy of up to 106lm/W in standard operation, greater luminous flux of up to 900lm, and a typical color rendering index (CRI) of 82.

The firm says that advances in LED production have yielded four distinguishing features: they are compact, lightweight, economical and much brighter than before.

Sharp has retained the 15mm x 12mm x 1.6mm dimensions, along with an aluminium ceramic plate as carrier material. The flat surface of the ceramic plate and the existing soldering points make it possible to attach the modules to a suitable heat sink, without too much effort or additional connecting material, it is claimed, achieving efficient heat dissipation.

Depending on the module, the new variants have a long service life of 40,000 operating hours at an operating temperature of up to 90°C. The new generation is specified for use with a forward voltage of 17.7V and a forward current of 480mA, but the arrays can also be operated using a current of up to 800mA, yielding output of up to 1300lm. Colour temperatures are 3000–5000K (‘Natural White’, ‘Warm White’ and ‘Pure White’).

Sharp says that its extensive range of LED lighting arrays allows it to provide numerous marketable solutions for the use of LEDs as light sources for lamps and lighting fixtures. The Mini Zeni modules suit applications including spot lighting and LED retrofit lamps.

Initial samples are available (via Sharp’s sales offices and European distribution partners) with colour temperatures of 3000 and 4000K.

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

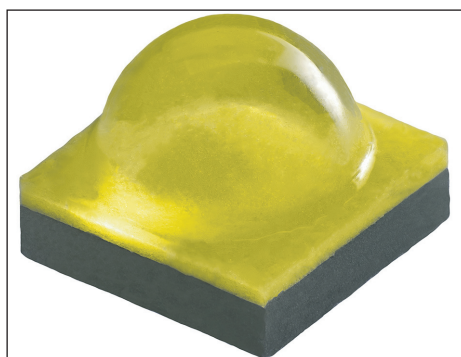


## Cree launches XB-D lighting-class LED on new platform that doubles lumens-per-dollar

Cree Inc of Durham, NC, USA has launched the XLamp XB-D LED. The first LED based on a new technology platform, the XB-D ushers in what is claimed to be a new era of price-performance for lighting-class LEDs. Cree adds that the LED can further simplify designs, ultimately removing a key barrier to widespread LED implementation — up-front system cost.

Leveraging Cree's proven silicon carbide (SiC) technology and expertise, the XB-D LED delivers luminous flux and efficacy, effectively, up to 139 lumens and 136 lumens per watt in cool white (6000K) or up to 107 lumens and 105 lumens per watt in warm white (3000K), both at a drive current of 350mA and a temperature of 85°C.

Cree claims that the XB-D LED delivers twice the lumens-per-dollar of other LEDs, in the industry's



**Cree's new XLamp XB-D LED.**

smallest lighting-class footprint of 2.45mm x 2.45mm. The XB-D LED is 48% smaller than the XLamp XP package and suitable for lighting applications where high lumen density and compact light sources are required. The developments behind this next generation of lighting-class LEDs can enable significantly lower prices for LED lighting products by using up to three times

fewer LEDs, three times fewer optics, and substantially smaller circuit boards than current designs, the firm adds.

"With this new platform Cree has fundamentally redefined the price-performance paradigm for our components customers," reckons Mike Watson, senior director of marketing, LED components. "It's not enough to just make LEDs brighter—it's also about improving product payback and market acceptance of LED lighting."

XB-D LEDs are also compatible with most existing XP family secondary optics, which can speed the optical design process and create direct cost savings for existing XP family-based designs.

Samples are available immediately and production volumes are available with standard lead times.

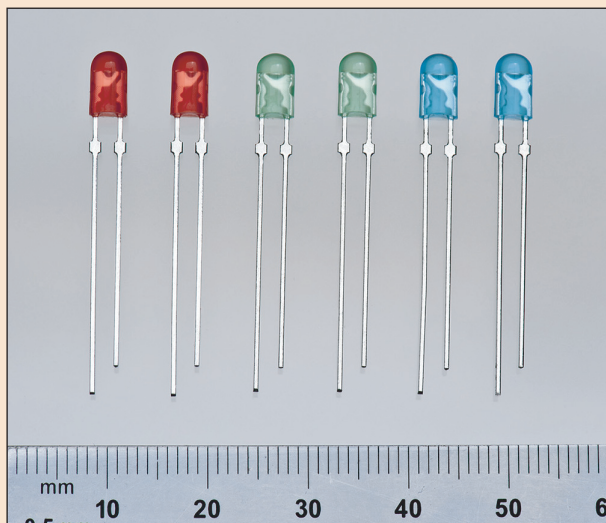
[www.cree.com/products/xlamp\\_xbd.asp](http://www.cree.com/products/xlamp_xbd.asp)

## First HB-LED optimized for elevated outdoor video screens

Cree Inc has extended its high-brightness LED range with the commercial availability of the new Screen Master C4SMT and C4SMD 4mm LEDs.

The LEDs' brightness and far-field pattern matching, combined with its packaging technology, can enable better viewing and achieve lower system and operating costs than previous generations of LEDs, says Cree.

The C4SMT and C4SMD are the two brightest LEDs in Cree's high-brightness P2 oval LED family. The C4SMD offers the brightest performance at 0° intensity and the C4SMT offers the brightest peak intensity performance at a -20° angle. Both LEDs are designed to maintain tight and consistent viewing across the entire viewing angle and far-field pattern of the LED, allowing for an even viewing experience for the end customer from different



**Screen Master C4SMT and C4SMD 4mm LEDs.**

angles and viewing positions.

The C4SMT is claimed to be the first commercially available HB-LED with a tilted -20° viewing angle, optimized for outdoor video screens and digital billboards that are installed higher than the viewing audience. Designed to have its

brightest point below the horizon, the C4SMT LED minimizes wasted light and can save up to 32% in power consumption compared to a standard through-hole oval LED with a 0° viewing angle.

"Cree's relentless focus on high-brightness LED innovation has produced the first IPX5-rated water-resistant SMD LEDs, the first IPX6/8-rated SMD LED optimized for

ease-of-manufacturing, and now, the first angled

LEDs, which can revolutionize the large-screen viewing experience," claims Mike Watson, Cree, senior director of marketing, LED components.

Screen Master C4SMT and C4SMD HB-LEDs are commercially available now.

# SemiLEDs revenue rebounds by 27%, driven by lower-price indoor components

## Fourth quarter of loss drives spending cuts while awaiting Chinese government's lighting plan

For its fiscal first-quarter 2012 (to end-November 2011), LED chip and component maker SemiLEDs Corp of Boise, ID, USA (which has chip fabrication facilities in Hsinchu Science Park, Taiwan) has reported revenue of \$6.75m, down 48% on \$13m a year ago but rebounding 27% from \$5.3m last quarter (which has been down 5% on the prior quarter). This is also at the high end of the \$6–7m guidance given in November).

Founded in 2005, SemiLEDs' manufactures proprietary blue, green and ultraviolet (UV) LED chips under the MvpLED (metal vertical photon LED) brand for sale mainly to chip-packaging customers in China, Taiwan and other parts of Asia such as Korea, or to distributors who sell to packagers. It also packages chips into LED components for sale to distributors and end-customers in selected markets (mainly for general lighting applications, including street lights and commercial, industrial and residential lighting).

Sequential growth is due to 93% growth in LED component sales (to about 45% of total revenue) — largely as a result of developing new, lower-price indoor lighting products — SemiLEDs continues to diversify its product revenues and provide more complete product solutions. In contrast, revenue from LED chip sales fell 29% (to 30% of total revenue). Other revenue (mainly luminaires, manufacturing of which is outsourced) has risen to 25% of total revenue.

"Our strategy of pursuing the indoor lighting market has already proven fruitful, as demonstrated by our financial results," says chairman & CEO Trung Doan.

Compared with +51% a year ago, gross margin was negative 12%,

although this is an improvement from negative 93% last quarter. Operating margin was negative 95%, compared with 38% a year ago. However, margins have improved slightly from last quarter due to managing expenses. R&D expenditure was cut sequentially by \$0.6m to \$1.7m. SG&A expenditure was cut by \$0.9m to \$3.9m (although last quarter included a charge of \$1.1m for bad debt reserve).

On a non-GAAP basis, net loss was \$7.1m, the firm's fourth consecutive quarter of losses, although cut from \$13.6m last quarter. This compares with net income of \$3.9m a year ago.

Cash used in operations was \$3.5m plus capital expenditure of \$5.8m yielded free cash flow of negative \$9.3m. Cash and cash equivalents hence fell during the quarter from \$83.6m to \$74m (a drop of \$9.8m, slowing slightly from the decline of \$10.8m last quarter).

"The industry remains very challenging," says Doan. "We believe the steps we are taking will allow us to weather the storm and position us well for when the industry recovers," he adds.

"In early November, I said that the market remained challenging in

Asia for LED chips and components," continues Doan. "The China market is still the same, and economic conditions around the world are full of uncertainty. However, pockets of demand have emerged." For example, on 15 December, Taiwan announced a street-light project valued at about NT2bn (US\$66m) which will be used to help local government install 250,000 LED street lamps in place of existing mercury vapor lamps.

Although the firm is still using some 2-inch wafers for R&D and certain legacy products, SemiLEDs' production lines in Taiwan are now qualified to produce chips on 4-inch wafers. In addition, the China SemiLEDs joint venture (formed in January 2010 in Foshan, Guangdong Province) is running entirely at 4-inch. In fiscal second-quarter 2012 (ending 29 February), SemiLEDs is scheduled to start selling products on the China market that will incorporate chips manufactured by China SemiLEDs and be packaged locally.

For fiscal second-quarter 2012, SemiLEDs expects revenue to grow to \$7–8m. However, gross margin is expected to still be negative, as production capacity will still not be fully utilized. CapEx should be just \$1.5m.

China's 12th five-year plan includes a commitment to drive energy efficiency and LED lighting adoption, and SemiLEDs claims to be one of the few companies that meets the program's requirements. "However, we have not seen this plan released yet," notes Doan. "Therefore, we are still producing a limited production and are continuing to focus on yield and reducing cost to ensure we are well positioned when the market improves."

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

**The China SemiLEDs joint venture is running entirely at 4-inch.**

**We are still producing a limited production and are continuing to focus on yield and reducing cost to ensure we are well positioned when the market improves**



# Osram's GaN LED chips on 150mm Si enter pilot stage

## Efficiency and brightness of prototypes reach competitive market

Researchers at Osram Opto Semiconductors GmbH of Regensburg, Germany have fabricated high-performance blue and white LED prototypes in which the light-emitting gallium nitride (GaN) layers are grown on 150mm-diameter silicon wafers.

The silicon wafers replace the sapphire substrates commonly used in the industry, with no loss of quality, it is reckoned. Already in the pilot stage, the new LED chips are being tested under practical conditions, so Osram Opto's first LEDs on silicon could enter the market in as little as two years.

Due to its already widespread use in the semiconductor industry, the availability of large wafer diameters and its very good thermal properties, silicon is an attractive and low-cost option for large-volume fabrication, particularly for future lighting markets, says Osram. Quality and performance data on the fabricated GaN-on-silicon LED chips match those of sapphire-based chips: the blue UX:3 chips (measuring 1mm<sup>2</sup>) in Osram's standard Golden Dragon Plus package achieve what is claimed to be a record brightness of 634mW at 3.15V when driven at a current of 350mA, equivalent to 58% efficiency.

In combination with a conventional phosphor converter in a standard housing (i.e. as a white LEDs) these prototypes correspond to 140lm at 350mA with an efficiency of 127lm/W at 4500K.



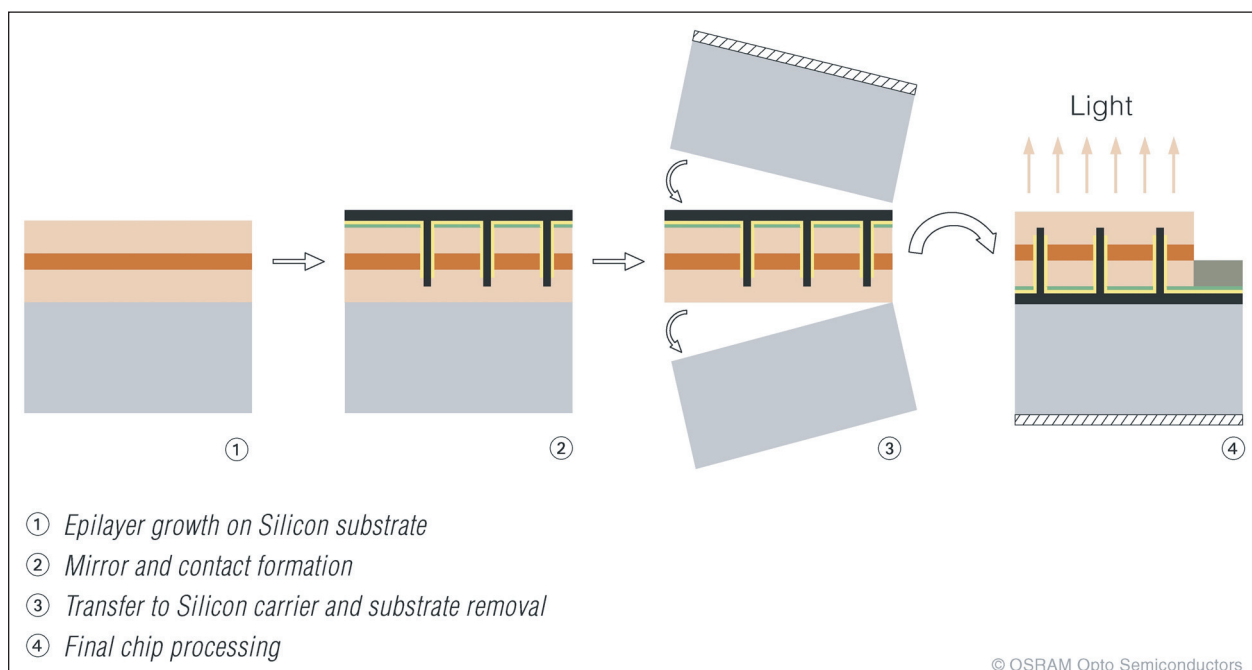
**OSRAM high-performance LED chips based on InGaN technology are fabricated on wafers with a diameter of 6 inches.**

"For these LEDs to become widely established in lighting, the component cost must come down significantly while maintaining the same level of quality and performance," says project manager Dr Peter Stauss. "We are developing new methods along the entire technol-

ogy chain for this purpose, from chip technology to production processes and housing technology," he adds. "Mathematically speaking, it is already possible today to fabricate over 17,000 LED chips of 1mm<sup>2</sup> in size on a 150mm wafer. Larger silicon wafers could increase productivity even more; researchers have already demonstrated the first structures on 200mm substrates.

Osram Opto says that it has acquired comprehensive expertise in the fundamental epitaxial growth technology over the last 30 years. The German Federal Ministry of Education and Research funds these activities as part of its 'GaNonSi' project network. "Our investments in years of research are paying off, because we have succeeded in optimizing the quality of the GaN layers on the silicon substrates to the point where efficiency and brightness have reached competitive market levels," notes Stauss. "Stress tests we've already conducted demonstrate the high quality and durability of the LEDs," he adds.

[www.osram-os.com](http://www.osram-os.com)



**Process diagram showing production of a UX:3 chip on a silicon wafer.**

## Soraa demonstrates high-power blue lasers in desktop projector at CES

In its private suite at the Consumer Electronics Show (CES 2012) in Las Vegas, Nevada (10–13 January), Soraa Inc of Fremont, CA, USA, which is commercializing nitride-based green and blue LEDs and laser diodes for application in general illumination and projection display, demonstrated high-power blue laser diodes (LDs) integrated into a desktop projector. The firm reckons that this represents the world's first desktop projector demonstration based on high-power nonpolar-semipolar laser diode technology.

Soraa has demonstrated output of more than 2W from a blue laser diode, and more than 4W from a blue laser array with continuous-wave power in multi spatial mode and multi spectral mode. At green wavelengths, Soraa has demon-

strated more than 100mW of continuous-wave power in single spatial mode and multi spectral mode. The devices can be directly modulated at the high speeds required for high-resolution displays with minimal speckle.

Soraa's laser diodes are based on indium gallium nitride (InGaN) technology and are fabricated on nonpolar and semipolar GaN substrates. The firm claims that its direct-diode green and blue lasers offer improvements in performance, size, weight and cost over conventional gas or solid-state lasers for consumer projection displays, defense pointers and illuminators, biomedical instrumentation and therapeutics, and industrial imaging applications.

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

## Luminus demos latest technology at CES, from 50lm pico projector to 4000lm hybrid projector

At the International Consumer Electronics Show (CES 2012) in Las Vegas (10–13 January), Luminus Devices Inc of Billerica, MA, USA, which manufactures PhlatLight (photonic lattice) LEDs for illumination applications, demonstrated the latest projector products illuminated by its projection chipsets.

In a private room at the Las Vegas Convention Center, invited visitors saw a side-by-side demonstration featuring an LED projector with brightness comparable to a traditional lamp-based projector rated at 2200 ANSI lumens. Confirming its focus on higher-brightness mainstream projectors targeted at business and education markets, the firm is also displaying a 4000lm hybrid LED/laser projector based on its latest red and blue LED technology.

In the ultra-portable projectors

category, Luminus is demonstrating several projectors rated at a performance of up to 500lm as well as a technology demonstration previewing the next generation of products.

"The latest advances in brightness of our Big Chip LEDs continue to offer to more segments and applications within the projection space, now including mainstream data projection," says Stephane Bellosguardo, director of Global Product Marketing, Display Business Group. "Through sustained R&D investment and product innovation, Luminus is now demonstrating that we are well positioned to expand in the mainstream front projector market, which is forecast to grow to over 9 million units per year by 2013."

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

### IN BRIEF

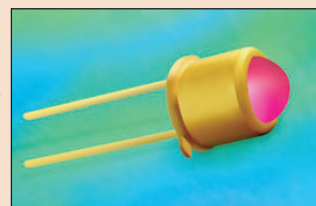
#### Opto Diode launches wide-emission, high-power IR LEDs

Opto Diode Corp of Newbury Park, CA, USA (a division in the Photonics Group of ITW) has launched the first of a family of three new infrared (IR) emitters. The OD-850W gallium aluminum arsenide (GaAlAs) LED features a wide emission angle for coverage over a large area, plus extremely high optical output (minimum 30mW, typically 40mW), with peak emission wavelength at 850nm.

The new device is an upgrade and replacement for the OD-880W IR LEDs, offering nearly double the output power, added stability, and much less degradation. Also, the 850nm wavelength is more closely matched to the peak response of photo-transistors and optoelectronic integrated circuits (ICs), making them suitable for industrial control applications such as photoelectric controls and optical encoders.

Hermetically sealed, the standard TO-46 package is designed with gold-plated surfaces

and welded caps for added durability. The



IR LED offers optical power of 40mW (typical) at 100mA, continuous forward current at 100mA and peak forward current at 300mA (absolute maximum ratings at 25°C). The storage and operating temperatures range from -40°C to 100°C, with a maximum junction temperature of 100°C.

The OD-850W IR LEDs are priced at \$2.80 each (minimum order of 100 pieces).

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

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

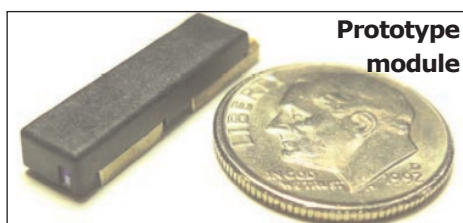


## QD Laser exhibits compact prototype 100mW, 532nm green laser module with high efficiency and high speed

QD Laser Inc of Kawasaki, Japan — together with University of Tokyo, its Institute for Nano Quantum Information Electronics, and Fujitsu Laboratories Ltd — have developed a high-power 532nm-wavelength compact green laser module with high-efficiency and high-speed modulation capability. A prototype module was exhibited at the SPIE Photonics West 2012 event in San Francisco (24–26 January).

High-power green lasers have been attracting attention in many fields, including life sciences and biomedical and industrial applications. Unlike near-infrared lasers for optical communications and red and blue lasers for optical storage, semiconductor lasers provide limited output characteristics at green wavelengths. So, for applications that require high output power at wavelengths around 530nm, diode-pumped solid-state (DPSS) lasers are normally used. In these applications, it is imperative to have improved wavelength stability and high-speed modulation capability as well as low power consumption and compact size.

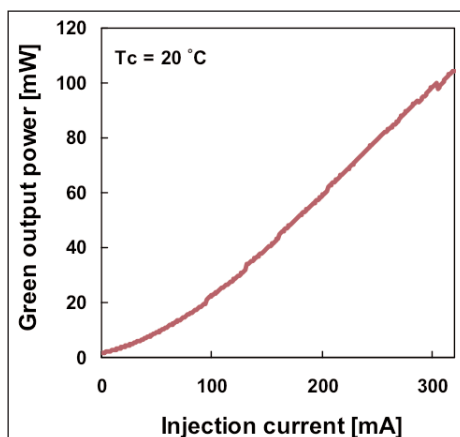
In collaboration with Fujitsu Laboratories and University of Tokyo (from which QD Laser was spun off in 2006), QD Laser utilized their collective proprietary technologies of semiconductor crystal growth, precise grating fabrication, and device design technology to develop 1064nm high-power single-mode lasers optimized for wavelength conversion (whereby doubling the frequency of the light output halves the wavelength to 532nm). QD Laser markets 1064nm-band DFB (distributed feedback) laser modules, mainly for industrial applications including as a seed source for fiber lasers, and has already shipped them to more than 30 companies worldwide. Furthermore, newly developed module assembly technology enables precise integration of these laser chips with a wavelength-conversion crystal.



A near-infrared high-power single-mode laser (based on proprietary semiconductor DFB laser technology) has therefore been combined with wavelength-conversion technology to yield a compact laser module (of about 0.5cc in volume) that can provide high output power of more than 100mW at a wavelength of 532nm.

According to the test results for the prototype module, 100mW output power under CW (continuous wave) conditions was obtained with power dissipation of about 900mW, representing high wall-plug efficiency of more than 10%. Optical spectral characteristics yielded a narrow linewidth of less than 0.01nm with a high side-mode suppression ratio, which is particularly suitable for precise measurements using optical interference or high resolution spectroscopy.

Tests also confirmed high-speed optical modulation capability of more than 100MHz and a short pulse of less than 1ns operation. This was performed with a simple direct current modulation scheme, which showed that it could be



**Light output characteristics (DFB current = 100mA).**

effective for time-resolved spectroscopy and other fields.

It is reckoned that the module shows promise for a wide range of applications such as fluorescence microscopes or spectral analysis in life science or biomedical applications, and precision measurement as well as nondestructive inspection in industry. Furthermore, what is claimed to be unique characteristics of high power, high efficiency, and high-speed modulation with a compact package are also expected to apply to future applications such as head-up displays or ultra-compact mobile projectors in consumer electronics, which are attracting much attention and growing in the market.

QD Laser has already started shipping samples of QLD0593-P05, a module with 5mW output power. In addition, in April it plans to ship samples of the high-power (>50mW) QLD0593-P50 module, for mass production from fourth-quarter 2012.

Development of the green laser module has been supported in part by Japan's New Energy and Industrial Technology Development Organization (NEDO) and 'Project for Developing Innovation Systems' conducted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

In addition, in-house epitaxial growth and grating technology provides the flexibility to handle a wide range of wavelength bands, so QD Laser is now extending the wavelength lineup of its DFB laser modules from 1030 to 1300nm. The firm therefore also has the potential to combine them with wavelength-conversion technology to yield visible wavelengths in regions such as 515nm and 555nm for special green laser or 560nm and 590nm for yellow to orange colors. QD Laser says that it will continue with these technical developments to meet market requirements.

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

## QD Laser develops compact yellow-green and orange laser modules with high-speed modulation capability

QD Laser Inc of Kawasaki, Japan — together with the Institute for Nano Quantum Information Electronics (NanoQuine), University of Tokyo — have developed compact laser modules emitting at wavelengths of 561nm (yellow-green) and 594nm (orange) with high-speed modulation capability. Prototypes were exhibited at the SPIE Photonics West 2012 event in San Francisco (24–26 January).

Based on the platform developed for the QLD0593 Series high-power, compact green laser modules, QD Laser and University of Tokyo have extended the wavelength band to the yellow-green and orange visible color regions.

QD Laser and University of Tokyo have finely tuned both the oscillation wavelength of distributed feedback (DFB) near-infrared single-mode lasers as well as the operating wavelength of PPLN (periodically poled LiNbO<sub>3</sub>) crystal for wavelength conversion to 561nm and 594nm, before combining them in recently developed compact modules of 0.5cc volume (5.6mm x 3.8mm x 22mm).

Normally, diode-pumped solid-state (DPSS) lasers are used in the green-yellow to orange wavelengths. QD Laser says that the new semiconductor-based modules enable great compactness, high

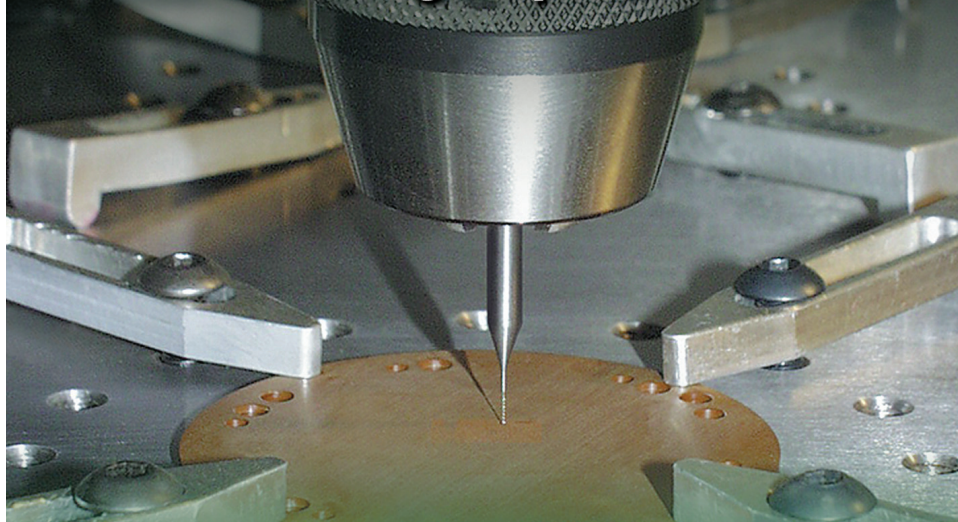
stability in power and wavelength, and high-speed modulation, providing a common platform for a wide variety of application areas, particularly in life science and biomedical applications such as fluorescence microscopes, spectral analysis and gas sensing.

Development of the modules was supported in part by Japan's New Energy and Industrial Technology Development Organization (NEDO) and 'Project for Developing Innovation Systems' conducted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT).



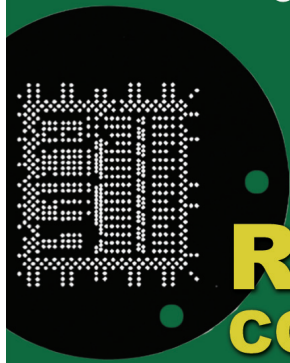
Projected laser light (561nm and 594 nm) from compact laser modules.

**Burr-free  
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that meets your most  
demanding requirements.



### Drilling Capabilities

- all drilling and inspection performed under climate-controlled conditions
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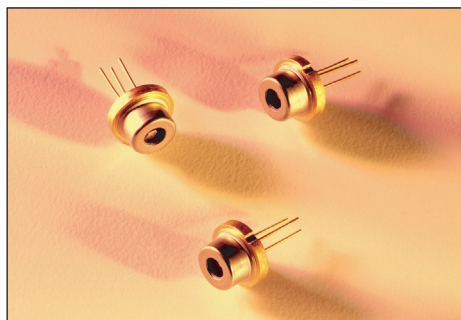


## Intense first to provide 300mW laser at 980–780nm

Intense Inc of North Brunswick, NJ, USA, which makes monolithic laser array products, high-power single-emitter laser diodes, and electro-optical subsystems, has announced the production release of a 300mW version of its Series 6030 and Series 6130 ultra-high-power, high-brightness single-mode laser diodes. Designed for defense, medical and print/imaging applications such as spectroscopy and industrial coding, the diodes are available in 980, 830, 808, 785 and 780nm wavelengths. Custom packaging and wavelengths are available on request.

Part of the Series 6000 family of single-mode lasers, the Series 6030 and 6130 are based on patented quantum well intermixing (QWI) technology, which increases the brightness and reliability of laser diodes while avoiding the usual problems associated with catastrophic optical mirror (COD) damage.

"Intense has been producing highly reliable, complex multi-



**Intense's 6000 Series lasers.**

channel, individually addressable 200mW single-mode diode arrays in high-volume for several years," says CEO Kevin Laughlin.

Until now, 300mW of true single-mode power has not been available, particularly at shorter wavelengths (808–830nm and 780–785nm). The availability of these new wavelengths and ultra-high-power offerings are driving new uses, particularly in illumination, spectroscopy, life science, and atomic clock applications, says Intense.

The Series 6030 and 6130 offer high electrical conversion efficiency in a range of operating temperatures,

from 25°C to 50°C. The lasers are available in a selection of free-space packages, including 9mm, C-mount, 5.6mm; a PDM (piezoelectric deformable mirror) is optional. Multi-emitter, individually addressable, custom ultra-high-power arrays have also been designed using the basic 6030 design.

Intense offers the Series 6030 and 6130 single emitters in a variety of standard beam divergences to match specific applications requirements. Multiple fast-axis collimation (FAC) lensing options are also available.

Intense is also able to fabricate ultra-high-power, single-mode, individually addressable, multi-channel arrays in wavelengths from 650nm to 980nm with 10–270 channels per array. Arrays can be integrated with full drive electronics and micro and macro lens options.

The Series 6030 and 6130 single-mode laser diodes are also available in custom packaging to match OEM system requirements. OEM discounts are based on quantities ordered.

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

## Intense launches 10W version of 793nm pump module for thulium and holmium pulsed laser systems

At the SPIE Photonics West 2012 event (24–26 January), Intense launched a 10W version of its Series 8000 793nm high-brightness laser pump modules.

The medium-power pump delivers 10W of output from a 105µm-core fiber (numerical aperture = 0.22). The compact module is designed for use as a pump source for thulium and holmium pulsed laser systems, which are seeing increased use in defense and medical applications.

The Series 8000 793nm fiber-coupled packages provide robust and compact solutions for pumping applications with power requirements in the 10W range. With this launch, the high-power chip technology of the Series 8000 793nm is now available in fiber-coupled single emitters at 4.5W, as well as

compact, multi-emitter, high-brightness, fiber-coupled 10W and 20W modules.

"Intense continues to lead the 793nm pump market, a market we established over 5 years ago with the production version of our 4.5W high-brightness, single-emitter pumps," claims CEO Kevin Laughlin. "When we introduced the 20W version last year, medical OEMs approached us with requests for a lower-power, high-efficiency, high-brightness pump in a more compact package," he adds. "Today's introduction of the 10W 793nm completes development of what has become a formidable and wide-ranging 793nm pump product portfolio."

The entire Series 8000 793nm family of pump lasers is based on

Intense's next generation of 793nm single-emitter chips that incorporate narrow beam divergence and Intense's patented quantum well intermixing (QWI) technology to maximize power, brightness and reliability.

The 793nm fiber-coupled packages come standard with 105µm (0.22NA) fibers; 0.15NA fiber options are available on request. The same 793nm chip technology is also offered in a variety of free-space configurations with FAC options.

The Series 8000 793nm single- and multi-emitter pump modules (4.5W, 10W and 20W) are available in custom packaging to match OEM system requirements. OEM discounts are based on quantities ordered.

## 3S Photonics Group becomes 3SPGroup

### 3S Photonics, Avensys and Manlight merged into one brand

Following synergies between 3S Photonics, Avensys and Manlight, 3S Photonics Group is uniting the three companies into the single entity 3SPGroup of Nozay, France, with the aim of simplifying its image and pursuing its internal and external growth strategy.

3S Photonics was founded in 1994 as Alcatel Optronics S.A. (a subsidiary of the Alcatel group) and acquired in 2003 by Avanex Corp of Fremont, CA, USA, becoming Avanex France S.A. In April 2007, it was bought by entrepreneur Alexandre Krivine (becoming president & CEO) and chief technology officer Didier Sauvage (former director of Avanex France) and renamed 3S Photonics. The firm designs and manufactures both active optoelectronic components (incorporating gallium arsenide and indium phosphide laser chips fabricated in-house at Nozay, France) and passive fiber-based optical components (made at what was formerly Avensys Inc of Montreal, Quebec, Canada, acquired in early 2010). 3S is active in two global markets: high-speed telecom net-

works (both the historical core business of submarine telecoms as well as, more recently, terrestrial telecoms) and fiber lasers (supplying products for industrial, medical and defense applications).

For fiscal 2011 (to end June), 3S Photonics Group reported revenue of €51m (up 64% year-on-year, or up 44% for continuing business). Also, calendar 2011 saw a change in majority owner (with European-listed investment firm Eurazeo last October investing €37m to take an 83% stake). Subsequently, in November, the group acquired Manlight S.A.S. of Lannion France, which was founded in 2006 from the former Highwave Optical Technologies, and designs and manufactures optical fiber amplifier and laser products for telecom networking (from transport to broadband access), industrial, security (LIDAR) and defense.

Now, as well as designing and manufacturing optical components and modules for the telecom, industrial, security and defence, medical and R&D applications, the group also develops fiber-optic sys-

tems including high-power fused components, optical fiber sensors (OFS), fiber-laser components, and a complete range of 1.0µm, 1.5µm and 2.0µm fiber lasers and amplifiers. Through its Avensys Solutions division, it also provides instrumentation and integrated solutions for process and environmental monitoring systems.

3SPGroup says that in 2012 it will continue its acquisition strategy in order to strengthen its position in historical markets, and pursue vertical and market growth. To this end, it has decided to reorganize itself and simplify its image and name under a single brand.

"Beyond this marketing strategy, with the industrial and trade integration of our different structures, we wanted to offer a diversified and easily accessible range of products and solutions," says Krivine. "Our customers will continue to benefit from the increase of our production capacities and technical expertise."

3SPGroup exhibited in both the Canadian and French Pavilions at Photonics West in San Francisco.

[www.3spgroup.com](http://www.3spgroup.com)

## Intense extends 808nm pump module range to 30W

At Photonics West, Intense Inc launched a 30W version of its Series 8000 808nm laser pump modules.

The multi-emitter pump delivers 30W of output power from a 200µm-core fiber with a numerical aperture (NA) of 0.15 or 0.22. Intense says that compact size and a combination of efficiency and high brightness make it a high-performance pumping alternative to meet the growing demand for fiber and solid-state laser systems used in defense, medical, and industrial applications.

The Series 8000 808nm fiber-coupled packages provide robust, cost-effective, and compact solutions for applications with power requirements up to 30W, the firm claims.

The high-power chip technology of the Series 8000 808nm is now available for power levels from fiber-coupled single emitters at 6W, to multi-emitter, high-brightness, fiber-coupled modules at 30W.

"The new compact 30W module was introduced to serve a growing number of defense and industrial customers who were using our 793 and 808nm mini fiber packages," says CEO Kevin Laughlin. "The 30W 808nm was introduced as a compact, high-efficiency and high-brightness pumping alternative for fiber and solid-state laser systems," he adds. "Intense's family of Series 8000 QWI-enabled pumping modules has continued to evolve. It now

includes 808nm and 793nm offerings. In 2012, these will serve as the cornerstone for a much expanded product line."

The entire Series 8000 family of laser pump products is based on Intense's next generation of single- and multi-emitter chips that incorporate narrow beam divergence and patented quantum well intermixing (QWI) technology to maximize power, brightness, and reliability.

The 808nm chip technology is offered in a variety of free-space configurations with FAC options.

The 30W pump modules are also available in custom packaging to match OEM system requirements.

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



## IN BRIEF

**20G VCSEL sampled**

Oclaro is sampling a vertical-cavity surface-emitting laser (VCSEL) operating at 20Gb/s.

Having shipped over 100 million VCSELs (including over 500,000 10G VCSELs in the last year), Oclaro's products have been designed into consumer electronics such as notebook PCs, optical cables, mice and smartphones.

VCSELs can be used to connect devices such as peripherals, workstations, displays, disk drives and docking stations. Because VCSELs are very reliable and meet the stringent requirements of consumer devices, they are rapidly being adopted in all areas of consumer electronics. Oclaro claims it has secured volume leadership in VCSELs by leveraging its expertise in optical laser technology and reliability and quickly achieving the high-volume production capacities needed for consumer products.

By offering new VCSELs that deliver higher data rates, Oclaro says it can enable users to develop faster-performing products at better price/performance points. "Just as we are continually addressing the increased bandwidth requirements of the core optical network, we are also committed to meeting the demands of the consumer industry by enabling customers to increase the data transfer rates between various devices such as computers, disk drives or HD TVs," says Karlheinz Gulden, senior director product management. "With the introduction of reliable 20G VCSELs, Oclaro is helping its customers to double the bandwidth over existing solutions and be first to market with higher-performing next-generation consumer devices," he adds.

The 20G VCSELs are particularly suited to the growing 16G Fiber Channel transceiver market, which is starting to ramp this year.

**Oclaro lasers enable development of first 15kW direct-diode laser systems**

Optical component, module and subsystem maker Oclaro Inc of San Jose, CA, USA says that its laser diodes have been designed into the industry's first 15kW direct-diode fiber-coupled laser systems.

Featuring what is claimed to be the broadest wavelength range, the laser diodes scale from 910nm to 1070nm at high power levels and leading brightness to meet the demanding performance requirements of the next-generation 15kW systems. Oclaro showcased its line of laser diodes — which are shipping in volume to the industrial, semiconductor, automotive and materials processing markets — at the SPIE Photonics West 2012 conference in San Francisco (24–26 January).

Oclaro says that 15kW and other multi-kilowatt systems suit applications such as metal welding, cladding and cutting, which continually require higher power to improve the performance of the laser system and process efficiency. Due to their output power, brightness and 'colors', Oclaro's laser diodes have been driving the development of the next-generation laser systems. Because the power of the systems scales linearly with the number of wavelengths available for multiplexing, Oclaro's ability to provide lasers with wavelengths from 910nm up to 1070nm with high power levels and high brightness is allowing users — for the first time — to design commercial fiber-coupled multi-kilowatt direct-diode laser systems that can meet and exceed 15kW.

One of the first customers designing next-generation 15kW laser systems is high-power diode laser system maker Laserline. Oclaro says that Laserline chose its direct-diode solutions because they deliver the power, brightness and reliability needed to bring 15kW direct-diode systems to market.

In addition, Oclaro was able to pro-

vide Laserline with its in-house design and manufacturing expertise along with the capability to scale to volume quickly and cost effectively.

Oclaro says that key innovations of its direct-diode solutions include the following:

- Optimization of the laser diode design structure. Oclaro has its own design capabilities in-house, enabling significant improvements in overall efficiency and design (with epitaxial engineering being one of Oclaro's key competencies).
- Expert soldering process. Telecom-grade AuSn (gold tin) hard solder make the Oclaro laser diodes suitable for demanding applications in continuous-wave (CW) and hard-pulse operation mode.
- E2 Passivation Techniques. Like all Oclaro high-power lasers, the front facet is protected against catastrophic optical damage (COD) by the firm's E2 mirror passivation process, which enables higher power densities on each laser diode (allowing power scaling of diodes).
- Vertical Integration. By owning the laser diode development from initial design and wafer form to final product, Oclaro can deliver designs that reach the power, brightness and reliability required at leading cost structures, it is claimed.
- Manufacturing strength. Oclaro's global R&D, chip fabs, assembly lines and supply chain enable users to enjoy faster time to market and volume capacity.

Oclaro's portfolio of laser diodes includes low-fill-factor bars from 50W to 80W and high-fill-factor conduction-cooled bars at 120W and active-cooled bars up to 200W. These products, all of which have a wavelength range of 910–1070nm, allow for wavelength multiplexing with five to six colors (assuming 30nm spacing).

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

## Teledyne and Zephyr partner on high-bandwidth interconnects for harsh-environment datacoms

Zephyr Photonics of Zephyr Cove, NV, USA and Teledyne Microelectronic Technologies of Los Angeles, CA (a business unit of Teledyne Technologies Inc of Thousand Oaks, CA) have partnered to develop and market optical interconnect technology solutions to meet the high-bandwidth and harsh-environment demands of the defense, aerospace, commercial aviation, and oil & gas industries.

The partnership combines Zephyr's proprietary vertical-cavity surface-emitting laser (VCSEL) technology with Teledyne Microelectronics Technologies' five decades of experience designing and manufacturing multichip modules (MCMs) and ruggedized fiber-optic assemblies for a variety of applications.

This is the first major commercial partnership for Zephyr, which was founded in 1987 as the R&D firm OptiComp and recently transitioned to a commercial enterprise. The agreement with Teledyne includes joint product development to address future market opportunities, provides a collaborative sales channel to reach more customers faster while opening new markets via Teledyne's multiple divisions, and establishes a trusted partnership for government funding proposals for new technology development.

Teledyne Microelectronic Technologies is already a Department of Defense (DoD) Trusted Source for microelectronics, while Zephyr provides solutions to the DoD and to the aerospace, industrial, energy and intelligence industries.

"This is a significant step for Zephyr Photonics as we work to establish our foothold as a trusted resource and partner for optoelectronic technology across a variety of markets and industries," says the firm's CEO Tom Steding. "Working with Teledyne Microelectronic Technologies provides credibility to our

customers via a trusted manufacturing facility and further demonstrates our commitment to the defense OEMs and, ultimately, the warfighter," he adds.

The joint manufacturing and product marketing collaboration aims to provide optical interconnect fiber-optic products that can overcome harsh-environment data communications obstacles and enable optical interconnect solutions that meet the requirements of national security and commercial applications.

"Together, we will deliver unparalleled and reliable solutions to system designers and improved SWaP for applications and environments where data communications is not just important, it is mission critical and potentially life-saving," says Terry Thomas, Zephyr's executive VP of business development.

"Zephyr Photonics' proprietary high-temperature VCSELs can withstand temperatures over 155°C and are well suited for unmanned airborne vehicles, in addition to extreme heat conditions in down-hole oil drilling applications," he adds.

"Teledyne Microelectronic Technologies relationship with Zephyr Photonics expands our range of optoelectronic packaging solutions well beyond the competition's," reckons Albert Andry, VP & general manager of Teledyne Microelectronic Technologies. "By partnering with Zephyr Photonics, we can take our superior fiber-optic packaging capabilities to the Oil & Gas sector, where extreme temperature requirements are driving technology to limits not seen before."

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

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

### IN BRIEF

#### Opnext adds 660nm red laser with built-in monitor photodiode

Opnext Inc of Fremont, CA, USA has launched a 660nm red high-power laser with a built-in monitor photo-diode (for mass production in April).

Designed for applications such as LIDAR and plastic optical fiber (POF) communications, the HL65051DG achieves what is claimed to be optimal performance and output by enabling system designers to monitor the laser's performance and adjust output power in real time.

Opnext's laser diode family features the HL63142DG (launched in January 2011), which also has built-in monitoring, which allows system designers to control optical performance by monitoring the photodiode current and adjusting for temperature and power variation. Opnext says that performance-monitoring capabilities are essential for maintaining constant output power in laser imaging detection and ranging as well as POF communications, such as the automotive market, where there are changes in the operating environment. The HL65051DG operates at up to 60°C and 120mW in the 660nm waveband in a 5.6mm-diameter TO industry-standard package.

"We expect to see initial demand for this high-quality laser from industry applications where precise laser control is an important performance parameter," says Tadayuki Kanno, president of Opnext's devices business unit. "The industry trend is moving toward producing high-power laser diodes that consume less energy," he adds.

Opnext demonstrated end-application products using its laser technology at Photonics West (24-26 January).

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



## IN BRIEF

## OneChip on photonic integrated circuits panel at Photonics West

At Photonics West in San Francisco, OneChip Photonics Inc of Ottawa, Canada, which makes optical transceivers based on InP monolithic photonic integrated circuits (PICs) for access networks and other mass-market broadband applications, featured on a panel discussion on 24 January on the topic 'Silicon Photonics and Photonic Integrated Circuits'.

The panel discussed demand for smaller and cheaper optical interconnections inside computers as a main driver for silicon photonics, creating a new market for miniaturized, low-cost photonic components that can leverage the scale of CMOS manufacturing. The panel also discussed developments in silicon photonics and how it can impact industries from computing and communication, to biomedicine, and imaging.

OneChip says it was chosen for the panel discussion based on its development of PIC-based PON transceivers that will help system providers and carriers to deploy fiber-to-the-x (FTTx) more cost-effectively than before — and to meet consumer and business demand for high-bandwidth voice, data and video services.

Panelist Andy Weirich, OneChip's VP of product line management, has over 28 years of telecoms industry product development management experience (ranging from digital signal processing systems to broadband access and optical transport systems), as well as executive management experience. Most recently, he was VP of Products and Technology at CIena Corp and a co-founder and VP of System Architecture at Catena Networks.

[www.onechip Photonics.com](http://www.onechip Photonics.com)

## Opnext's 10G module production at Thailand's Fabrinet transferred from Chokchai to Pinehurst

### Return to capacity due early in June quarter

Following the severe flooding in Thailand that halted operations at the Chokchai campus of its primary contract manufacturer Fabrinet on 22 October, optical module and component maker Opnext Inc of Fremont, CA, USA says that production at Chokchai remains suspended, and that production is unlikely to resume there.

Opnext has hence relocated limited production capacity to its manufacturing facilities in Fremont and Totsuka, Japan. It has also diverted part of 10Gb module production capacity to Fabrinet's Pinehurst plant 7 miles north of Chokchai. Fabrinet has allocated surface-mount technology (SMT) lines at Pinehurst to Opnext, and new test systems are being constructed to replace systems lost in flooding. Opnext expects Fabrinet to start production in February and ramp production as new test systems come online.

Opnext is also engaging an extra contract manufacturer with the aim of dual sourcing manufacturing of certain high-volume products. The firm had restored about 20% of the lost 10G module production capacity by the end of 2011, and anticipates continuing to increase capacity during the March quarter, with a return to full capacity expected early in the June quarter.

Opnext expects the loss of capacity at Fabrinet to have a significant impact on its operations and its ability to meet demand for its products for the remainder of fiscal 2011 (to end-March 2012). Production at Fabrinet comprised \$37.3m (43%) of Opnext's total revenue in fiscal Q2/2012 (to end-September 2011). The firm expects the loss of revenue in both fiscal Q3 (to end-December 2011) and Q4 (to end-March 2012) to be material. Multiple factors will affect the extent of revenue loss, including (but not limited to)

Opnext's ability to move production to other locations, existing inventory from which to meet customers' needs, the firm's ability to source parts from suppliers that have been impacted by the flooding or from alternative suppliers in instances where the firm has had to locate alternatives, the level of demand from customers, and Opnext's ability to incrementally increase production at its other facilities.

Also, Opnext has experienced some loss of equipment and inventory in connection with the flooding. At the time of the flooding, its production equipment in Chokchai consisted mainly of 10Gbps module test sets (with an original cost of \$31.3m). Some of the more sophisticated measurement equipment escaped damage from the flood waters, but as of the end of 2011 Opnext was still to determine the extent of equipment lost. The firm also had \$15.7m of inventory with Fabrinet (\$7.6m of raw materials and \$8.1m of finished goods). Although about half of the finished

**Fabrinet comprised \$37.3m (43%) of Opnext's total revenue in fiscal Q2/2012**

goods had already been determined to be in good condition, Opnext was also still determining

the status of the remainder as well as the status of the raw materials.

While Fabrinet maintains insurance for the equipment and inventory at the facility (and Opnext maintains independent insurance for a portion of the inventory) and there are additional contractual protections in favor of Opnext that Fabrinet has stated it will honor, it is not clear that the insurance will be adequate to fully cover Opnext's losses.

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

# Oclaro's quarterly revenue down 28% year-on-year

## ...but recovery from Thailand flooding drives revenue above guidance

For its fiscal second-quarter 2012 (to end-December 2011), optical component, module and subsystem maker Oclaro Inc of San Jose, CA, USA has reported revenue of \$86.5m, down 18% on \$105.8m last quarter and 28% on \$120.3m a year ago.

Major customers (greater than 10% of revenue) were Fujitsu (14%), Infinera (11%) and Ciena (10%). Other customers traditionally over 10% include Huawei and Alcatel, which were both at 9% (with Huawei down from 17% a year ago and 13% last quarter), with mix changes associated with the flooding in Thailand.

Financial results were materially impacted by flooding on 22 October at the Chokchai and Pinehurst facilities of Thailand-based primary contract manufacturer Fabrinet Co Ltd (which manufactured 30% of Oclaro's total finished goods). However, revenue was above the guidance of \$75–85m provided on 9 November, due mainly to recovery efforts from the flooding.

By segment, revenue from Telecom Components has fallen from \$24.8m last quarter to \$22.3m. Some strengthening in Asia was more than offset by a drop in external modulator revenue due to the flood.

Revenue from Transmission Modules has risen from \$24m last quarter to \$31.4m, driven by growth in tunable XFP and 40G coherent transponder products. "We probably had more demand upside in this category, however we were limited in the short term by availability of PCBs we purchased from our contract manufacturer in Thailand," says chairman & CEO Alain Couder.

Revenue from Amplification, Dispersion Compensation and Switching products has almost halved, from \$40m last quarter to \$20.6m. This was the category hit most by the floods, as many of the firm's amplifier products, tunable dispersion compensation products and some wavelength-selective

switching (WSS) products are sourced from Thailand.

Revenue from Industrial & Consumer products has fallen from \$17.1m last quarter to \$12.2m, due mostly to high-power lasers being impacted for part of the December quarter by the flood, as well as some seasonal softness in consumer lasers.

Cost and expenses directly associated with the flood totaled \$9.1m, including write-off of damaged inventory and equipment totaling \$7.2m, and the cost of personnel directly engaged in recovery and other incremental outside costs.

On a non-GAAP basis, gross margin has fallen further, from 30% a year ago and 23% last quarter to 13%, due mainly to the drop in revenue (while the fixed manufacturing and overhead base through the rest of the firm remained largely in place) as well as lower overhead absorption levels in corresponding de-stocking of inventory.

Compared to +\$10.1m a year ago and negative \$4.5m last quarter, adjusted EBITDA has worsened to negative \$14.3m. However, this was at the high end of the guidance range of -\$13–18m due to the higher-than-expected revenue plus cost-control efforts. Likewise, compared to net income of \$5.9m a year ago, net loss has worsened from \$11m last quarter to \$17.7m.

Compared to \$10m per quarter in fiscal 2011, capital expenditure has more than halved from \$6.2m in fiscal Q1/2012 to just \$3m. During the quarter, cash, cash equivalents and restricted cash rose from \$51.7m to \$54.2m.

"We expect to be able to fund our Thailand recovery with about \$10m CapEx in total," says Couder. "We expect CapEx in the March and June quarter of \$6m per quarter, including CapEx associated with the flood recovery," he adds.

Production of high-power lasers (at the Pinehurst facility) resumed

in November, and is now back to pre-flood capacity. As of 4 January, Oclaro had re-started commercial production for four of the five affected product lines, including those transferred to Pinehurst from the defunct Chokchai facility (which represented 60–70% of Oclaro's Fabrinet-produced revenue). "We expect full commercial production by the end of March for three of our five affected product lines and within the June quarter for the remaining two," says Couder.

Specifically, amplifier production resumed in late December, and should be at pre-flood levels in March. Lithium niobate modulator production has resumed and will be at full capacity by the June quarter (meanwhile, some limited shipments have been coming out of Oclaro's sites in Italy). Tunable dispersion compensator production is due to resume production at the end of January, and be back to capacity by February. WSS production should resume in April and be at full capacity in the June quarter (meanwhile, a significant portion of Oclaro's WSS shipments have been coming out of existing sites in the West and Korea).

For its fiscal third-quarter 2012 (to end-March), Oclaro expects some recovery in revenue to \$90–97m (though this is still impacted by \$10–20m by the Thailand flooding). Gross margin should recover slightly to 14–19%, and adjusted EBITDA to -\$13.5–9m.

"In spite of the flood, we remain focused on enabling Oclaro to emerge from this period better positioned than before, in terms of our market position on certain existing products, recent introductions and our pipeline of new products and new technologies," says Couder. "By the June quarter we'll have improved our EBITDA bottom line by \$5m per quarter, versus June 2011 (assuming similar revenue)," adds Turin.

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



## GigOptix samples 28G MZM driver

GigOptix has started sampling its 28Gb/s Mach-Zehnder modulator (MZM) driver, designed for 40G and 100G metro and long-haul optical transmitters.

Features of the GX6262 include: a data rate up to 28Gb/s for use with 40G DQPSK and 100G DP-QPSK modulation formats; low RMS jitter degradation; differential output from 7V<sub>pp</sub>; adjustable eye cross point; and low power consumption of 2.7W.

"We developed the GX6262 in close collaboration with our tier 1 customers to be fully compliant with their specific requirements," says chief technology officer Andrea Betti-Berutto. "The competitor product burns more power than our GX6262, it requires more real estate on the PCB, and is not as cost effective," he claims. "Since each 40G DQPSK transponder requires two GX6262 drivers, these advantages are compounded and, therefore, the GX6262 enables customers to implement much more compact and efficient transponder solutions."

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

## Optical transport system maker Optelian acquires Versawave Vertical integration supplemented by 100G optical modulator provider

Optical transport system maker Optelian (which has sales, marketing and service operations in Marietta, GA, USA and in-house development and manufacturing in Ottawa, ON, Canada) has acquired Versawave Technologies Inc of Vancouver, BC, Canada. Using GaAs chips fabricated by suppliers in North America, Versawave designs and makes ultra-high-bandwidth optical modulators with patented polarization modulation technology.

Optelian says the strategic move further positions it to broaden its markets, extend technical expertise and strengthen its client services through product development in optical communications worldwide.

"Our acquisition of Versawave is very much a part of our core strategy of continuing to manufacture in North America and being as vertically integrated as possible to provide our customers with very cost-effective solutions and short

lead times," says Optelian's CEO David Weymouth.

A recent study from market research firm Infonetics Research found that operators have a strong preference for deploying 100Gbps technology as they upgrade their networks. "Versawave brings exceptional technology for 100Gbps and will accelerate Optelian's growth into the next generation of highly integrated photonic systems," continues Weymouth. Versawave is also involved in research to create a new generation of silicon photonic technology.

Led by Hiroshi Kato, Versawave will continue to operate at its current Vancouver facility as a division of Optelian. "The synergy with Optelian will enable Versawave to expand manufacturing, accelerate the making of new products, and enhance customer support," Kato stresses.

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

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

## Infinera ranked third worldwide in North America terrestrial long-haul WDM transport and ROADM market

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own InP-based photonic integrated circuits (PICs), says that Infonetics Research has ranked it the number-one supplier in the North America terrestrial long-haul WDM transport and ROADM market.

"In Q3/2011, Infinera posted a revenue increase that moves them into first position in North America and third position worldwide for combined terrestrial long-haul WDM transport and ROADM equipment," notes Andrew Schmitt, directing

analyst for optical at Infonetics.

North American market share was driven mainly by leading cable firms, wholesale carriers, tier 1 customers, and Internet content providers. European wholesale carriers and opportunities in the submarine space contributed to growth worldwide.

"Network operators benefit from the scale, simplicity and efficiency of Infinera's optical network solution," claims its CEO Tom Fallon. "Infinera's solution for network operators helps them be more responsive to their customers' needs while confidently planning for future network growth."

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

## CTO steps down but remains as advisor

Drew Perkins has stepped down as Infinera's chief technology officer in order to pursue other opportunities but is continuing to support the firm as a technical advisor.

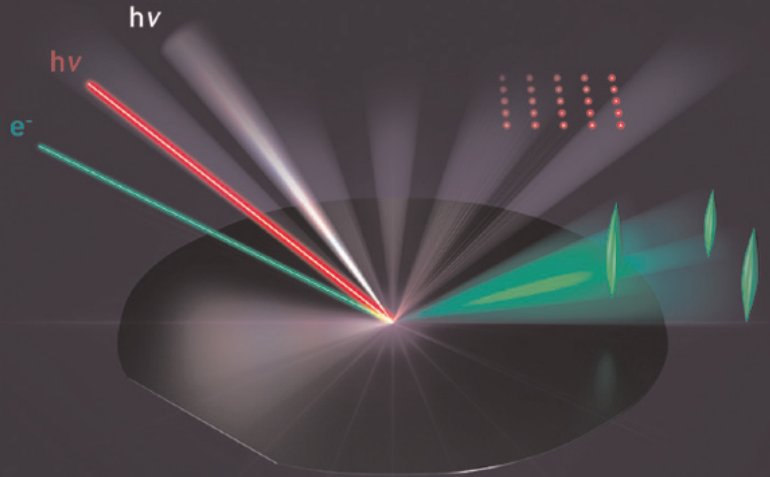
Perkins was one of Infinera's co-founders in 2001. "Infinera is well positioned for the next stage of their growth with continued investment in the DTN and the upcoming release of the DTN-X platform," says Perkins.

The CTO role has been assumed by executive VP & chief strategy officer Dr Dave Welch. A co-founder and board member, Welch was co-CTO for four years after the firm was founded.

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



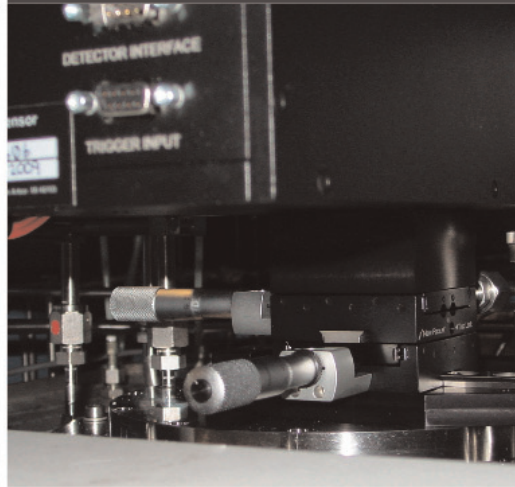
## Control Your Process! Real-Time Process Monitoring for MOCVD, MBE, Sputtering, and Thin-Film PV Deposition



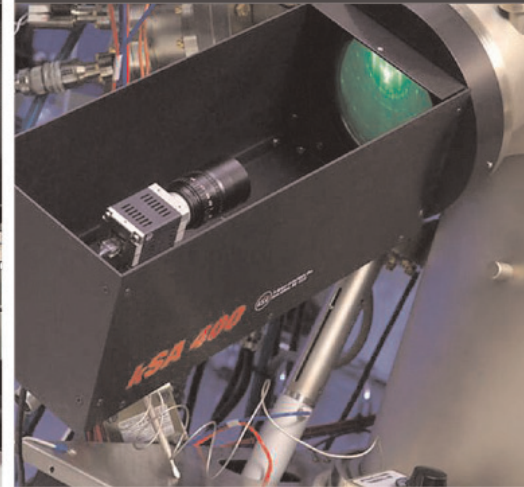
kSA BandiT Wafer Temperature



kSA MOS and kSA Mini-MOS  
Thin-Film Stress



kSA 400 Analytical RHEED



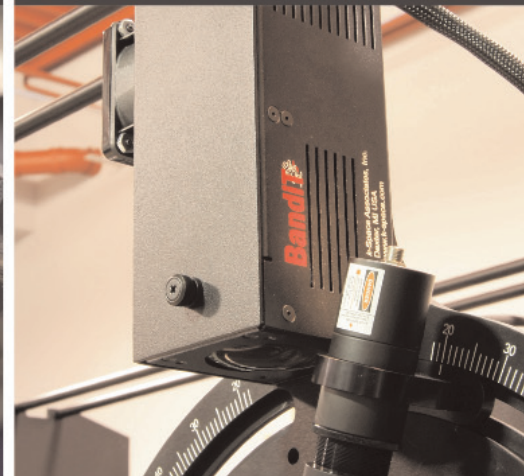
kSA MOS Ultra-Scan and  
Thermal-Scan Stress Mapping



kSA Rate Rat Pro Thickness &  
Deposition Rate



kSA BandiT PV Process Tuning





# Emcore's revenue up 5% sequentially to \$52.1m

## ...but Thailand flooding to push March quarter down to \$36-38m

For fiscal 2011 (to end-September), Emcore Corp of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, has reported revenue of \$200.9m, up 5% on fiscal 2010's \$191.3m. By segment, Fiber Optics revenue was \$125.6m (up 3% on \$121.7m) and Photovoltaics revenue was \$75.3m (up 8% on \$69.6m).

For Emcore's fiscal fourth-quarter 2011, revenue was \$52.1m, down 4% on \$54.1m a year ago but up 5% on \$49.5m last quarter.

By segment, Fiber Optics fell 10% from \$34.4m a year ago and 7% from \$33.3m last quarter to \$30.9m (59% of total revenue, down from 67% last quarter). This was due mainly to the decline in sales of end-of-life legacy products and cable TV broadband products. However, the full-band quadrature amplitude modulation (QAM) transmitters continue to be the leading solution for cost-effective broadband operating on the existing fiber coaxial network infrastructure. Also, demand continued to be strong for Emcore's radio frequency over glass (RfOG) fiber product, which uses passive optical network (PON) transceivers to provide the last-mile and is becoming increasingly effective for upgrading the traditional hybrid fiber coaxial (HFC) network through an all-fiber-optic solution, says Emcore. The Telecom business saw another quarter of nearly 30% sequential growth to a record \$9m in revenue for the tunable laser product, with integrable tunable laser assembly (ITLA) sales into 40 and 100Gb/s coherent transponder and line-card applications continuing to be very strong. Emcore also introduced and produced its newly qualified 4x14Gb/s FDR (Fourteen Data Rate) active optical cables (AOCs), shipping more than 5000 cables in the first quarter after the product's commercial release.

Photovoltaics revenue rose 8% from \$19.7m a year ago and 31% from \$16.2m last quarter to a record \$21.2m (41% of total revenue, up from just 33% last quarter). This was driven by record Space Photovoltaics business, due mainly to increased demand from key customers. However, Space Photovoltaic business can be "somewhat lumpy, due to the uneven timing of program awards and product deliveries," cautions CEO, president & director Hong Q. Hou.

Full-year fiscal 2011 gross margin was 21.3%, down from fiscal 2010's 26.5% (including Fiber Optics falling from 23.1% to 18.5% and Photovoltaics from 32.3% to 26%). Fiscal Q4 gross margin was 19.2%, down from 23.6% a year ago but up slightly from 19.1% last quarter, due mainly to a big improvement in the Photovoltaics division (partially offset by the Fiber Optic division). Although Fiber Optics has fallen further, from 20.4% a year ago and 19.4% last quarter to 18%, Photovoltaics has rebounded from 18.6% last quarter to 21% (although this is still well down on 29.3% a year ago). In particular, counter-acting some program losses for CPV projects, gross margin for the Space Photovoltaic business rebounded strongly from last quarter to 30% as product yields returned to normal levels.

Net loss has risen further, from just \$0.89m a year ago and \$11.1m last quarter to \$14.3m in fiscal Q4. But, excluding a \$8m impairment charge recorded on the long-lived assets of the Fiber Optics segment as well as settlements related to litigation with Avago Technologies, net loss was cut by \$3m sequentially. Full-year net loss was \$34.2m, up from fiscal 2010's \$23.7m.

During fiscal 2011, Emcore recorded \$1.8m of non-operating expense related to the Suncore concentrated photovoltaic (CPV) component- and system-making joint venture with San'an Optoelec-

tronics Co Ltd in Xiamen, China, including \$1m in fiscal Q4. However, Suncore's losses are expected to fall as it enters volume production. Suncore has moved into its new facility in Huainan City. Emcore is now developing and qualifying the manufacturing processes for CPV receivers and modules, and plans to start full production (with an annual capacity of 200MW of modules) in February. The product line is due to launch by the end of fiscal 2012.

During Q4, Emcore's cash, cash equivalents and restricted cash balance fell back from \$21.1m to \$16.1m. Regarding measures taken

**Flooding in Thailand... has had a significant impact on Emcore's operations and ability to meet demand for fiber-optics products**

to improve liquidity, in December Emcore amended its three-year, \$35m credit facility with Wells Fargo bank to increase potential borrowings by up to \$14m. Also, in August the firm entered into an equity line of credit arrangement with Commerce Court Small Cap Value Fund Ltd, enabling it to sell up to \$50m in shares of common stock over the 24-month term.

Hou says Emcore had a "clear line of sight to profitability" by the middle of fiscal 2012. However, flooding in Thailand has impacted that plan and forced it to reset priorities and expectations. As disclosed on 24 October, after rain in the northern Thailand from July through October caused flooding in most areas of Thailand (especially the outskirts of Bangkok), flood waters infiltrated the offices and manufacturing floor-space of Emcore's primary contract manufacturer, Fabrinet Co Ltd. The areas used to manufacture Emcore's fiber-optic products and process & test equipment were

► submerged in several feet of flood water for more than a month, damaging the manufacturing infrastructure that supports about 50% of Fiber Optics revenue. This has had a significant impact on Emcore's operations and ability to meet demand for fiber-optics products.

Production capabilities for three major product lines were impacted, including: Telecom products, such as tunable lasers (ITLAs) and the high-volume tunable XFP line (Emcore's low-volume TXFP production line is in the Bay Area and producing products); Cable TV (CATV) lasers (components and transmitters); and legacy products. In the two months since the flood, Emcore developed and implemented alternative manufacturing plans in its own facilities in China and the USA to meet short-term customer demand. Concurrently, it has been focusing on rebuilding high-volume production infrastructure for impacted product lines in other sites owned by Fabrinet, as well as its own facility in China. "Our focus during the rebuild is on a quick recovery and strategies to better configure the equipment for efficiency, reduce our cost structure, and provide manufacturing diversification in order to turn this crisis into an opportunity," says Hou.

Purchase orders have been issued to replace the damaged process and test equipment, and new equipment is being received. Between Emcore's own facilities and Fabrinet, the firm expects to rebuild production capacity for the CATV business by the end of March and production capacity for the Telecom production lines by the end of May. "We are working closely with customers on our recovery manufacturing plan to align with their needs," says Hou.

"We are working with our key suppliers to expedite the building of our manufacturing line," notes chief financial officer Mark B. Weinswig. "As part of those measures, we have extended payment terms on our payables to provide us with additional flexibility over the next

12 months. Our manufacturing partner will also assist in financing the rebuild of our manufacturing lines at their facility. This will help us finance the CapEx needs while we wait for payment of our insurance proceeds," he adds.

"We've also signed agreements with certain customers to receive prepayments for future shipments. This allows us to replenish the inventory and fund other working capital requirements," says Weinswig. Emcore was able to move a significant portion of finished goods inventory to the second story of the facility just before flood water reached the manufacturing floor. The main focus is to meet near-term needs of key customers and to ascertain that demand will still be there for products on return to full capacity. "Many of our key customers for Telecom products have stepped up and committed their demand through non-cancelable purchase orders and pre-payments," notes Hou. "As a result, our production capacity for tunable lasers in calendar 2012, when it is fully recovered, is almost fully booked with the existing commitments," he adds. "We are very appreciative of our customers in the long-term purchase commitment we've received that will allow us to focus on the production line rebuild. The

### **The firm expects to rebuild production capacity for the CATV business by the end of March and production capacity for the Telecom production lines by the end of May**

products we have introduced over the last couple of years and the new products in the pipeline will drive significant growth once we have our fulfillment

infrastructure rebuilt," Hou says. "We have been working with the insurance carriers, banks, customers and business partners to obtain funding for required capital expenditures to restart operations," notes

Hou. Emcore had business interruption insurance through its own carrier, and expects to receive \$5m in January for those claims. Also, Fabrinet has insurance coverage related to consigned inventory and equipment.

Emcore has entered into agreements with Fabrinet and Wells Fargo Business Credit, significantly improving its liquidity position while it processes and receives proceeds from insurance claims. "We have a solid plan in place to rebuild our impacted business, and we expect to come out of this disaster as a stronger company compared to the pre-flood conditions," Hou believes.

To improve its financial position, Emcore has since moved quickly to make significant improvements. In November, it implemented cost reductions including salary and discretionary spending cuts, reducing the cost structure significantly. "The salary deductions are a temporary measure that reduces the cash burn while we are rebuilding our Fiber Optics production infrastructure," comments Weinswig.

While Emcore analyzes the flood's impact on the Fiber Optics business, it is providing order backlog information only for the Photovoltaics segment (for which manufacturing infrastructure was not impacted). During Q4, Emcore secured several key contracts for commercial and government projects, boosting the 12-month backlog by 10% (from \$39.6m to \$43.5m, due solely to the Space Photovoltaics business).

Despite this, for fiscal first-quarter 2012 (to end-December 2011) Emcore expects revenue to drop sequentially to \$36–38m, due to the impact of the flooding on the Fiber Optics business.

Nevertheless, the business outlook in Space Photovoltaics continues to be very robust, with several additional large commercial awards in 2012 expected to maintain the year-on-year growth. Also, several customers for terrestrial CPV solar cells will be ramping up their demand in the next couple of quarters.

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



## IN BRIEF

## Emcore announces reverse stock split

Emcore Corp of Albuquerque, NM, USA, which makes components, subsystems and systems for the fiber-optic and solar power markets, says that its board of directors has approved a 1-for-4 reverse split of its common stock.

The reverse split was approved by shareholders at the annual meeting on 14 June 2011, and will become effective following the filing of an amendment to Emcore's corporate charter.

Emcore expects its stock to begin trading on the NASDAQ Global Market on a split-adjusted basis on 16 February. Nasdaq may append a 'D' to the end of Emcore's trading symbol to indicate the split, but it would revert to 'EMKR' after about 20 trading days. Also following the reverse split, the stock will trade under a new CUSIP number.

When the reverse split becomes effective, every four shares of issued and outstanding common stock will be automatically combined into one share without any change in the no par value per share or rights and preferences of common stock. This will cut the number of shares from about 94 million to about 23.5 million. No fractional shares will be issued in relation to the reverse split, as any fractional shares from the reverse split will be rounded up to the next whole share. Also, proportional adjustments will be made to Emcore options, warrants and other securities, entitling the holders to purchase Emcore shares. The number of authorized shares will also be proportionally reduced from 200 million to 50 million.

Further information on the reverse split is in Emcore's definitive proxy statement filed with the Securities and Exchange Commission (SEC) on 5 May 2011.

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

## Semprius raises \$3m in funding Duke Energy's president joins board

Semprius Inc of Durham, NC, USA, which designs and manufactures high-concentration photovoltaic (HCPV) solar modules, has secured an additional \$3m in its latest venture funding round involving Morgan Creek Capital Management, as well as existing shareholders Illinois Emerging Technologies Fund (a fund managed by In-Q-Tel and IllinoisVENTURES).

This latest tranche of funding is a follow-on to the \$20m Series C round (closed last July), led by Siemens Venture Capital and joined by existing investors Arch Venture Partners, Applied Ventures, Inter-south Partners, and GVC Investment. Previously, after being spun out of the University of Illinois in 2005, Semprius had raised a \$4.7m round A in 2007 and won an extra \$7.9m round in 2009. Also last July, Semprius received an incentives package via North Carolina Department of Commerce worth more than \$7.88m to construct a pilot plant in Henderson, NC.

Proceeds from the new funding will be used to speed construction of a pilot plant to produce high-efficiency, low-cost solar modules, with an annual capacity of 5MW (expandable to 35MW). The pilot line will be used to scale up and optimize production for Semprius' subsequent large-capacity plants.

In addition, Gregory Wolf, president of Duke Energy Renewables, has joined Semprius' board of directors. Wolf leads Duke Energy's non-regulated renewable power business, which delivers wind and solar energy solutions for customers throughout the USA. "There is a large market opportunity for Semprius as they capitalize on the growing global demand for utility-scale solar," says Wolf.

Semprius delivers a unique HCPV module design that begins with its proprietary micro-transfer printing process. This enables use of what are reckoned to be the world's

smallest solar cell — about the size of a pencil point — to create modules with what are claimed to be unmatched cost and performance advantages.

Semprius' HCPV modules use high-performance glass lenses to focus sunlight onto very small, highly efficient triple-junction GaAs-based microcells (600µm by 600µm in area and less than 10µm thick). The firm's triple-junction cells have reached a conversion efficiency of 41.7%, as tested by the US National Renewable Energy Laboratory (NREL) according to Semprius' staff development engineer Kanchan Ghosal. Optics concentrates the sunlight 1000 times so that just 0.1% of the module area is covered with the microcells. The microcell's very small size enables use of low-cost optics and electrical interconnects, which remove the heat, eliminating the need for costly thermal management solutions. Also, Semprius grows its cell structures on top of a release layer so that they can be epitaxially lifted-off as part of its patented micro-transfer printing process, allowing it to reuse the GaAs substrate and hence cut costs dramatically. Semprius also uses an automated manufacturing process, leveraging standard manufacturing

**This latest tranche of funding is a follow-on to the \$20m Series C round (closed last July)**

equipment and commodity materials, to reduce capital and labor costs. "The additional capital, together with our investors' and board's support, will help us advance key initiatives to position Semprius for aggressive growth," says CEO Joe Carr. "In addition, the ability to attract an industry veteran like Greg to join our board is a solid testimonial to the value of the technology we are pioneering," he adds.

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

## GreenVolts partners on providing CPV to agriculture

Concentrating photovoltaic (CPV) system maker GreenVolts Inc of Fremont, CA, USA, which provides what it claims is the industry's only complete and fully integrated solar system, has announced a strategic partnership with Independent Solar Developers LLC (ISD) of Coachella, CA, a turnkey solar system developer, owner and operator that specializes in providing solar energy solutions for Southern California agricultural applications.

Using solar energy for agriculture is a large and untapped opportunity, says GreenVolts. In California alone, agricultural businesses require over 2000MW of capacity and use more than 10TWh annually. These businesses have plenty of land and sun, and are very interested in lowering their cost of electricity, which can exceed 20% of production costs.

GreenVolts and ISD have worked closely together to develop a solution that provides long-term,

economical electricity supply along with a unique set of land use, project planning, installation, and operational benefits tailored to the agricultural market. ISD can also provide financing, overcoming the primary barrier for most projects. With their first project installed and operating in California's Coachella Valley, and others in progress, the firms are delivering tailored solutions for irrigation, cattle, food processing, and other agricultural applications.

A complete system from one supplier with a single, overall, 20-year warranty presents advantages to an owner considering solar energy," says ISD's principal Peter Molloy. "GreenVolts is high performance, rugged, and an overall excellent fit for agricultural applications," he believes.

GreenVolts claims that its CPV systems are the most efficient solar technology available for hot, sunny environments such as the

Southwest US agricultural areas. The modular design can be configured for distributed loads, such as irrigation pumps located on different parcels of land, or scaled up to meet higher demand, such as refrigeration in the processing of vegetables. ISIS, the energy management software included with the system, allows remote monitoring and management of all the systems from anywhere on the Internet.

"ISD has established themselves as a total solution partner to their customers, going beyond just solar," says GreenVolts' president & CEO David Gudmundson. "They offer energy analysis, system audits that include usage and load patterns, financing, and operations and maintenance," he adds. "Our installation for irrigation in Coachella Valley went well, and we already have projects for several different applications underway."

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

## Magnolia presents limits of InGaAs quantum well solar cell performance at Photonic West

On 23 January in San Francisco at a SPIE Photonic West conference on the Physics, Simulations and Photonic Engineering for Photovoltaic Devices, Dr Roger E. Welser, chief technology officer of Magnolia Solar Inc of Woburn, MA and Albany, NY, USA, presented the invited paper 'Exploring the Radiative Limits of Dark Current Operation in InGaAs Quantum Well Solar Cells' as part of a special session on 'Quantum Well and Superlattice Solar Cells'.

Founded in 2008 to develop and commercialize thin-film solar cell technologies that employ nano-structured materials and designs, Magnolia's solar cells combine exclusive material structures with advanced optical coatings. The patent-pending technology can capture a larger part of the solar spectrum to produce high-efficiency

solar cells, and incorporates a unique nanostructure-based anti-reflection coating technology to further boost the efficiency, reducing the cost per watt. Last August Magnolia demonstrated high-voltage InGaAs quantum well waveguide solar cells.

"Magnolia Solar has developed a novel device structure that suppresses undesirable recombination events, enabling photovoltaic devices to reach new levels of performance," says Welser. "To better design and realize ultra-high-efficiency solar cells, we continue to explore the underlying physical mechanisms controlling the power output," he adds.

"The aim of our ongoing work summarized at the SPIE conference in San Francisco is to increase both the current and voltage output of single-junction cells by employing a

quantum-structured active region and advanced light-trapping strategies," Welser continues. "With this patent-pending approach, we expect to demonstrate high solar electric conversion efficiency over a wider range of operating conditions."

"Photovoltaic devices can provide a mobile source of electrical power for a variety of commercial and defense applications in both space and terrestrial environments," comments president & CEO Dr Ashok K. Sood. "Many of these applications can directly benefit from enhancements in the efficiency of the photovoltaic devices," he adds. "In collaboration with our partners, we intend to update our shareholders as we continue the development effort for next-generation high-performance solar cells."

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



## Amonix CEO Brian Robertson killed in light aircraft crash

Amonix Inc of Seal Beach, CA, USA, which makes utility-scale concentrated photovoltaic (CPV) systems using III-V multi-junction solar cells, says that its CEO and board director Brian Robertson was killed on 22 December when the light aircraft he was piloting crashed in York County, PA en route to join his family for the holidays. Robertson was a keen pilot, with instrument and commercial rating licenses.

"Brian was an energetic, charismatic leader with such drive and ambition," comments founder, chief technical officer & chairman Vahan Garboushian. "He was devoted to establishing the commercial viability of CPV in this huge arena of solar energy... We will continue on the path to realize his dream," he adds.

Robertson joined Amonix in late 2009, through the acquisition of solar power manufacturing plant development company Sunworks Solar LLC (where he was co-founder & CEO from 2008 to 2009). Previously, in 1996 Robertson co-founded web-based services start-up PlanetAll, where he served as chief technical officer until Amazon.com acquired the firm in 1998.



**Amonix' CEO Brian Robertson, killed in an aircraft crash on 22 December.**

In 1999, he co-founded Visible Markets (an electronic trading platform for mortgage- and asset-backed securities), where he was CEO until its acquisition by Thomson Financial in 2001. He then co-founded Sun Edison LLC (North America's largest solar energy services provider) and was its chief financial officer from 2004 to 2007 and

president from 2007 to 2008, before its acquisition in 2009 by MEMC Electronic Materials (which makes silicon wafers for the semiconductor and solar industries).

Robertson had a degree in Computer Science from Massachusetts Institute of Technology (MIT) and an MBA from Harvard Business School (where he led students' efforts to install solar panels on the Shad Hall athletic facility).

Robertson leaves behind a wife and three children.

For those wishing to make a donation in Robertson's honor, the 'Brian D. Robertson Foundation' has been established. Tax-deductible donations will be used to provide support for the organizations and causes including the Solar Foundation, YMCA Indian Princess/Guide Program, MIT, Harvard Business School, and the American Heart Association. Checks should be made payable to 'Brian D. Robertson Foundation' and sent to: Brian D. Robertson Foundation, c/o The Boston Foundation, 75 Arlington Street, Boston, MA 02116, USA.

[www.tbf.org](http://www.tbf.org)

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

### Amonix achieves ISO 9001-2008 and IEC 62108 certifications

Amonix Inc of Seal Beach, CA, USA has received ISO 9001:2008 and IEC 62108 certifications, representing "key milestones in Amonix' quality management system and field operation durability".

To become ISO 9001:2008 compliant, Amonix worked with a leading ISO accreditation agency that leveraged its aerospace and defense program knowledge to conduct a thorough assessment to be eligible for submission to the International Organization for Standardization. The certification of compliance recognizes that the policies, practices and procedures ensure consistency and the highest quality standards in the prod-

ucts provided to customers.

Receiving IEC 62108 compliancy verifies that Amonix CPV solar power systems are capable of withstanding extreme climate conditions. Amonix says that this certification further proves its long-term and reliable operation in utility-scale applications.

"Implementing an ISO-inspired, robust quality management process adds immense value to our development and manufacturing plans," says Azmat Siddiqi, VP of quality & reliability. "ISO achievement was accomplished in record time based on an existing solid foundation," he adds.

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

Jan van Dokkum, a partner at lead investor Kleiner Perkins Caufield & Byers (KPCB), has been named interim CEO. Prior to joining KPCB, he was with UTC Power (a division of United Technologies) for seven years, where he was involved in the development of its on-site power generation products and services, including stationary fuel cells, renewable power solutions, and combined cooling, heating and power applications for commercial buildings. Previously, he was president & CEO of Siemens Power Transmission & Distribution.

Amonix' board has enlisted an executive search firm and formed a committee for the selection and appointment of a new CEO.

# Soitec dedicates San Diego North American headquarters and manufacturing plant

Soitec of Bernin, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers (as well as III-V epiwafers through its Picogiga International division), has dedicated its new North American solar headquarters and manufacturing plant in San Diego, CA, USA at a ceremony on 16 December.

Governor Edmund G. Brown Jr, provided remarks at the event. Also participating were San Diego mayor Jerry Sanders, San Diego Gas & Electric Company (SDG&E) chairman & CEO Jessie J. Knight Jr and commissioner Timothy Simon of the California Public Utilities Commission (CPUC), as well as governmental officials and more than 300 community and business leaders.

The factory is located in San Diego to supply more than 300MW in solar projects that will provide electricity to SDG&E. All power purchase agreements (PPAs) have been approved by the CPUC. The new factory will enable a manufacturing capacity of 200MW of Soitec's fifth generation of Concentrix concentrator photovoltaic (CPV) modules, with the opportunity for future expansion to double the capacity to 400MW per year.

Soitec says that its efficient, durable CPV systems have enabled it to plan for more than 300MW in utility-scale solar power plant projects throughout the Southwest USA, including 155MW in PPAs with SDG&E, approved by the CPUC in November. Also approved on 15 December was a power purchase agreement for up to 150MW for the Imperial Solar Energy Center West project, which is being developed by Tenaska Solar Ventures LLC (an affiliate of independent energy firm Tenaska) also using Soitec's CPV technology. Tenaska's CEO Jerry Crouse also attended the San Diego dedication event.



**Soitec's chairman & CEO André Jacques Auberton-Hervé speaking at the dedication ceremony for the firm's North American solar headquarters.**

"SDG&E has signed more contracts using CPV technology than any other utility in the world," reckons SDG&E's chairman & CEO Knight. "At the time we began our talks with Soitec, we realized we had a unique opportunity to negotiate not only a good contract for solar energy at prices that competed head-to-head with other technologies, but also to solidify an agreement that would bear fruit for years to come in new local jobs and overall economic benefits," he adds. "From a reliability and grid stability perspective, this technology is far superior to other typical ground-mounted arrays."

Soitec has CPV installations on four continents around the world. The company claims that the technology demonstrates unique cost competitiveness compared to other solar technologies, due largely to its higher production yields at peak times and lower construction and maintenance costs. In addition, its abilities to operate without cooling water, to withstand hot ambient temperatures, and to accommodate the dual use of

land with minimal environmental impact make it suitable for use throughout the desert southwest USA.

Soitec employs a distributed manufacturing model that locates CPV module factories close to its customers, with the aim of providing the most efficient and environmentally beneficial power. The distribution model also calls for a large percentage of local content and local job generation.

"Soitec's new facility will create hundreds of well-paying jobs and build on San Diego's growing reputation as one of the world's leading clean-technology clusters," comments Sanders. "San Diego's collaborative business community will continue to work with Soitec to ensure the company's success and prosperity," he adds.

"The expansion of clean energy businesses is a direct result of legislation mandating that one-third of California's electricity come from renewable sources by 2020," notes California Governor Edmund Brown.

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

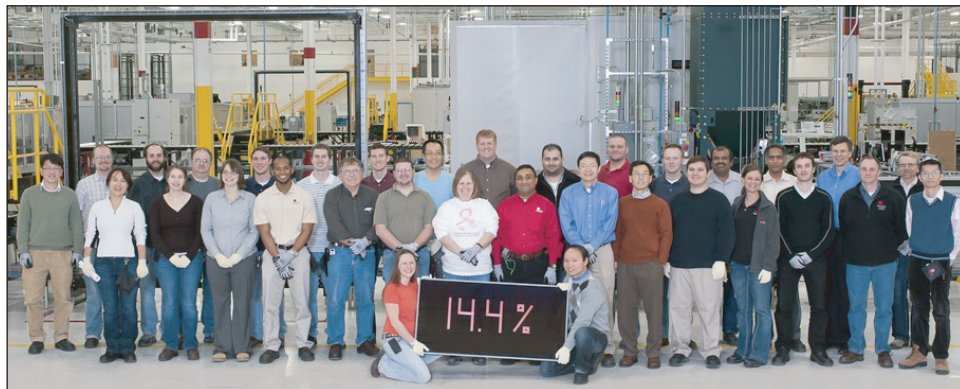


# First Solar raises CdTe PV module efficiency record from 13.4% to 14.4%

Process improvements part of updated roadmap for 14.5–15% average efficiency for production modules by end 2015

First Solar has set a new record for CdTe PV solar module efficiency of 14.4% total area efficiency. The US Department of Energy's National Renewable Energy Lab (NREL) confirmed the record, which eclipsed the prior record of 13.4% (also set by First Solar).

Announced at the World Future Energy Summit in Abu Dhabi in the United Arab Emirates by First Solar chief technology officer Dave Eaglesham, the record comes just six months after First Solar leapfrogged the record for CdTe solar cell efficiency with a mark of 17.3%. Cell efficiency measures the proportion of light converted to energy in a single solar cell, whereas total area module efficiency measures light conversion across a production-size, multi-cell solar module, providing a more realistic assessment of real-world performance than cell or aperture-area efficiency. Both the cell and module record-setters were constructed using commercial-scale manufacturing equipment and materials at the firm's factory in Perrysburg, OH.



First Solar associates hold the record 14.4%-efficient module.

"This considerable achievement supports our module efficiency roadmap and demonstrates our ability to convert our record-cell technology into ongoing module-level improvements," says chief technology officer Dave Eaglesham. "These records also underscore the tremendous ongoing potential of CdTe compared to silicon-based technologies," he adds.

First Solar updated its module efficiency roadmap in December 2011 to the increased goal of 14.5–15% average efficiency for its production modules by the end of 2015, and the process improvements devel-

oped for the record-setting cell and module continue to be implemented as part of that roadmap. The average efficiency of First Solar modules rose from 11.4% in 2010 to 11.7% in 2011 and is expected to reach 12.7% in Q4/2012.

"Our continuous investment in R&D has enabled the steady progress of our technology, punctuated by landmark achievements such as this," says chairman & interim CEO Mike Ahearn. "Our consistent progress gives us confidence in our ability to achieve our roadmap goals, drive down costs and develop sustainable markets," he adds.

## First Solar recognizes top suppliers with achievement awards

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services, recently honored its premier suppliers at its first Supplier Recognition Day, which was held on 8 December in Phoenix, AZ.

About 60 of its top-spend suppliers attended the event, three of which were honored with the company's NOVA award for outstanding performance in 2011: STR Holdings Inc (which special-

izes in solar panel encapsulation); Grenzebach (a material handling solutions company); and Master Pack (a specialty packing and shipping company).

Collaboration with STR Holdings contributed significantly to the cost-per-watt roadmap, quality performance and supply risk reduction, says First Solar, while Grenzebach's flexible partnering approach enabled on-time execution of key technical initiatives, and Master Pack's support contributed significantly to First Solar's cost-per-watt roadmap in Malaysia.

First Solar created the NOVA award to recognize suppliers that significantly support the company's mission. "Our suppliers play an essential role in achieving our mission to create enduring value by enabling a world powered by clean, affordable solar electricity," says Doug Duval, vice president, Global Supply Chain. "We appreciate the exceptional efforts of these NOVA award recipients and value they provide through the highest standards of quality, cost and performance," he adds.

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

## Abound and Solarsis announce commissioning of plant in Andhra Pradesh, India

Cadmium telluride (CdTe) thin-film photovoltaic (PV) solar module maker Abound Solar of Loveland, CO, USA and Hyderabad-based Solar Integration Systems India Pvt Ltd (Solarsis) of have announced the official commissioning of a 1MW photovoltaic plant in Kadiri, Andhra Pradesh, India less than a year after the two firms announced a long-term partnership targeting the fast-growing Indian solar market.

The project was commissioned under the Rooftop and Other Small Solar Power Generation Plant (RPSSGP) Scheme administered by IREDA under the Jawaharlal Nehru

National Solar Mission (JNNSM). It is the first project in the state of Andhra Pradesh to use Abound's modules. Abound says that the combination of its low-cost modules, along with Solarsis' home-grown tracking and solution, cut down on the overall balance-of-system (BoS) cost of the project.

"This plant will generate operational data on different technology performance in Indian weather conditions as this 1MW plant uses 620KW of thin-film-based Abound modules and 380KW of crystalline silicon with single-axis tracking technology," notes Solarsis'

Venkat Rajaraman.

"India is a key market for Abound Solar due to our US-made CdTe panel's excellent performance in India's climate, our commercial focus over the past two years, and our successful use of US Export-Import Bank financing" says Abound's president & CEO Craig Witsoe. "We have a significant installed base in India and see this growing in 2012," he adds. "Solarsis is a good partner for us, offering project and local industry expertise."

[www.solarsis.in](http://www.solarsis.in)  
[www.abound.com](http://www.abound.com)

## MidAmerican buys 49% stake in 290MW Agua Caliente CdTe PV project from NRG

Global energy services provider MidAmerican Energy Holdings Company of Des Moines, Iowa has acquired a 49% stake in the 290MW Agua Caliente solar photovoltaic (PV) project (situated in Yuma County on 2400 acres of land between Yuma and Phoenix in Arizona) from power generation firm NRG Energy Inc of Princeton, NJ, USA.

NRG acquired the \$1.8bn project from First Solar Inc of Tempe, AZ, USA, which makes thin-film PV modules based on cadmium telluride (CdTe) as well as providing engineering, procurement and construction (EPC) services. NRG's acquisition had been contingent upon the financial closing of the project's loan guarantee of up to \$967m from the US Department of Energy (DOE)'s Loan Programs Office (announced in December 2010).

Agua Caliente is the world's largest solar photovoltaic project currently under construction (by First Solar). The project is expected to create up to 400 construction jobs through its completion date in 2014. The first 30MW phase began commercial operation on 19 January. Supported



**The Agua Caliente solar project under construction.**

by a long-term power purchase agreement with Pacific Gas and Electric for all of the electricity generated (enough to serve more than 225,000 homes), it should offset about 5.5 million metric tons of carbon dioxide over 25 years (equivalent to taking more than 40,000 cars off the road annually).

In May, NRG announced its intention to bring partners into its large-scale solar projects, noting the strength and creditworthiness that credible partners can bring. "Partnering with an industry leader like MidAmerican on Agua Caliente, one of the largest PV projects in the world, enhances the strength and

credibility of what was already one of the world's leading solar projects," says president & CEO David Crane. "NRG and MidAmerican complement each other in the capabilities and experiences they bring to this project and to solar power more generally," he adds.

"We are aggressively pursuing opportunities to expand our presence in the renewable energy sector, and the Agua Caliente project is another important step toward that goal," comments MidAmerican's chairman, president & CEO Greg Abel.

On 7 December, MidAmerican announced that it had acquired from First Solar the 550MW Topaz project being built in San Luis Obispo County, CA (one of the world's largest solar projects). MidAmerican already claims to be the largest owner of wind-powered energy among rate regulated utilities; at year-end 2011, 28% of its total generation capacity will be from renewable and non-carbon sources.

[www.nrgenergy.com](http://www.nrgenergy.com)  
[www.midamerican.com](http://www.midamerican.com)  
[www.firstsolar.com](http://www.firstsolar.com)



## CIGS market to nearly double to \$2.35bn & 2.3GW in 2015

The market for solar installations based on copper indium gallium diselenide (CIGS) thin-film panels will nearly double to \$2.35bn in 2015, as manufacturers signaled a breakout year in 2011 by taking advantage of falling production costs, improving module conversion efficiencies and increasing adoption in commercial rooftops, according to the report 'Sorting through the Maze of CIGS Technologies: Who Will Cash in on the Breakout Year?' from Lux Research.

The technology is emerging into an early-growth phase and will benefit from a surge in demand to nearly 2.3GW in 2015, nearly double the current 1.2GW, reckons Lux. But it will still face many challenges, including a sharp fall in venture capital. In the emerging environment, few manufacturers will succeed (e.g. Solar Frontier, Avancis and Solibro), mainly through strategic partnerships and investments that are critical to ramp capacities and improve production processes.

"Manufacturers have begun ramping meaningful capacities and there

have been tremendous improvements in module efficiency," says the report's lead author, Lux Research analyst Pallavi Madakasira. "Now, strategic partnerships between start-ups and industrial conglomerates are likely to determine this technology's overall viability and competitiveness," he adds.

Lux researchers positioned CIGS developers using the Lux Innovation Grid, based on their Technical Value and Business Execution. Firms that are strong on both axes reach the 'Dominant' quadrant. Lux also assessed each firm's maturity, providing an overall 'Lux Take'. Among their conclusions:

- Solar Frontier is a clear winner, with a solid position in the 'Dominant' quadrant, and was the only firm to earn a 'Strong Positive' take. With inroads into new and emerging markets such as India, where it is selling more than 30MW of panels, it excels in overall execution.

- Global Solar, Avancis and Solibro are likely to consolidate, with the three firms likely to emerge as bankable players. Global Solar has

demonstrated slow but steady progress and is currently selling its PowerFLEX technology (a shingle product) to Dow. But to succeed it must adopt a less conservative approach. Avancis has a joint venture with Hyundai Heavy Industries for CIGS module production in Asia. But Solibro will need to quickly and independently strengthen its financial position to succeed, reckons Lux.

- Stion, Miasole and Nuvosun are all 'Dominant', with the potential to emerge as early champions in CIGS technology. However, success will depend on capacity utilization and ramp-up, customer relationships, strategic partnerships and consistent execution in terms of module costs, yield and module efficiency.
- ISET, Flisom and AQT are all 'High Potential' companies — with strong technical value but weaker business execution scores — and have assets that make them prized acquisition targets.

The report is part of the Lux Research Solar Components Intelligence service.

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

## Nanosolar's EVP of engineering & operations transitions to CEO

Nanosolar Inc of San Jose, CA, USA, which makes thin-film photovoltaic panels based on printing CIGS and nanoparticle inks (using roll-to-roll solar cell printing), has named Eugenia Corrales as CEO. Current CEO Geoff Tate will retire after two years at the firm.

Recruited by Tate in May 2010 as executive VP of engineering & operations, Corrales has led a transition to a commercial production phase while achieving both efficiency and production capacity benchmarks for Nanosolar. For the past 18 months she has managed all operations, as well as engineering, purchasing and planning for both San Jose and the assembly plant in Luckenwalde, Germany. Cumulative shipments have gone from zero to 10MW, and median panel efficiency is now 11.5%.



Corrales' executive roles have included several years as a VP at Cisco, running all product operations for Cisco-branded products. She was also responsible for router, switching and optical product manufacturing. Prior to Cisco, Corrales spent 11 years in engineering and R&D management at HP. Prior to joining Nanosolar, she was founder & VP engineering of two cleantech start-ups. She has a bachelor's degree in physics from Grinnell College and a master's in mechanical engineering from Stanford University.

Tate joined Nanosolar in early 2010 as an interim CEO to build an executive team capable of scaling

into high-volume manufacturing at high efficiencies and low cost. The latest transition is the culmination of that. He retired from Rambus in 2006 and is returning to retirement.

"This planned transition will allow the company to maintain its momentum and trajectory," says board member Erik Straser, a Mohr Davidow Ventures general partner. "Under her stewardship we can grow the market for Nanosolar Utility panels and expand our global footprint," he adds of Corrales.

"I am thrilled to lead such a talented team as we leverage this innovative printing technology to fulfill our mission to become the world's lowest cost cell and panel manufacturer, independent of subsidies," says Corrales.

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

# Imec and Flamac to develop new thin-film PV materials

## PVD/PECVD coater to screen materials as an alternative to CIGS

Nanoelectronics research center Imec of Leuven, Belgium is working with Flamac, a division of SIM vzw (Strategisch Initiatief Materialen in Vlaanderen, or Strategic Initiative Materials in Flanders), to develop novel semiconductor materials for solar cell applications. Within the collaboration, novel materials are screened as an alternative for the standard solar cells made of copper indium gallium and selenium (CIGS).

Subsidized by the Flemish Government, Flamac is a research center in high-throughput methodologies with a mission to enhance strategic collaboration between knowledge institutes and the materials and chemical industries in Flanders. It recently installed a PVD (physical vapor deposition)/PE-CVD (plasma-enhanced chemical vapor deposition) coater that allows the automated deposition of a variety of thin-film materials. The platform consists of eight process chambers enabling the study of PVD and PE-CVD coating processes. The coating system, combined with the variety of high-

throughput analytic tools available at Flamac, represents a powerful platform for accelerated screening of novel materials, says Imec.

Imec's work on solar cells focuses on improving the state-of-the-art efficiency and manufacturability of a number of key technologies, most notably silicon-based solar cells, and thin-film solar cells such as

**The coating system represents a powerful platform for accelerated screening of novel materials, says IMEC**

organic solar cells and printed inorganic cells based on nanoparticle inks. Its thin-film solar cell activities are integrated in the Solliance collaboration platform, which aims to strengthen the position of the Eindhoven-Leuven-Aachen triangle (ELAT region) as a world player in thin-film PV. Solliance aims to realize this by joint use of state-of-the-

art infrastructure, alignment of research programs, and close cooperation with the solar business community.

"Enabling R&D centres like Imec to speed up their materials development is exactly what Flamac aims to achieve," says Flamac's manager Johan Paul.

"We consider the cooperation with Flamac as an essential part in the broadening of our PV-portfolio," comments Jef Poortmans, Program Director Energy at imec. "By combining Flamac's expertise in high-throughput material research with our expertise in thin-film solar cells, we are convinced that we will achieve interesting results in a shorter timeframe," he adds. "This broadening allows us to maximize the valorization opportunities in Flanders and is a new important step in the strengthening of the ELAT region in the domain of thin-film solar cell technology as we strive to together with Solliance."

[www.imec.be](http://www.imec.be)  
[www.flamac.be](http://www.flamac.be)

## Solar Frontier to supply 100MWp of modules to enXco

Tokyo-based Solar Frontier (a subsidiary of Japanese energy business Showa Shell Sekiyu K.K.) and renewable energy project developer enXco of San Diego, CA, USA (an EDF Energies Nouvelles Company) have signed a supply agreement for up to 150MWp of Solar Frontier's (copper, indium, selenium) thin-film photovoltaic (PV) modules. A firm order for 26MWp was completed and delivered in fourth-quarter 2011 for the Catalina Solar Project in Kern County, CA, USA. When completed, the project will be the world's largest CI(G)S installation and will rank among the largest solar installations of any type globally, it is reckoned.

The plant will be built in two phases – the first phase of about

60MWp is targeted to go online by the end of 2012 and the remainder of the project by June 2013. The plant will generate enough energy to power the equivalent of about 35,000 homes annually and offset about 74,000 metric tons of greenhouse gas emissions every year.

"This is a landmark moment not only for Solar Frontier but the CI(G)S industry as a whole," claims Gregory W. Ashley, chief operating officer of Solar Frontier Americas Inc in Santa Clara, CA, USA. "We have demonstrated successfully that the unique characteristics of CIS technology are compelling to major customers by delivering more kWh over the lifetime of a project for a lower cost. We see this project as a launch pad for ever

greater CIS achievement in the USA and across the world. We are pleased to work with enXco, which has shown its commitment to the industry by continuing to develop and build utility-scale solar projects," he adds.

"With its gigawatt-scale production capacity, and favorable energy production profile, Solar Frontier and its parent company Showa Shell Sekiyu have positioned themselves through a long and proven development process to be able to meet the supply expectations required for such large utility-scale projects," says Kristina Peterson, VP, Solar Business Unit for enXco.

[www.solar-frontier.com](http://www.solar-frontier.com)  
[www.enxco.com](http://www.enxco.com)  
[www.edf-energies-nouvelles.com](http://www.edf-energies-nouvelles.com)



# AQT secures \$18.7m in Series B funding round

## California plant's production capacity to be doubled

According to a filing with the Securities and Exchange Commission (SEC), privately held AQT Solar Inc of Sunnyvale, CA, USA has raised the first \$18.7m of a planned \$21.7m Series B round of venture funding from four unnamed investors, at a higher valuation for the firm than the previous round, bringing the total capital raised since AQT was founded in 2007 to \$33.7m (including a \$10m round that closed in 2010). The latest funding will be used to deploy a second copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) solar cell production line at its Sunnyvale facility, doubling production capacity.

AQT says that this funding round follows a year of consistent progress and growth. After starting production in August 2010, the

Sunnyvale site is now operating around the clock and will have an installed annual capacity of more than 30MW by mid-2012. AQT's cells are currently used in 100W of CIGS PV modules that are being field deployed. By year-end, up to 180W of modules powered by AQT cells are expected to be available in the market.

AQT says that its CIGS 2.0 technology allows for continuous in-line production, which simplifies and streamlines the manufacturing process, resulting in what is claimed to be the highest projected capital efficiency in the industry, while minimizing component costs. This manufacturing path has resulted in the development, shipment and scaling of CIGS module product in just four years and for less than \$40m in funding.

"Our business strategy uniquely positions us to compete and grow in an increasingly crowded, noisy and aggressive market," states AQT's Michael Bartholomeusz. "AQT is laser focused on what we believe are the key elements to success in any commodity industry: leverage, cost, risk mitigation, partnerships and future proofing," he adds.

In January 2011, AQT selected a facility in Richland County, South Carolina as the site for its second manufacturing plant, targeting initial annual production capacity of 30-40MW by the end of 2011, expanding to 1000MW by 2015. However, the firm now says that its plans for manufacturing outside California "will be clarified at a future date".

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

## AQT readies 'CIGS 3.0' CZTS thin-film PV cells for commercialization

AQT Solar, which makes copper indium gallium diselenide (CIGS) thin-film solar cells, has achieved near-record efficiencies using an even lower-cost and production-friendly sputter-deposited copper zinc tin sulfide (CZTS) thin-film cell.

AQT has established that the same proprietary manufacturing-ready processes and platforms used to make its CIGS 2.0 solar cells are suited to CZTS. The firm has adopted the term 'CIGS 3.0' to refer to its future CZTS product to reflect the broad production compatibility and similarities of the two systems. Like their CIGS counterparts, AQT's CZTS cells are manufactured as drop-in replacements for crystalline silicon cells, making their adoption seamless with existing crystalline silicon module manufacturing equipment and infrastructure, the firm claims.

The 'earth abundant' raw materials comprising CZTS are substantially cheaper than those in CIGS,

making it much cheaper to produce. An added benefit is that these constituents are mined and available worldwide, mitigating any geopolitical influence on raw material sourcing and eliminating concerns such as the indium availability and price volatility that have impacted the display and thin-film photovoltaics (TFPV) industries in the past.

A great deal of R&D has been conducted on CZTS since the mid-1990s, and CZTS thin-film cells made by IBM employing a complex organometallic spin-coating process have recently achieved efficiencies as high as 10.4%. By comparison, AQT has rapidly achieved close to 10% efficiencies for sputtered CZTS by leveraging the manufacturing process and platform foundation established for its CIGS product.

AQT plans to have CZTS modules 'under sun' later this year and to actively begin the product com-

mercialization process. The firm says that, by employing the same capital-efficient platform as for its CIGS product, it is further validating the flexibility and long shelf-life of its equipment and manufacturing strategy.

"The founders of AQT, all of whom have previously worked in capital intensive commodity industries, have experienced first-hand the huge disruption to business that occurs when re-capitalization is required due to technology migration, and we have done everything possible to avoid this from affecting our business," says CEO Michael Bartholomeusz. "Early on we recognized the critical necessity to adopt a future-proofed manufacturing platform and strategy, and it remains a cornerstone of our business, enabling us to easily adapt solar cell production to new, advantageous materials such as CZTS," he adds.

## NuvoSun chooses FactoryLOOK and VistrianMES systems

Vistrian Inc of Milpitas, CA, USA is to provide its FactoryLOOK and VistrianMES software systems to NuvoSun Inc (also of Milpitas), which manufactures copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) cells and modules on flexible foil (using a proprietary high-speed roll-to-roll sputtering process).

FactoryLOOK is a server-based 'manufacturing intelligence system' used by firms including manufacturers of solar, semiconductor, advanced lighting, data storage, networking, and electronic assembly. It allows the gathering, analyzing and archiving of significant amounts of information from throughout the factory, including tooling, utilities, testing, metrology, recipe tracking and legacy data systems/databases. It also allows for the immediate alerting and identifying of process anomalies and the ability to quickly identify factors affecting the development process or manufacturing process and their associated variables, thus reducing costs and reducing product development time.

VistrianMES software integrates with FactoryLOOK using Vistrian's 'Quick Launch' feature, which brings what is claimed to be a uniquely high degree of usability to all users, with all functions accessible with just a few clicks of the mouse. VistrianMES allows managing of the factories materials, workflow, WIP and long-term field correlation.

Vistrian configures all elements of FactoryLOOK and VistrianMES without the need for a third-party integrator or internal IT department resources, significantly reducing implementation cost, the firm claims.

"Vistrian is a company founded and operated by manufacturing executives who have integrated their knowledge and experience into a software system allowing for a true benefit to the user," says

co-founder & CEO Ronald Allen. "Our products allow for us to accommodate unique customer needs with our installation base growing worldwide," he adds. "The integration of FactoryLOOK and VistrianMES along with our unique 'Quick Launch' system will allow our product to be adopted by all users in the organization, providing full adoption and visibility to NuvoSun," Allen notes.

"The team at Vistrian has worked closely with us to implement their system to meet our specific needs and work with us every step of the way," says NuvoSun's president & CEO Dave Pearce. "Vistrian's short implementation time has allowed us to bring up our process in record time while being scalable to our future needs," he adds. "We are confident with Vistrian's software we can run a consistent process at any factory location throughout the world."

FactoryLOOK is used as a tool to integrate all processes and equipment data and to provide access to all users using a web browser. This includes the Facility, Environmental, Tooling, Test Equipment, Flat Files, Legacy systems (MES, ERP) and Operator interfaces. Its tool-set features provide analysis, alerts, dashboards and reports using the integral rules engine in real-time, providing timely information to optimize operations and processes. Users have reported significant improvements in utilization and yields, claims Vistrian.

Vistrian says that FactoryLOOK has proven invaluable with its user base both in high-volume and pilot-production environments as a way to increase yields, reduce process and development time, and increase process uptime through significantly increased visibility to the process and the variables that affect it.

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

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

### IN BRIEF

#### TFG increases stake in Ascent Solar from 20% to 41%

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight CIGS-based thin-film photovoltaic modules using flexible substrate materials, says that TFG Radiant Investment Group Ltd is poised to raise its stake in the firm, from about 20% (acquired last August) to 41%.

TFG Radiant will purchase the stake currently owned by Norsk Hydro Produksjon AS for \$4m (about \$0.50 per share). The transaction is expected to close by April.

"We continue to be very excited about the market potential for Ascent's transformational solar power technology," says TFG's managing director Victor Lee (who was made an Ascent board member last November). "No other manufacturer can match the combination of power density and flexibility, which we believe will enable TFG Radiant to lead in rooftop and portable power applications in East Asia," he adds.

Last August, TFG also reached a joint development agreement to establish CIGS PV module manufacturing facilities in East Asia. TFG committed \$165m for the initial fabrication plant. Ascent also agreed to exclusively license its technology for fabrication and distribution of flexible, lightweight CIGS PV modules to TFG for East Asia (including China, Taiwan, Hong Kong, Malaysia, Indonesia, Thailand, Korea and Singapore).

"Our most recent strategic partner, and licensee for our technology in East Asia is increasing its commitment to Ascent," says Ascent's president & CEO Ron Eller. "We have the same vision for our unique, high-performing flexible technology to bring solar power to everyday lives."

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



# Quantum well steps to efficient multi-junction solar cells

The University of Tokyo shows how photovoltaic junction current can be increased for devices with up to 20 quantum wells.

University of Tokyo researchers have been investigating the application of quantum well technology to solar cells based on indium gallium arsenide phosphide (InGaAsP) semiconductors [Yu Wen et al, Appl. Phys. Express, vol4, p122301, 2011]. In particular, they found that inserting GaAs step layers between the quantum wells and barriers improved the short-circuit current of the devices.

Indeed, a device with 20 quantum wells (QWs) had a current density of 20.25A/cm<sup>2</sup> under 1 sun air-mass 1.5G (AM1.5G) illumination. For 10 QWs, the current density was 19.29A/cm<sup>2</sup>. A comparison device with no quantum wells had 18.80A/cm<sup>2</sup> short-circuit current density under the same conditions. Thus the 10-well device, which was of a similar thickness to the comparison device, had 14% more current. The improvement in short-circuit current only degraded the open-circuit voltage significantly in comparison QW devices without the GaAs step structure (Table 1).

The researchers see MQW devices as having application in tandem solar cells that use multiple junctions to extract energy from different energy bands of light. One problem with such devices is that the current running through all the junctions has to be matched for high conversion efficiency.

This is a particular problem for InGaP/GaAs/germanium designs. It is hoped that, by using semiconductor nanostructures such as quantum wells, the currents can be tuned to match with other junctions in the structure. One disadvantage of quantum wells is that they can trap carriers, thereby allowing them to recombine either by re-emitting light or through other non-radiative mechanisms.

These trapping effects such as increased dark current and reduced open-circuit voltage can be minimized by strain-balancing. The Tokyo GaAs-step is designed to create an escape route for photo-generated carriers, reducing recombination in the wells. The step structure is also combined with strain compensation to allow

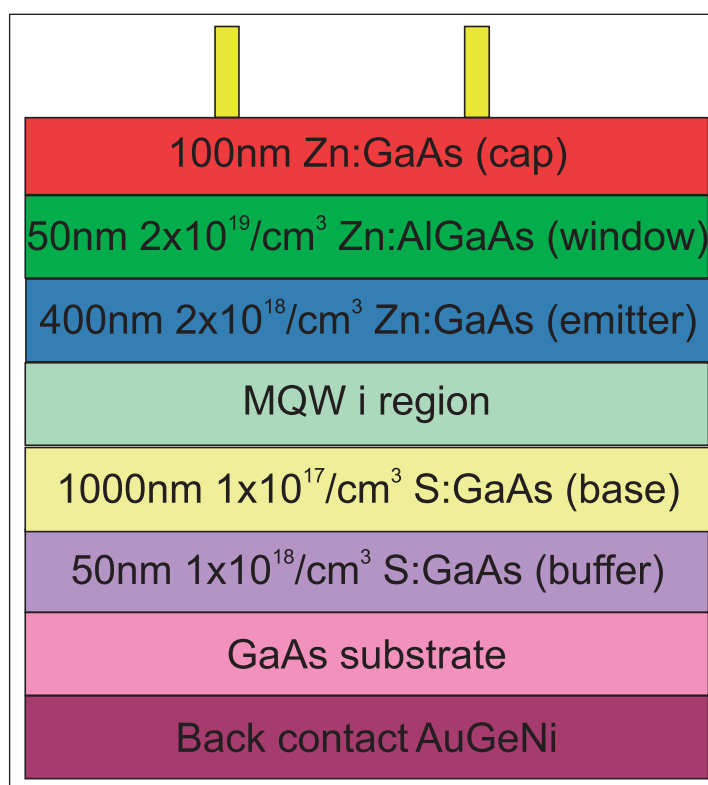


Figure 1. Schematic structure of QW solar cells.

a large number of wells to be created.

The strain compensation is achieved through careful design of the composition and thickness of the InGaAs wells (16% In, 7.6nm), GaAs steps (2x8nm) and GaAsP barrier (21% P, 11.6nm). The step layers also improve the material quality of the structure, as confirmed in atomic force microscope (AFM) and x-ray studies.

Four structures were tested (Table 1): sample A with a 20-period multi-quantum well (MQW) including GaAs step; sample B with a 10-period MQW with GaAs step;

Table 1. Characteristic structure and performances of QW cells.

Sample	QW stacks	GaAs step	J <sub>sc</sub> (mA/cm <sup>2</sup> )	V <sub>oc</sub> (V)	FF (%)	Efficiency (%)
A	20	Yes	20.25	0.88	80	14.2
B	10	Yes	19.29	0.88	79	13.4
C	10	No	16.85	0.89	71	10.7
D	N/A	N/A	18.80	0.97	82	14.9

sample C with 10-period MQW without GaAs step, but with an extra 160nm intrinsic GaAs layer; and, sample D, a reference cell with no QWs but 350nm intrinsic GaAs. The three last devices had roughly comparable active regions in terms of thickness (~350nm).

The structures (Figure 1) were grown on GaAs substrates using MOCVD. The epitaxial material was processed into small mesa-type devices with a 1mm-diameter circular active region. No anti-reflective coating was applied. The p-contacts were titanium/gold.

In terms of spectral response (Figure 2), all the devices responded to radiation with photon energies above the GaAs bandgap — i.e. wavelengths shorter than 870nm. However, the devices with QWs also responded to longer wavelengths up to 1000nm.

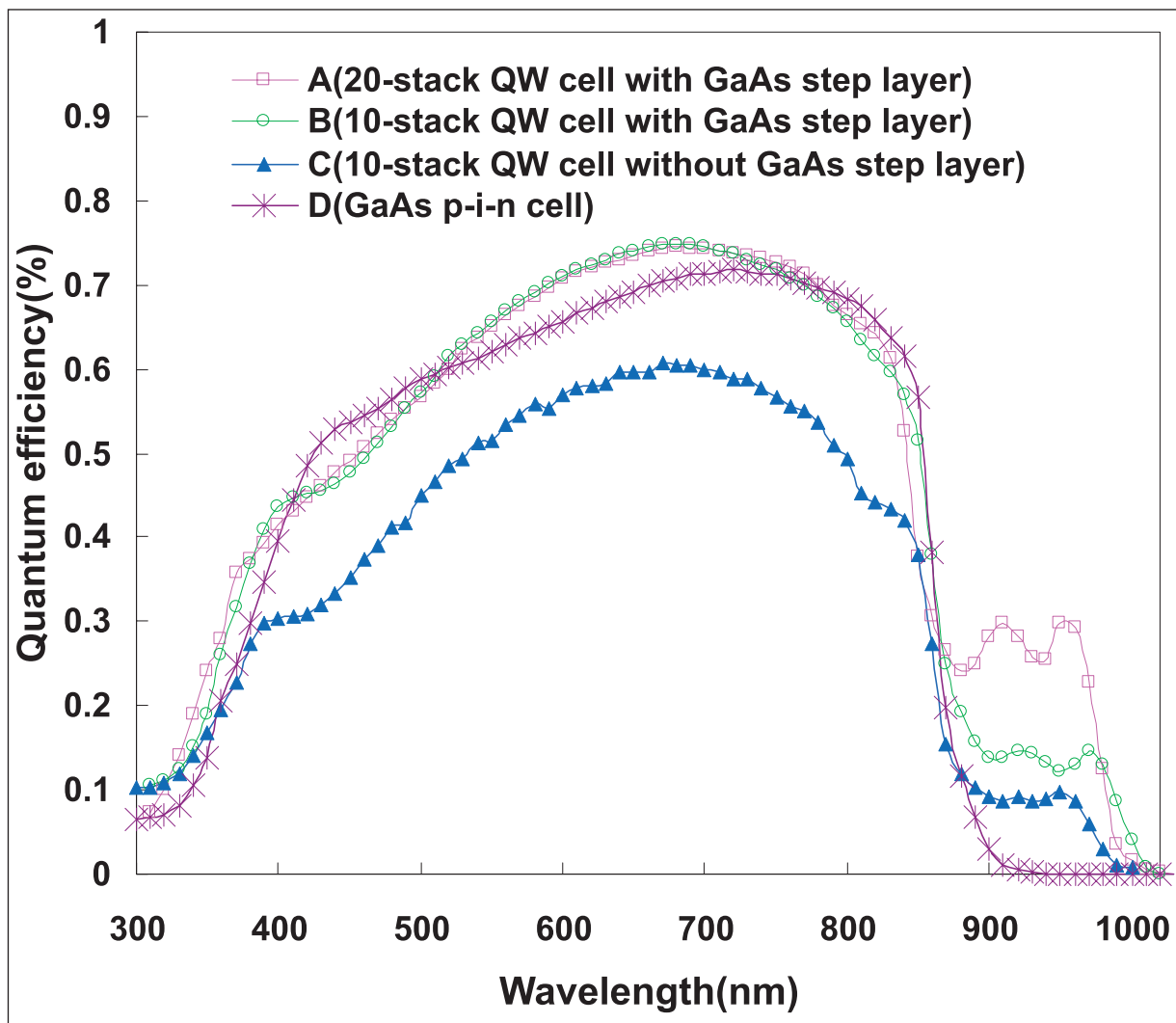


Figure 2. External quantum efficiencies versus wavelength for the four structures that were tested.

Device C, without GaAs-step, had reduced response in both regions, compared with A and B. The responses for A and B were comparable to that of D above the GaAs bandgap. ■

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Author: Mike Cooke

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# THz pulse boosts electron density in GaAs 1000-fold

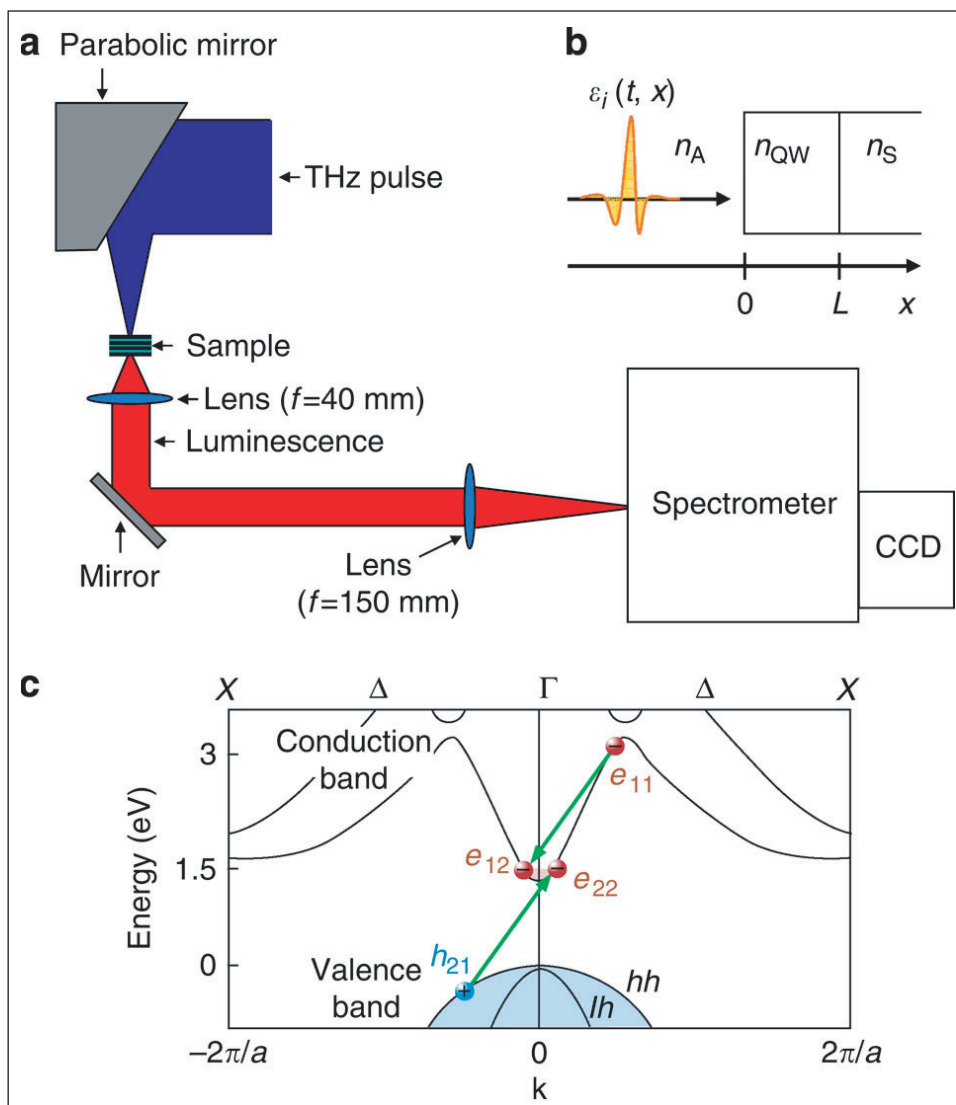
Kyoto University findings could lead to ultra-high-speed transistors and high-efficiency solar cells.

Researchers at Kyoto University have reported what they claim is a breakthrough with broad implications for semiconductor-based devices ('Extraordinary carrier multiplication gated by a picosecond electric field pulse' by H. Hirori et al, *Nature Communications*, 20 December issue; doi: 10.1038/ncomms1598). The findings could lead to the development of ultra-high-speed transistors and high-efficiency photovoltaic cells, it is reckoned.

Working with standard GaAs, the team observed that exposing the sample to a terahertz (1000GHz)-range electric field pulse caused an avalanche of electron-hole pairs (excitons) to burst forth. This single-cycle pulse, lasting just a picosecond ( $10^{-12}$ s), resulted in a 1000-fold increase in exciton density compared with the initial state of the sample.

"The terahertz pulse exposes the sample to an intense  $1\text{MV}/\text{cm}^2$  electric field," explains Hideki Hirori, team leader and assistant professor at Kyoto University's Institute for Integrated Cell-Material Sciences (iCeMS). "The resulting exciton avalanche can be confirmed by a bright, near-infrared luminescence, demonstrating a three-order-of-magnitude increase in the number of carriers," he adds.

Research at Kyoto using terahertz waves is led by professor Koichiro Tanaka, whose lab at the iCeMS pursues numerous applications including the development of new biological imaging technologies. "Since terahertz waves are sensitive to water, our goal is to create a microscope that will allow us to



**Figure 1: Measurement of THz pulse induced luminescence and impact ionization process. (a)** Generated THz pulses are focused onto the GaAs QWs sample, and the luminescence is detected by a CCD camera after it has passed through a spectrometer. **(b)** The geometry of the sample interfaces with air ( $n_A=1$ ), QWs ( $n_{QW}=3.5$ ) and a quartz substrate ( $n_S=2.1$ ). It is assumed that the QWs with thickness ( $L=6\mu\text{m}$ ) on the quartz substrate has a homogeneous refractive index ( $n_{QW}=3.5$ ) represented by the average of the refractive indices of the wells ( $n_w=3.6$ ) and barriers ( $n_b=3.4$ ).  $\epsilon_i(t, x)$  is incident THz electric field from the air. **(c)** Electron-initiated impact ionization transitions in the schematic GaAs band structure for momentum in the  $\Delta$  direction. The lattice constant  $a$  of GaAs is  $5.6\text{\AA}$ , and  $\pm 2\pi/a$  corresponds to  $\pm 1.1 \times 10^{10} \text{ m}^{-1}$ . The diagram shows electron and hole positions before and after the transition at the threshold.

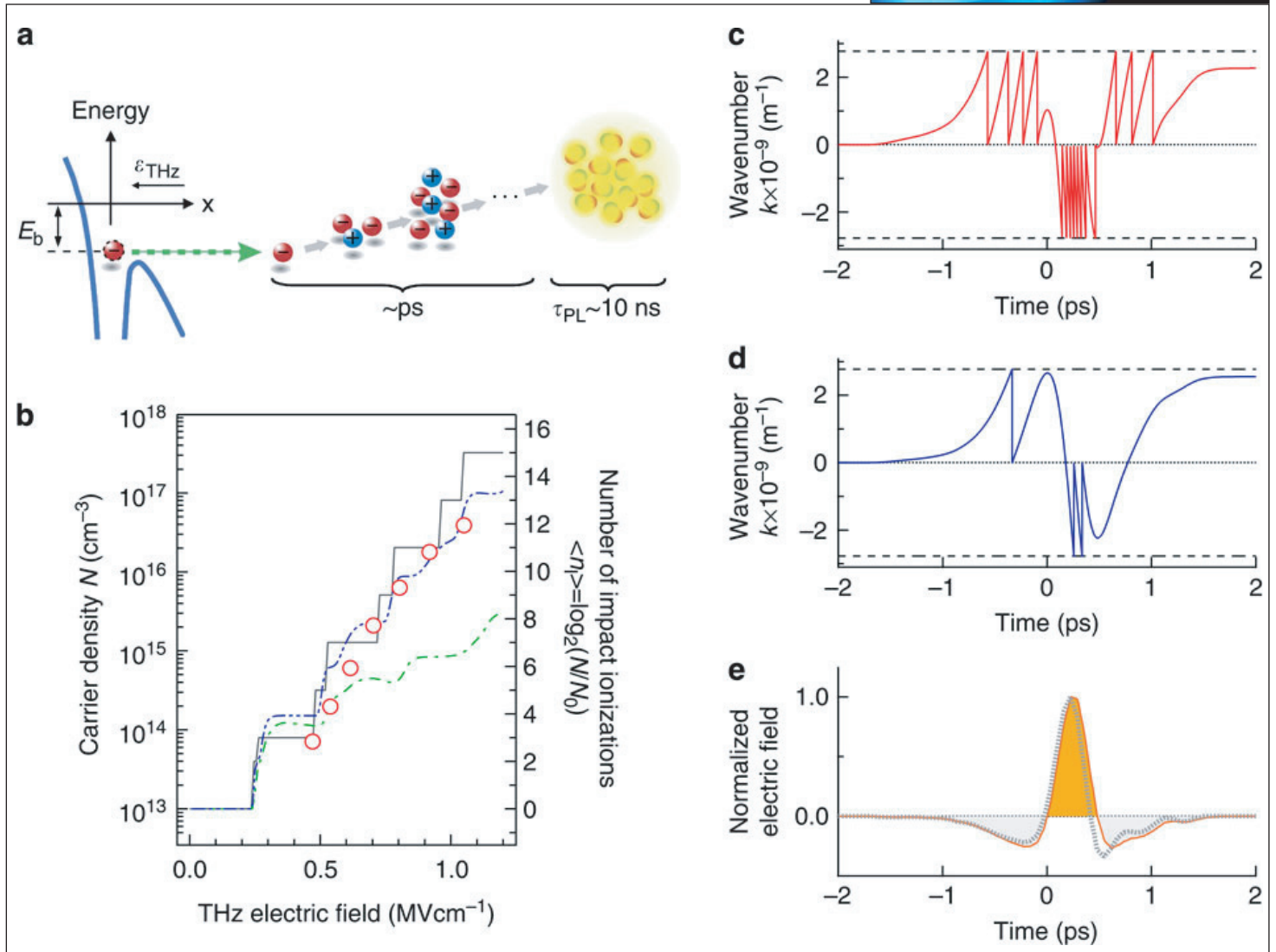
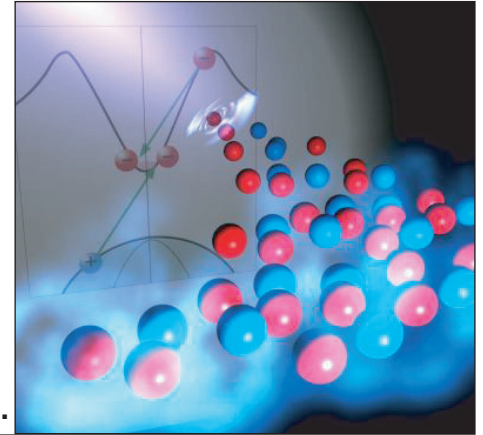
look inside living cells in real time," says Tanaka. "These just-released results using semiconductors are an entirely different field of science, but they demonstrate the rich potential that lies in the study of terahertz waves," he adds.

The work was supported by Grant-in-Aid for Young Scientists (B) (grant no. 21760038) of the Japan Society for the Promotion of Science and also by Grant-in-Aid for Scien-

tific Research on Innovative Area 'Optical science of dynamically correlated electrons (DYCE)' (grant no. 20104007) and Grant-in-Aid for Creative Scientific Research (grant no. 18GS0208) of Japan's Ministry of Education, Culture, Sports, Science and Technology.

[www.nature.com/ncomms/journal/v2/n12/full/ncomms1598.html](http://www.nature.com/ncomms/journal/v2/n12/full/ncomms1598.html)

**A picosecond THz pulse causes an avalanche of excitons from GaAs (right).**



**Figure 2: Comparison of experimentally and theoretically obtained carrier densities. (a)** The sketch visualizes the distortion in the Coulomb potential of donors, causing the potential to widen and free electrons to be released, and subsequent evolution of unbound e-h gas generated by a series of impact ionizations into a pure population of excitons emitting luminescence. **(b)** Electric field dependences of carrier density obtained in the experiment (red open circle) and calculations for three different impact ionization rates  $\gamma_i^{\text{cal}}$ ; one is infinity (grey solid line), and the others are derived with  $C=C_0=870\text{ps}^{-1}\text{eV}^{-2}$  (green one-dot-dashed line) and  $C=5C_0$  (blue two-dot-dashed line). It was assumed that  $N_0=10^{13}\text{cm}^{-3}$ . For the experimental (red open circles) and calculated data (grey solid line), the carrier density  $N$  is plotted together with the corresponding  $\langle n_i \rangle$ . Panels (c) and (d) show the electron wavenumber  $k(t)$  calculated for  $\epsilon=1.05$  and  $0.47\text{MVcm}^{-1}$ , respectively. Dashed lines indicate the wavenumbers in the range of  $\pm 2.77 \times 10^9 \text{m}^{-1}$ , where the electron energy corresponds to the threshold energy  $E_{\text{th}}$  of 1.7eV determined from the dispersion of the GaAs band structure. **(e)** Normalized electric field of the temporal profile of the incident THz pulse (grey dotted line) and of THz pulse with multiple reflections inside the sample (orange solid line).

# First yellow-green and amber micro-LED arrays

Long-wavelength emission achieved using (0001) sapphire substrates.

The University of Strathclyde in Scotland, UK, China's Peking University, and Shanghai-based Epilight Technology Co Ltd have made what they believe to be the first demonstration of yellow-green and amber III-nitride micro-LED arrays, based on new epitaxial structures [Z Gong et al, *Semicond. Sci. Technol.*, vol27, p015003, 2012].

The researchers see applications for micro-LED arrays coming from scientific instrumentation, optical communications and micro-displays. The LED emissions can be tuned to the absorption lines of biological active molecules, allowing optogenetic experiments to be controlled in both time and space, for example. Optoelectronic tweezer (OET) control is another possibility.

Rather than using expensive non- or semi-polar nitride substrates, the epitaxial material was grown on standard (0001) sapphire using metal-organic chemical vapor deposition (MOCVD). Free-standing nitride substrates are particularly used for producing devices with longer wavelengths (green, yellow, amber, etc), where reducing defects and polarization field effects are critical to performance.

Different buffer and active layers of InGaN/GaN wells and barriers (Figure 1) were used in two device types emitting light of wavelengths 560nm (yellow-green) and 600nm (amber). The researchers used a low-indium-content InGaN/GaN electron reservoir layer (ERL) that is believed to increase carrier capture in the quantum wells (QWs) above, improving radiative efficiency.

It is also believed that the use of an ERL makes the usual electron-blocking layer (EBL) above the active layers unnecessary. EBLs are used to stop electrons overshooting the wells and from entering the p-type hole injection layers, reducing radiative efficiency.

To produce devices, the epitaxial material was flipped so

Emission 560nm	Emission 600nm
360nm p-GaN Mg-doped	210nm p-GaN Mg-doped
75nm $\text{In}_{0.3}\text{Ga}_{0.7}\text{N}/\text{GaN} \times 6$ MQW	73nm $\text{In}_{0.4}\text{Ga}_{0.6}\text{N}/\text{GaN} \times 5$ MQW
25nm $\text{In}_{0.12}\text{Ga}_{0.88}\text{N}/\text{GaN} \times 2$ ERL	65nm $\text{In}_{0.18}\text{Ga}_{0.82}\text{N}/\text{GaN} \times 5$ ERL
2 $\mu\text{m}$ n-GaN (Si-doped)	4 $\mu\text{m}$ n-GaN (Si-doped)
2 $\mu\text{m}$ u-GaN buffer	1.5 $\mu\text{m}$ u-GaN buffer
(0001) sapphire	(0001) sapphire

**Figure 1. Schematic epitaxial structures for yellow-green (560nm) and amber (600nm) micro-LED arrays.**

that light emission was through the polished sapphire substrate. The micro-LEDs consisted of 10x10 circular device arrays of 40 $\mu\text{m}$  diameter and 100 $\mu\text{m}$  pitch.

The mesas for the LEDs were created using inductive coupled plasma to etch down to the n-type layer. The current-spreading p-contacts consisted of nickel/gold.

The n-contact of titanium/gold was formed in the space between the devices. Four n-contact electrode pads were created at the middle of each side of the square array for more uniform current spreading on the n-side of the device.

Silicon dioxide was used as electrical isolation, allowing titanium/gold p-metal buses to be deposited for electrical access to the p-contacts of individual pixels. The arrays were then bonded to printed circuit boards.

There is a large spectral blue-shift to short wavelengths in main device peaks as the current injection increases in the devices. For the yellow-green LED the

**Table 1. Typical electrical and optical characteristics per pixel for yellow-green and amber LED arrays.**

Type of device	$V_{\text{on}}$	$R_s$	Maximum power per pixel	Maximum power density
Yellow-green	3.2V	360 $\Omega$	100 $\mu\text{W}$	8.0W/cm <sup>2</sup>
Amber	3.8V	730 $\Omega$	55 $\mu\text{W}$	4.4W/cm <sup>2</sup>



shift is around 45nm in moving up to 5.57kA/cm<sup>2</sup> current density. There is also movement in light from the ERL (~450nm, blue), with the peaks initially blue-shifting to about 12nm at 0.6kA/cm<sup>2</sup> and then red-shifting. The ERL peak is very small in the green-yellow device, but quite large at low current for the amber LED.

The researchers used simulations to explore the spectral shifting effects of screening by current injection of the quantum-confined Stark effect from variation of the spontaneous and piezoelectric polarization fields (blue-shift), band-filling (blue-shift) and Joule heating (red-shift). They believe the screen effect dominates below 3.5kA/cm<sup>2</sup>, whereas band-filling accounts for further blue-shifts above that value.

The researchers comment: "Further optimization of the epitaxial structures is feasible to suppress these spectral shifts, and the insights obtained from the simulations should help guide the design of more advanced epitaxial structures."

The power output (Figure 2) of one pixel was measured by placing a silicon photodetector close to the sapphire surface, collecting the usable light in the upward direction. The calibration for the power measurement was over the 500–600nm range to allow for the spectral shift of the device. The peak power (thermal roll-over) was attained at 0.1mW and 55mA (4.4kA/cm<sup>2</sup>) for the yellow-green pixels and at 0.055mW and 60mA (4.8kA/cm<sup>2</sup>) for the amber pixels. These correspond to power densities of 8W/cm<sup>2</sup> and 4.4W/cm<sup>2</sup>, respectively. Further characteristics can be found in Table 1.

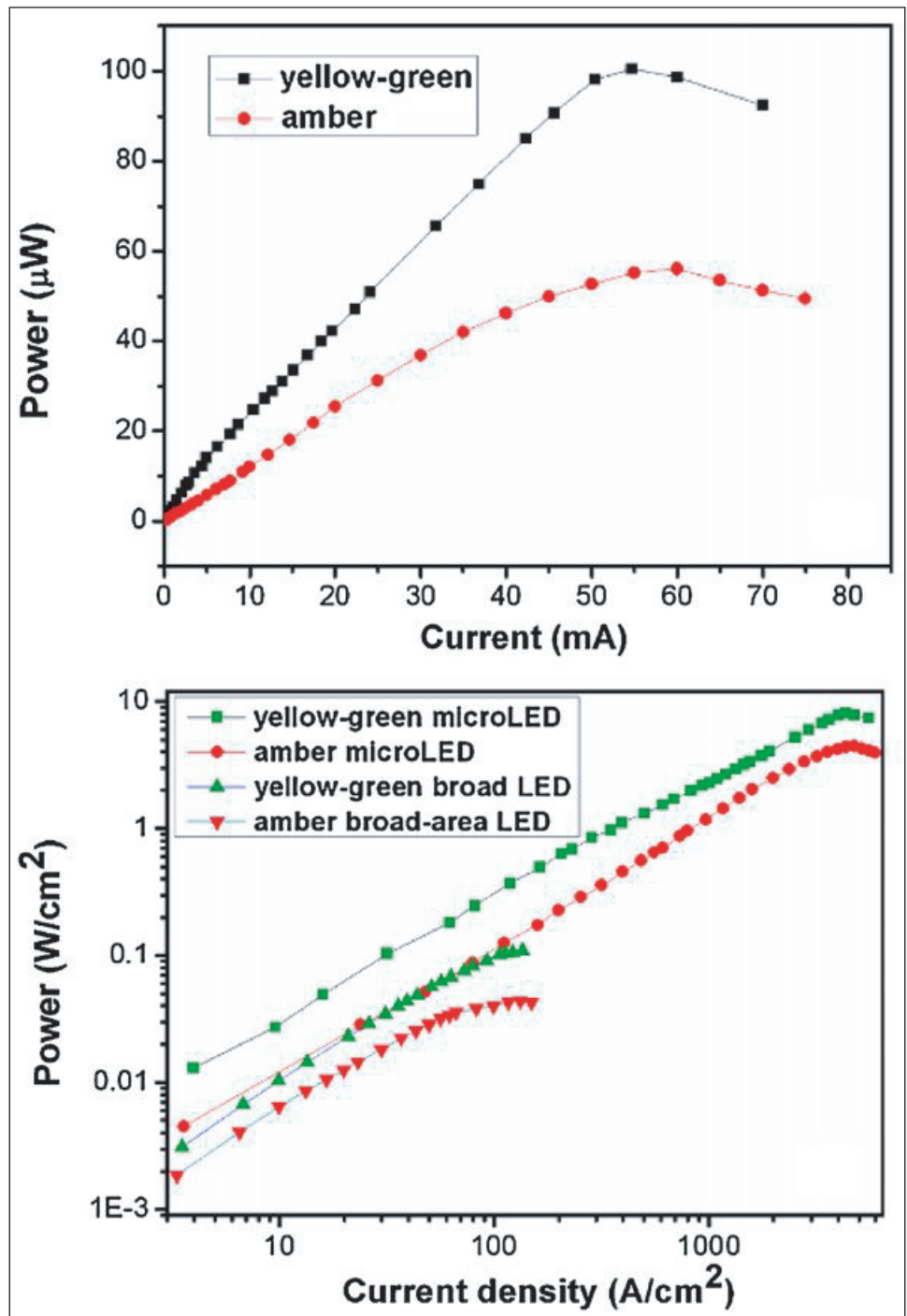
The researchers comment:

"These power densities exceed by more than an order of magnitude the requirements typical for applications."

The devices perform better than broad-area devices. The

**These power densities exceed by more than an order of magnitude the requirements typical for applications.**

**The devices perform better than broad-area devices**



**Figure 2. (a) Power outputs of yellow-green micro-LEDs and amber micro-LEDs as function of injection current; (b) power density vs current density of yellow-green micro-LEDs and amber micro-LEDs. For comparison, power densities of conventional broad-area LEDs made from same wafer are also plotted.**

researchers comment: "This is consistent with the numerical results of size-dependent self-heating that we have presented previously for LEDs emitting at 400nm, where we showed the junction temperature in a smaller pixel to be much lower than that in a larger one under the same current density." ■

<http://iopscience.iop.org/0268-1242/27/1/015003>

<http://www.shblue.com/en/>

Author: Mike Cooke

# Reflections on deep UV light extraction

**Nagoya-based researchers have increased deep UV LED light output power by 1.55x using reflecting contact regions.**

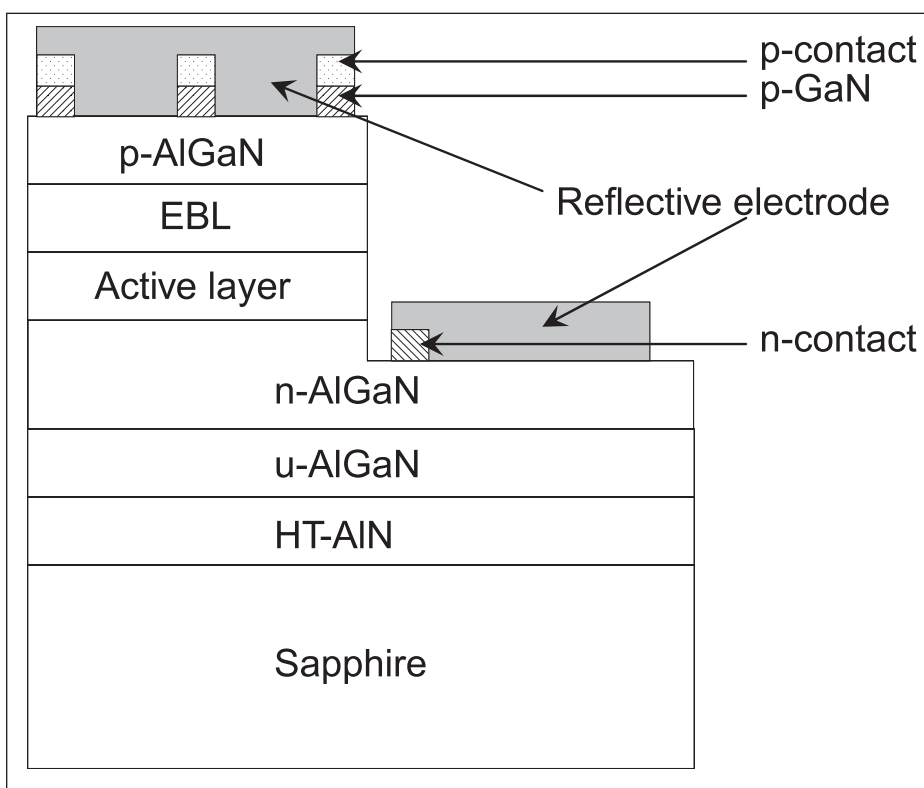
**R**esearchers based in Nagoya, Japan have been using reflective contacts to improve light extraction from deep ultraviolet light-emitting diodes (DUV-LEDs) [Tetsuhiko Inazu et al, *Jpn. J. Appl. Phys.*, vol50, p122101, 2011]. Power increases of up to 1.55x over devices without reflectors were observed.

DUV-LED devices are being developed for sterilization and water purification applications that need light with wavelengths less than 300nm. Other possible applications include UV curing of thin coats, printing, phototherapy, and photocatalysis.

Presently, DUV light is produced by mercury lamps that are fragile and contain poisonous material. For semiconductor devices to be a viable alternative, the present external quantum efficiencies (EQEs) of a few percent for aluminum gallium nitride (AlGaN) DUV-LEDs need to be increased. One way to boost EQE is to increase photon extraction from the device. Reflective contacts can decrease light absorption in the p-semiconductor layers and n-contact. The p-semiconductor tends to be GaN in order to achieve reasonable hole densities for injection. However, the GaN energy bandgap is narrower than that of the AlGaN active region, meaning that it strongly absorbs DUV light.

The researchers from UV Craftory Co Ltd and Meijo and Nagoya universities grew devices (Figure 1) on sapphire substrates using metal-organic chemical vapor deposition (MOCVD). The active light-emitting layer consisted of a single well of  $\text{Al}_{0.35}\text{Ga}_{0.65}\text{N}$ . The undoped buffer (u-AlGaN) and silicon-doped cladding (n-AlGaN) consisted of material with 60% Al, grown on high-temperature (HT)-deposited AlN. The magnesium-doped p-type layers were a 70%-Al electron-blocking layer (EBL), a 45%-Al cladding layer and a pure GaN contact layer. The 45%-Al AlGaN layer gave an ultraviolet cut-off of 280nm.

The mesa area was  $0.16\text{mm}^2$  in a  $0.64\text{mm}^2$  chip. The



**Figure 1. Schematic design of LED structure with reflective electrodes.**

reflective p-electrode (Figure 2) was formed by etching down through the p-GaN to the p-AlGaN cladding using a nickel mask. This reduced the p-GaN area to 33%. Nickel-gold ohmic contacts were made on the remaining p-GaN. The p-AlGaN windows were made reflective by electron-beam evaporating onto them 100nm aluminum, 100nm titanium, and 200nm gold. Finally, titanium-gold bond pads were deposited.

The n-contact consisted of a  $20\mu\text{m}$ -wide ohmic contact adjacent to the mesa side-wall and Al/Ti/Au reflector covering the rest of the exposed n-cladding surface. The n-reflector covered  $0.35\text{mm}^2$  and the contact  $0.05\text{mm}^2$ .

Comparison devices without reflectors were also produced. The chips were flipped onto aluminum nitride submounts and packaged in TO-5 metal cans/headers.

The observed improvements in light extraction were broken down by making devices with just p- or n-reflectors. The light output was increased 1.16x with just an n-reflector and 1.27x with just a p-reflector.

With both n- and p-reflectors, the power was increased 1.55x over a device without any reflectors.

The electroluminescence spectrum at 20mA dc shows a single peak at 295nm without parasitic satellites. One effect of the reflectors was to reduce the contact area, particularly for the p-type side of the device, resulting in a higher forward voltage (+0.45V).

Endurance tests were also carried out with the light output of the device with reflective contacts remaining over 80% of its original value at 20mA

dc after 1000 hours. The forward voltage did not fluctuate over this period. The devices without reflectors degraded in performance more slowly.

The researchers are not clear why the performance of the devices with reflectors should decay more quickly, although they suggest that a decrease in reflectance from Al-Ti/Au alloy formation over time may be responsible. This alloying may also be encouraged by the higher forward voltage that leads to more self-heating at the junction.

The reflective device extrapolated lifetimes for 70% and 50% light output power operation at 20mA dc were 4000 hours and 10,000 hours, respectively.

The researchers applied their reflectors also to 288nm

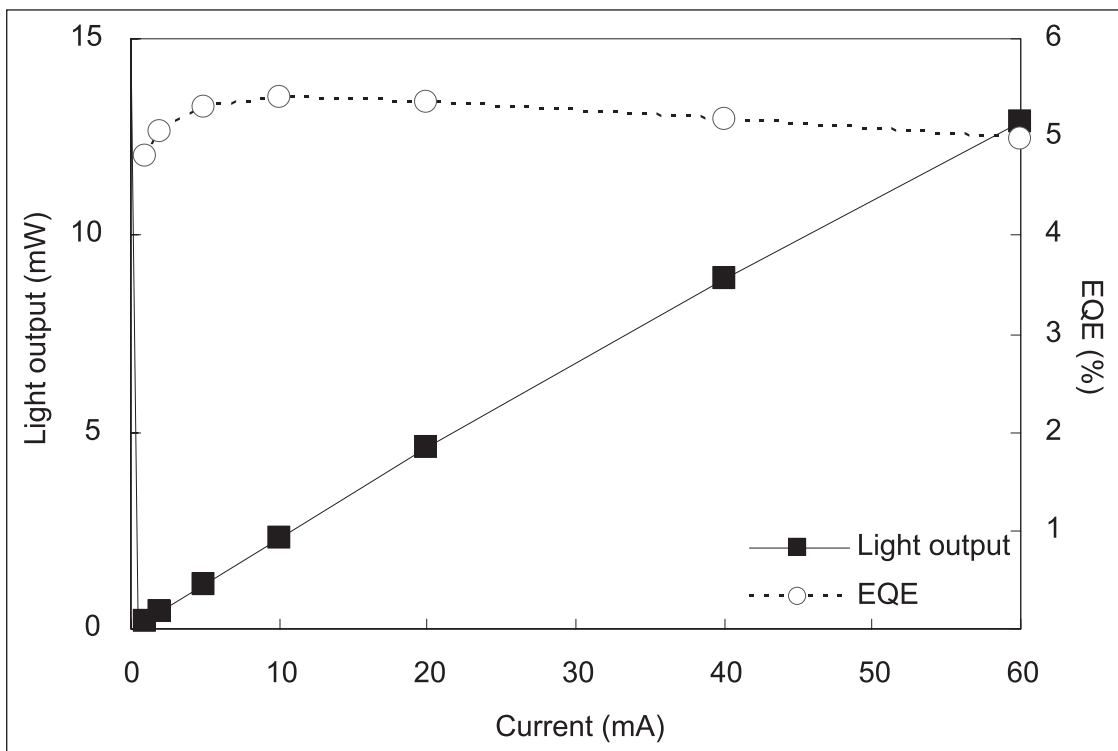


Figure 2. Dependences of EQE and output power on forward current for 288nm LED.

LEDs grown on higher-quality AlGaIn templates. A peak EQE of 5.4% was achieved at 10mA (Figure 2). The same research group achieved 5.1% EQE with 280nm LEDs without reflectors earlier this year [Cyril Pernot et al, *physica status solidi (a)*, vol208, p1594, 2011]. With DC operation, the light output from the 288nm LEDs with reflectors was 4.6mW at 20mA and 13mW at 60mA.

The same team has also developed moth-eye technology that they hope could boost performance by up to 50% [www.semiconductor-today.com/news\_items/2010/JUNE/NAGOYA\_140610.htm]. ■

<http://jjap.jsap.jp/link?JJAP/50/122101>

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# InGaAs buffer/channel structure boosts effective mobility 4.2x that of silicon

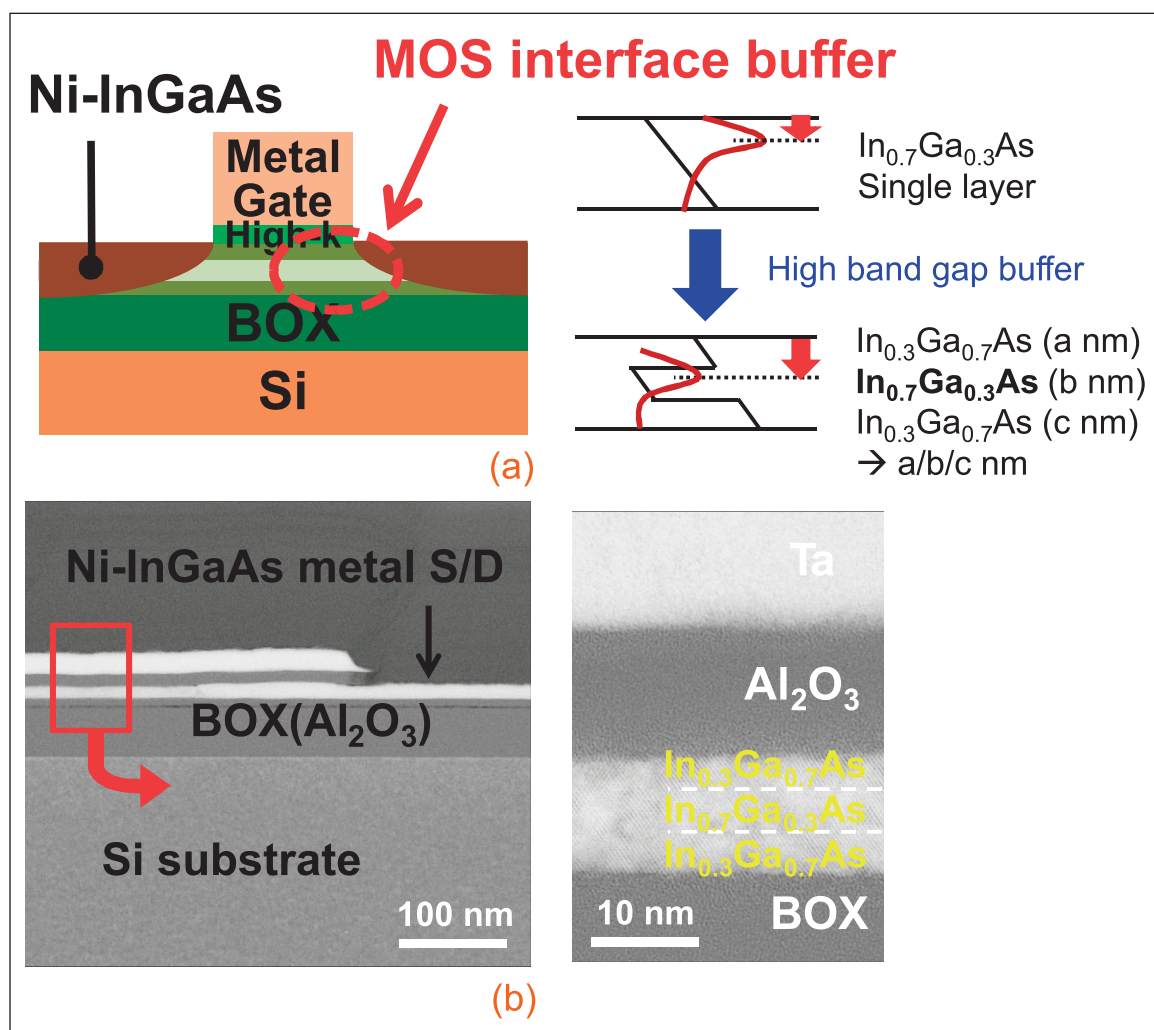
Japanese researchers increase performance of InGaAs-channel MOSFETs by 1.6x over that of InGaAs channel without interface buffer.

Researchers in Japan have been using metal-oxide-semiconductor (MOS) interface buffer layers of wider-bandgap material to boost the effective mobility of indium gallium arsenide (InGaAs) channels for future silicon electronics [SangHyeon Kim et al, Appl. Phys. Express, vol5, p014201, 2012].

The effective electron mobility for 5nm-thick channels was  $2810\text{cm}^2/\text{V}\cdot\text{s}$  with a sheet charge carrier density of  $10^{12}/\text{cm}^2$ . The mobility is enhanced over that for silicon (4.2x), and even over that for InGaAs without top and bottom buffer barriers (1.6x).

"This significant enhancement is attributable to the insertion of the buffer layers and resulting reduction in surface roughness scattering due to the smoother epitaxial-channel interfaces," the researchers say.

The buffer/barrier interface layers consist of lower indium content InGaAs. Lower indium content tends to widen the bandgap. Other groups have used indium aluminum arsenide (InAlAs) or indium phosphide (InP) to create MOS interface buffer layers



**Figure 1. (a) Schematic of  $\text{In}_{0.7}\text{Ga}_{0.3}\text{As}$ -OI MOSFETs with a MOS interface buffer layer. Band energy diagram with an electron distribution is also shown. (b) A cross-sectional TEM image of fabricated MOSFET with a  $T_{\text{body}}$  of 2/5/3nm.**

designed to reduce the scattering effects that degrade mobility.

The researchers explain their choice of InGaAs: "Here, we have used very thin  $\text{In}_{0.3}\text{Ga}_{0.7}\text{As}$  layers as the MOS interface buffer, because of the good MOS interface properties of  $\text{Al}_2\text{O}_3/\text{InGaAs}$ , the relatively large permittivity ( $\sim 14$ ), and the stable successive-growth condition without epitaxial surface degradation

in the growth of InAlAs and InP due to the change of gas species during the epitaxial growth.”

High-mobility channels are seen to be necessary for future (~2015, <16nm) mainstream electronics to achieve the targets of higher performance and lower power consumption.

The research builds on the recent work of the group consisting of The University of Tokyo, Japan's National Institute of Advanced Industrial Science and Technology (NAIST) and Sumitomo Chemical Co Ltd in the direct wafer bonding of III-V-on-insulator (III-V-OI) structures ([www.semiconductor-today.com/news\\_items/2011/DEC/UNITOKYO\\_021211.html](http://www.semiconductor-today.com/news_items/2011/DEC/UNITOKYO_021211.html)) where effective mobilities of 1700cm<sup>2</sup>/V-s were achieved.

The researchers grow their epitaxial layers on indium phosphide substrates using metal-organic chemical vapor deposition (MOCVD). The structures are then flipped onto silicon and the InP substrate and some etching sacrificial layers removed.

In the new devices the extremely thin body channel consisted of an In<sub>0.7</sub>Ga<sub>0.3</sub>As well sandwiched between In<sub>0.3</sub>Ga<sub>0.7</sub>As barriers. The thickness of the body layer was varied (1nm, 3nm, and 5nm) with the top and bottom barriers 2nm and 3nm thick, respectively.

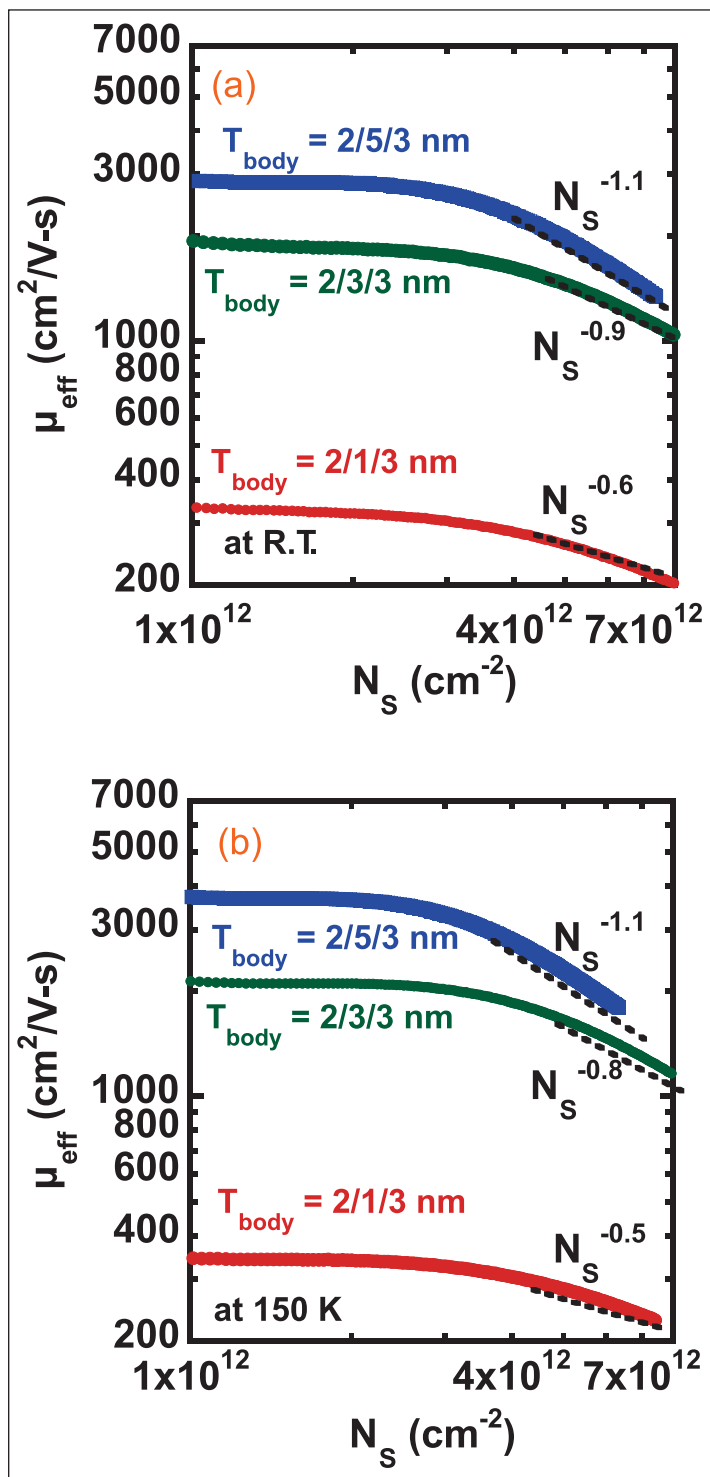
The source-drain electrodes consisted of Tokyo/NAIST/Sumitomo's recently developed nickel-InGaAs structures ([www.semiconductor-today.com/news\\_items/2011/FEB/NAIST\\_040211.htm](http://www.semiconductor-today.com/news_items/2011/FEB/NAIST_040211.htm)). The gate stack was tantalum on high-dielectric-constant insulating aluminum oxide.

The on-off current ratio of 5nm extremely thin body (ETB) channel devices was found to be ~10<sup>5</sup> at 1V drain bias. The subthreshold slope was 172mV/dec. The thinnest ETB devices of 1nm were normally operational, despite the hazard of the breaks in the channel, and had improved on-off ratios of 10<sup>7</sup> and lower subthreshold slopes of 103mV/dec.

The dependence of effective mobility on sheet carrier concentrations was measured at room temperature and at low temperature (150K) to separate phonon scattering from other effects (e.g. interface scattering) in degrading performance (Figure 2).

Although reducing the temperature increased the value of mobility slightly, the shapes of the mobility-concentration curves were almost the same. The shapes are attributed to the impacts of a combination of surface roughness and channel-thickness fluctuation. In particular, in thinner channels, fluctua-

**In order to reduce the influence of both scattering mechanisms and to achieve higher mobility with T<sub>body</sub> thinner than 10nm, it is very important to form uniform and flat InGaAs-OI layers**



**Figure 2. Mobility characteristics of In<sub>0.7</sub>Ga<sub>0.3</sub>As-OI MOSFETs with a MOS interface buffer layer with different T<sub>body</sub> values at (a) room temperature and (b) 150K.**

tions have more relative impact, severely reducing mobility between 3nm and 1nm.

The researchers conclude: “As a result, in order to reduce the influence of both scattering mechanisms and to achieve higher mobility with T<sub>body</sub> thinner than 10nm, it is very important to form uniform and flat InGaAs-OI layers.” ■

<http://apex.jsap.jp/link?APEX/5/014201>

Author: Mike Cooke

# Creating high-performance nitride semiconductor MOSFETs on silicon

**Taiwanese researchers report record normalized drive current of  $172\mu\text{A}/\text{V}^2$  using  $\text{LaAlO}_3/\text{SiO}_2$  dielectric with nitride MOSFETs on Si.**

**N**ational Chiao Tung University has used lanthanum aluminate ( $\text{LaAlO}_3$ ) and silicon dioxide ( $\text{SiO}_2$ ) dielectric layers to create nitride semiconductor metal-oxide semiconductor field-effect transistors (MOSFETs) on silicon substrates [C. Y. Tsai et al, IEEE Electron Device Letters, published online 25 November 2011]. The  $\text{LaAlO}_3$  allowed high-dielectric-constant ( $\kappa$ ) layers to be formed.

The devices achieved a record normalized drive current (mobility  $\times$  oxide capacitance) of  $172\mu\text{A}/\text{V}^2$ . The on-resistance was a low  $13.5\Omega\text{-mm}^2$  at a gate voltage  $+2\text{V}$ , and the transconductance was high at  $136\text{mS}/\text{mm}$ . Breakdown occurred at  $385\text{V}$  with a gate potential of  $-1\text{V}$ .

The use of an insulated gate allows a positive threshold voltage ( $V_t$ ), unlike nitride semiconductor transistors with a Schottky gate that usually have negative threshold. The researchers aimed at a low  $V_t$  value to match the needs of smart power control using silicon CMOS drivers that operate below  $1\text{V}$ . With a drain bias of  $3\text{V}$ , the threshold of the nitride MOSFET was  $+0.1\text{V}$  and the peak transconductance was  $136\text{mS}/\text{mm}$ . The on/off drive current ratio was 76. The subthreshold slope was  $0.53\text{V}/\text{decade}$ .

The subthreshold slope (SS) was one of the most favorable among the insulated-gate GaN devices

reported so far (Table 1), but is much higher than that achieved with silicon and needs to be improved. The researchers suggest that using lightly doped p-GaN would be one way to do this.

Increasing the on/off ratio is a particular challenge for GaN MOSFETs. Although gate recessing is used to increase its value, beyond a certain point the channel becomes broken, causing device failure. Therefore, one seeks ways to reduce the off-state leakage current.

Possible strategies include reducing the background n-type doping, using an InAlGaN buffer consisting of a tuned combination of four elements (quaternary), or thinning the GaN buffer thickness. The researchers believe that the peak transconductance and on-current values could be increased by reducing the gate-source spacing.

The aluminum gallium nitride/gallium nitride (AlGaN/GaN) epitaxial structures were grown on (111) silicon, resulting in a material with two-dimensional electron gas (2DEG) of carrier density  $1.08 \times 10^{13}/\text{cm}^2$  and mobility  $1458\text{cm}^2/\text{V-s}$ . The growth began with  $2.4\mu\text{m}$  low-temperature deposited GaN, followed by  $1.2\mu\text{m}$  GaN channel,  $30\text{nm}$   $\text{Al}_{0.25}\text{Ga}_{0.75}\text{N}$  barrier, and  $2\text{nm}$  GaN cap.

Mesa structures were etched using a mix of boron trichloride and chlorine plasmas. The gate was

	Gate dielectric	$V_{th}$ (V)	$R_{on}$ ( $\Omega\text{-mm}$ )	$I_{on}/I_{off}$	Subthreshold Slope (V/dec)	Mobility ( $\text{cm}^2/\text{Vs}$ )	$g_{m,max}$ (mS/mm)	$\mu C_{ox}$ ( $\mu\text{A}/\text{V}^2$ )	Breakdown Voltage (V)
<b>This Work</b>	<b><math>\text{LaAlO}_3/\text{SiO}_2</math></b>	<b>0.1</b>	<b>13.5 (<math>V_g=2\text{V}</math>)</b>	<b>76</b>	<b>0.53</b>	<b>201</b>	<b>136</b>	<b>172</b>	<b>385</b>
Ion-implanted MOSFET [2]	$\text{SiO}_2$	2.7	700 ( $V_g=34\text{V}$ )	1667	3.4	45	6	0.38	700
Ion-implanted MOSFET [3]	$\text{SiO}_2$	3.3	90 ( $V_g=30\text{V}$ )	1250	0.49	167	-	2.87	-
MOSFET w. SAG [4]	$\text{SiO}_2$	2.1	62.5 ( $V_g=20\text{V}$ )	$2 \times 10^6$	0.75	113	-	3.72	60
MOSHEMT [5]	PEC $\text{SiO}_2$	-5	16 ( $V_g=2\text{V}$ )	-	1.35	-	50	27.8	
Gate-recessed MISFET [6]	$\text{Si}_3\text{N}_4$	5.2	25 ( $V_g=13\text{V}$ )	-	8.64	120	-	-	400
RESURF MOSFET [7]	$\text{SiO}_2$	-0.5	135 ( $V_g=30\text{V}$ )	-	-	120	-	7.3	730
Gate-recessed MOSFET [8]	$\text{Al}_2\text{O}_3$	2	9.7 ( $V_g=6\text{V}$ )	-	0.9	225	98	6.25	40
Gate-recessed MISHEMT [9]	$\text{Al}_2\text{O}_3$	3	6.2 ( $V_g=10\text{V}$ )	-	1.31	-	155	13.7	320
Ion-implanted MOSFET [10]	$\text{TiO}_2\text{-MgO}/\text{MgO}$	1.3	62.5 ( $V_g=8\text{V}$ )	3500	0.34	13	-	1.49	-

**Table 1. Comparison of crucial device characteristics of GaN MOSFETs.**



recessed using a timed etch and measurement of the source–drain current of ungated devices. The recess was cleaned and then the gate dielectric of 1.5nm SiO<sub>2</sub> and 6.5nm LaAlO<sub>3</sub> was deposited using electron-beam evaporation at room temperature.

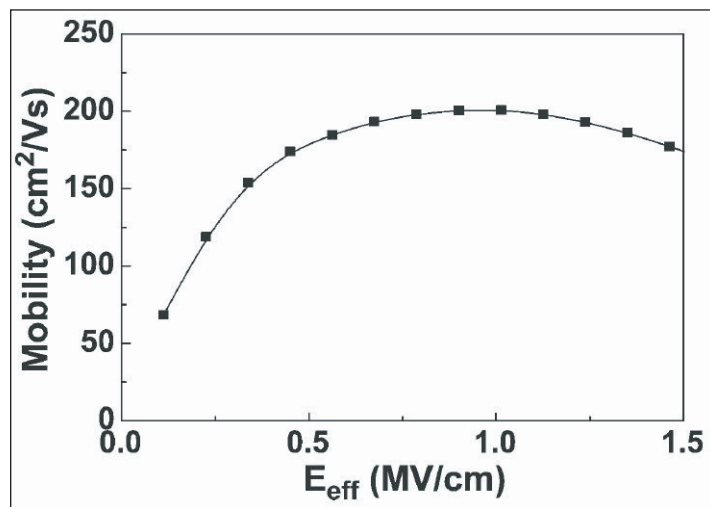
“The interfacial SiO<sub>2</sub> is vital for achieving favorable high-κ MOSFET performance with low V<sub>t</sub>,” the researchers comment.

The deposition was followed by annealing at 400°C for 5 minutes in oxygen. The aim of the anneal step was to improve the quality of the dielectric layers and the interface with the underlying GaN.

The source–drain regions were then defined and formed by removing the dielectric stack with a reactive-ion etch process. The ohmic source–drain electrodes consisted of titanium/aluminum/titanium/gold. The 5μm-long gate was nickel-gold. The gate width was 100μm. The gate was positioned with drain- and source-spacing of 10μm and 5μm, respectively.

Capacitance–voltage measurements on the gate structure gave a capacitance equivalent thickness (CET) of 3nm. The peak mobility of 201cm<sup>2</sup>/V-s is described as one of the most favorable results for GaN MOSFETs. This value falls far short of the 1458cm<sup>2</sup>/V-s found for the 2DEG at AlGaIn/GaN measured before dielectric deposition.

The difference is attributed to dielectric/GaN interface scattering. However, the mobility degradation at high



**Figure 1. Mobility as a function of effective field of gate-recessed GaN MOSFETs with high-κ LaAlO<sub>3</sub>/SiO<sub>2</sub> dielectric.**

effective electric field is considerably slower than for silicon-based devices (Figure 1), probably due to the lower carrier effective mass in nitride semiconductors (~0.2x mass electron in GaN, ~0.26x in Si). “This trait is a strong merit of the GaN nMOSFET,” the researchers comment. ■

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Author: Mike Cooke

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# Digital etching for damage-free gate recess in nitride transistors

**AlGaIn/GaN HFETs produced on silicon with 420mS/mm extrinsic transconductance and 500mA/mm maximum drain current.**

**R**WTH Aachen University in Germany has produced aluminum gallium nitride (AlGaIn) semiconductor heterostructure field-effect transistors (HFETs) on silicon with record performance [Herwig Hahn et al, Appl. Phys. Express, vol4, p114102, 2011]. In particular, the extrinsic transconductance was 420mS/mm and the maximum drain current was 500mA/mm. The threshold was +0.5V, allowing enhancement-mode/normally-off behavior that is desired for applications.

The results were achieved using a new etch technique that allows recessing of the gate into the barrier while not damaging the epitaxial material. The 'digital etch' technique can be seen as comparable to operating atomic layer deposition (ALD) in reverse. Like ALD, digital etch uses pulsed plasmas to increase control of the process.

The researchers processed standard commercial epitaxial wafers of AlGaIn/GaN on (111) silicon substrates. The barrier layers consisted of 26%-Al AlGaIn on an AlN mobility-enhancement layer, with 2nm GaN cap. The total barrier thickness was 17.4nm.

Processing began with a standard chlorine-based etch to create the isolation mesa. Ohmic contacts consisted of titanium-aluminum-titanium-gold alloyed at 825°C in nitrogen. A 120nm silicon nitride (SiN) passivation layer was added with plasma-enhanced chemical vapor deposition (PECVD). The SiN was also used to define the gate foot through lithography and fluorine-based plasma etch.

Using the SiN as etch mask, the digital etch was performed to create the recessing for the gate foot. The etch sequence consisted of alternating oxidation and boron-trichloride (BCl<sub>3</sub>) plasmas. The BCl<sub>3</sub> etches oxide much faster than the underlying nitride semiconductor. The researchers describe the process as being 'semi self-limiting'. "As a consequence, dead times at the beginning of an etch are eliminated and the etch rate control is improved," they comment.

The digital etch was optimized to give minimal damage and an etch rate of 1nm/etch cycle. The root mean square (rms) roughness was 1.17nm before the etch

and 1.20nm after. The gate was completed by depositing nickel-gold.

Three types of device were produced: without gate recessing (NR), or with shallow (6.3nm, SR) or deep (10.3nm, DR) recessing. These recessing types correspond to barrier thicknesses of 17.4nm, 11.1nm, and 7.1nm, respectively. The gate was 1µm long (L<sub>g</sub>), with source-gate and gate-drain distances also each 1µm. The gate width was 2x50µm (i.e. the gate extended out 50µm on each side of a central feed line).

One effect of increasing the recess depth was to push the threshold voltage to positive values: without recessing the gate threshold at 3V drain bias was -1.0V; this increased to -0.1V for shallow recessing and reached +0.5V for deep recessing. The positive threshold gives the deep recessed transistor an enhancement-mode normally-off behavior.

Although the on-drain current was reduced for the deep recessed device to 500mA/mm from the 600mA/mm of the non-recessed and shallow-recessed devices, the researchers comment: "Nonetheless, this value is still the highest reported drain current for enhancement-mode AlGaIn/GaN-on-Si HFETs".

The maximum intrinsic transconductance for the non-, shallow- and deep-recessed HFETs were 265mS/mm, 363mS/mm, and 420mS/mm, respectively. The 420mS/mm value is described as "the highest value reported so far for enhancement-mode AlGaIn/GaN-on-Si HFETs" and "very much comparable to the values from enhancement-mode HFETs on SiC with even lower L<sub>g</sub>". On the basis of these results, the researchers draw the conclusion that their process is nearly damage-free.

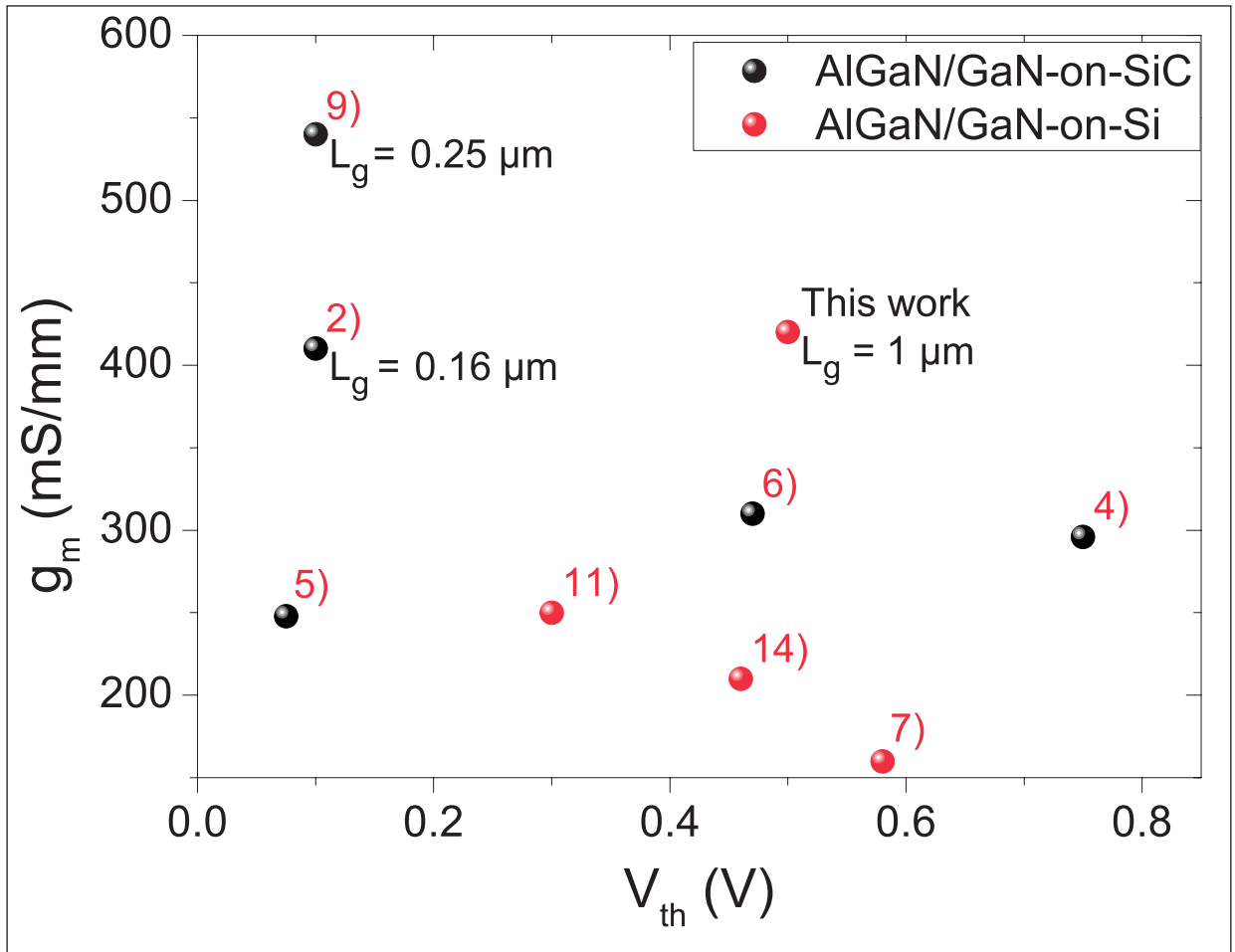
The off-state current is limited by gate leakage, with all devices showing similar behavior below a gate potential of -2V. "The extrapolated on/off ratios exceed four orders of magnitude, which is an excellent value for HFETs with a Schottky gate and without a backbarrier," the researchers comment. A backbarrier would improve electron confinement in the channel, and hence would give a harder pinch-off. The researchers also observe no increase in off-current resulting from

barrier thinning.

However, the turn-on voltage of the gate-diode is reduced by recessing, reducing in turn the maximum forward gate bias and maximum drain current ( $I_d$ ) of the deeply recessed device. The researchers comment: "The reduction in Schottky barrier height prevents a further increase in  $I_d$  and, therefore, the addition of an insulating layer, forming a MIS-HFET device, is desirable."

Pulsed measurements were also carried out to assess current collapse: temporary drain current reductions due to surface and bulk carrier trapping. The results suggest improvements of more than 40% in current recovery after the pulse for both shallow- and deep-recessed devices, compared with no recessing.

Comparing their results with other groups using silicon and silicon carbide substrates (see Figure),



**Figure 1. Comparison of extrinsic transconductance versus threshold voltage for HFETs based on AlGaIn/GaN-on-SiC (black squares) and AlGaIn/GaN-on-Si (red triangles). The reference numbers refer to the original paper.**

the researchers declare: "Our work represents a new milestone for Si-based AlGaIn/GaN HFETs". In view of the difference in gate length with the SiC devices shown, they add: "the devices demonstrated here are highly comparable to published results on SiC". ■

<http://apex.jsap.jp/link?APEX/4/114102>

Author: Mike Cooke

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# Back-barrier enhancements to AlN/GaN HEMTs

Researchers at France's IEMN show how the drain voltage can now be increased from a 10V limit to more than 50V using a DHFET structure.

France's Institute of Electronic, Micro-electronic and Nanotechnology (IEMN) has added a back-barrier to its aluminum nitride on gallium nitride (AlN/GaN) high-electron-mobility transistors (HEMTs) to increase electron confinement and hence lower sub-threshold drain leakage beyond 50V [Farid Medjdoub et al, Appl. Phys. Express, vol4, p124101, 2011]. Further improvements include enhanced RF performance figures.

The researchers believe that their technology could lead to cost-effective millimeter-wave high-power/high-linearity device applications.

The heterostructures (Figure 1) were grown by the company EpiGaN on highly resistive 4-inch (111) silicon using MOCVD. Two device types were compared: an ordinary HEMT and a new double heterostructure field-effect transistor (DHFET). In-situ MOCVD silicon nitride was used as early passivation and to prevent strain relaxation.

The GaN channel layer in the DHFET was grown thick enough to minimize the effect of the GaN/AlGaN back-barrier interface on the two-dimensional electron gas (2DEG) channel layer near the AlN/GaN interface. The Hall charge carrier

concentration was  $2.2 \times 10^{13} / \text{cm}^2$  for the HEMT structure and only slightly less at  $2 \times 10^{13} / \text{cm}^2$  for the DHFET. The respective mobilities were  $1200 \text{ cm}^2 / \text{V-s}$  and  $1400 \text{ cm}^2 / \text{V-s}$ . These values resulted in sheet resist-

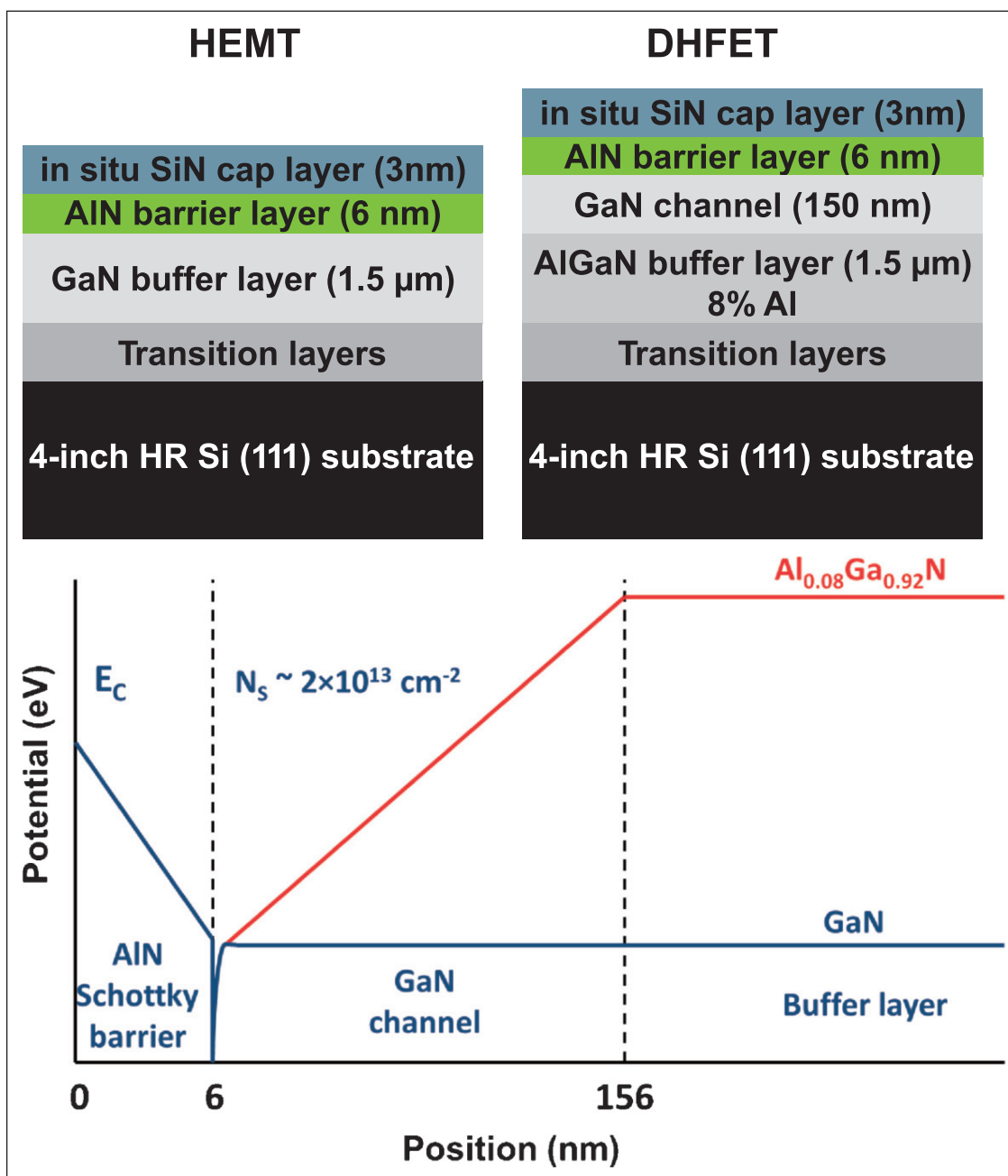


Figure 1. Cross section of the fabricated AlN/GaN-on-Si HEMTs (top left) and DHFETs (top right) and schematic of the conduction-band diagram of the HEMT and the DHFET.

ances of  $235\Omega/\text{sq.}$  and  $240\Omega/\text{sq.}$  for the HEMT and DHFET materials, respectively.

The ohmic source-drain contacts were titanium/aluminum/nickel/gold and the Schottky gate was nickel/gold. The gate length was  $0.2\mu\text{m}$ ; the source- and drain-gate distances were  $0.3\mu\text{m}$  and  $1\mu\text{m}$ , respectively. The device width was  $50\mu\text{m}$ . Nitrogen implantation was used to isolate devices. Further layers of plasma-enhanced chemical vapor deposited (PE-CVD) SiN were applied for more passivation.

The maximum output direct current density at a gate potential of 2V was  $1.8\text{A}/\text{mm}$  for both the HEMT and the DHFET. The researchers attribute the high current to the high sheet carrier density enabled by using AlN instead of AlGaIn for the top barrier. AlN has the highest spontaneous polarization of all the III-nitride semiconductor materials.

Total pinch-off occurs at a gate potential of 4V. The DHFET has a slight shift in threshold voltage and a more pronounced thermal effect due to the lower thermal conductivity of the AlGaIn back-barrier compared with the GaN buffer of the HEMT device. The transconductance of the two devices is almost identical at  $470\text{mS}/\text{mm}$  under optimum bias conditions.

However, at high drain bias the single-heterostructure AlN/GaN HEMT breaks down above 10V in terms of current pinch-off (Figure 3). The AlN/GaN/AlGaIn DHFET allows operation above a drain bias of 50V, while still

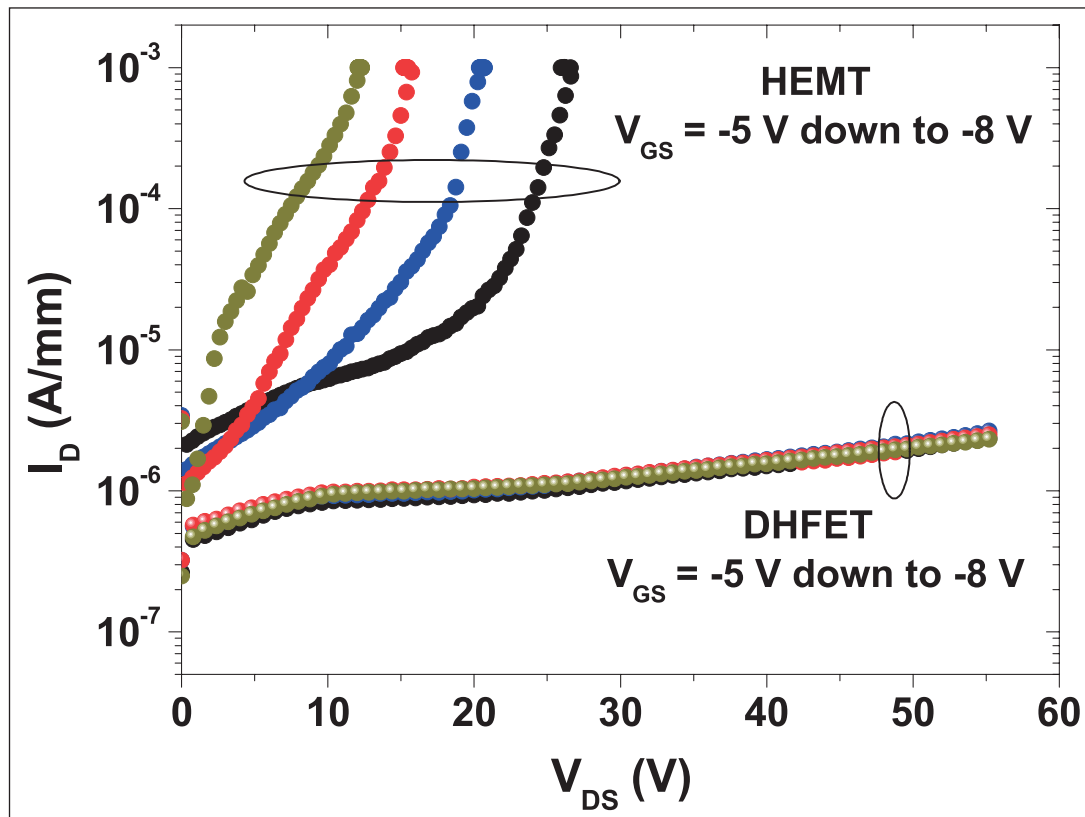


Figure 2. DC output for drain current vs drain bias ( $I_D$ - $V_{DS}$ ) characteristics of  $2 \times 25\mu\text{m}$  AlN/GaN-on-Si HEMT and DHFET in subthreshold region. Gate potential ( $V_{GS}$ ) swept from  $-5$  to  $-8\text{V}$  in 1V steps.

**The reduction of the short-channel effect results in a slightly better  $f_T$  and a decrease of the output conductance that involves a significant improvement of  $f_{max}$ . Reducing the DHFET gate length below  $100\text{nm}$  ( $0.1\mu\text{m}$ ) should "pave the way for higher-frequency operation of GaN-based devices grown on highly resistive Si substrate combined with high power (e.g. high current density and high voltage)."**

maintaining a subthreshold leakage of a few  $\mu\text{A}/\text{mm}$ .

The gate leakage for reverse bias is less than  $10\mu\text{A}/\text{mm}$  for both device types down to  $-60\text{V}$  gate potential. The breakdown in the HEMTs is thus attributable to electron injection into the buffer layer and excludes the possibility of surface leakage problems (which would show up as gate leakage).

The researchers comment: "For the DHFET, the AlGaIn back-barrier prevents the electron flow into the buffer under high drain bias, reducing the subthreshold drain leakage current and postponing the punch-through of the buffer layer."

The frequency performance of the devices were also determined, giving cut-offs ( $f_T$ ) of 44GHz and 52GHz for the HEMT and DHFET, respectively. Maximum oscillation ( $f_{max}$ ) occurred respectively at 68GHz and 91GHz. The researchers write: "The reduction of the short-channel effect results in a slightly better  $f_T$  and a decrease of the output conductance that involves a significant improvement of  $f_{max}$ ."

The researchers believe that reducing the DHFET gate length below  $100\text{nm}$  ( $0.1\mu\text{m}$ ) should "pave the way for higher-frequency operation of GaN-based devices grown on highly resistive Si substrate combined with high power (e.g. high current density and high voltage)." ■

<http://apex.jsap.jp/link?APEX/4/124101>

Author: Mike Cooke

# China creates its first high-performance InAlN HEMTs on sapphire

**Output power density of 4.69W and power-added efficiency of 48% achieved at 10GHz.**

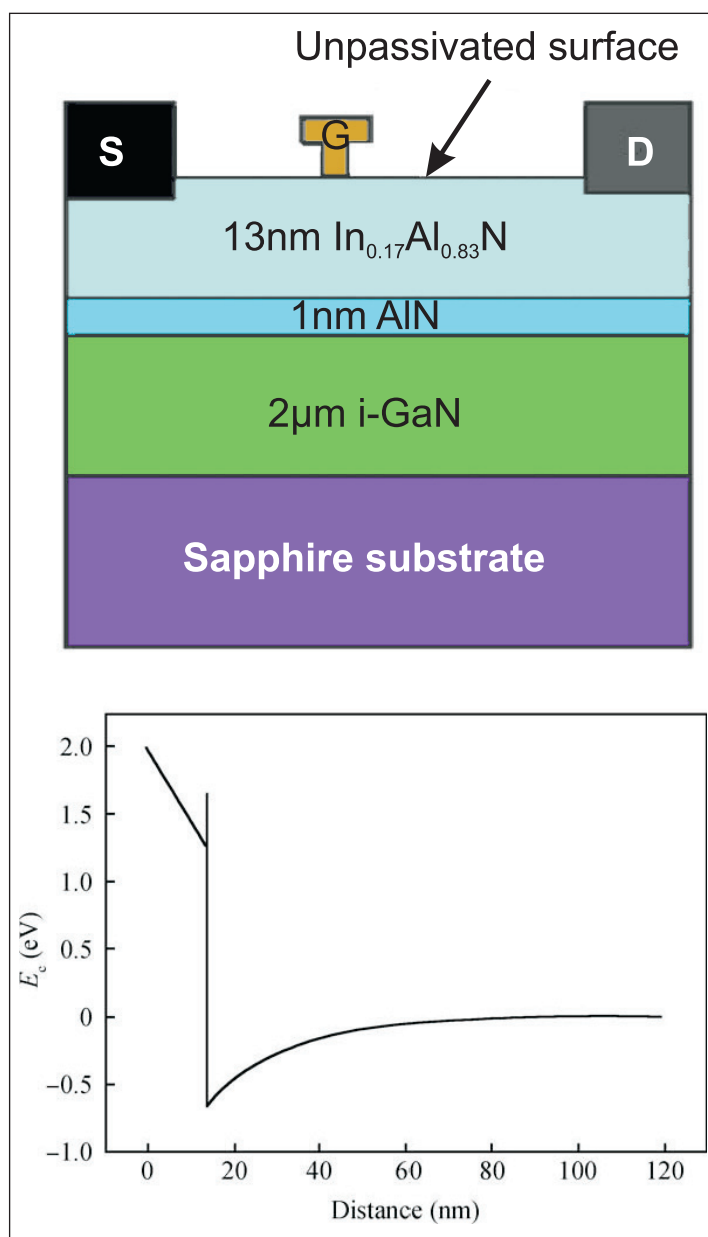
**H**ebei Semiconductor Research Institute and Harbin Institute of Technology researchers have made the first report in mainland China of high-performance high-electron-mobility transistors (HEMTs) using indium aluminum nitride (InAlN) barriers on gallium nitride (GaN) buffer layers [Liu Bo et al, *J. Semicond.*, vol32, p124003, 2011]. The team sees their work as strengthening the case for InAlN-based technology as a potential successor of aluminum gallium nitride (AlGaN) HEMTs for microwave and millimeter-wave power applications

Growth of high-quality InAlN has only recently become available. Potential advantages of InAlN over the more traditional AlGaN include lattice matching with GaN with In-content of  $\sim 17\%$  and high spontaneous polarization that creates high charge carrier densities in the two-dimensional electron gas (2DEG) that forms at InAlN/GaN interfaces. These properties allow the gate-channel distance to be reduced, improving electrostatic control of current flow through the device.

Usually AlGaN/GaN HEMT channel-gate distances are 25nm. The Hebei/Harbin InAlN/AlN/GaN devices had almost half that at 13nm. For example, the new devices had peak transconductance of 286mS/mm at gate potential of  $-3\text{V}$ . With sub-100nm gate lengths, the researchers expect to achieve transconductances of more than 400mS/mm, along with low output conductance and high gain at mm-wave frequencies.

Although the Hebei/Harbin InAlN/AlN/GaN device had modest frequency performance with extrinsic  $f_T$  cut-off of 34GHz and  $f_{\text{max}}$  maximum oscillation of 40GHz at a gate potential  $-4\text{V}$  and a drain bias of 8V, researchers based in Switzerland have recently achieved 205GHz cut-off with 55nm gate length and 3nm InAlN barrier layer.

Power measurements of Hebei/Harbin device subjected to a drain voltage of 24V in a load-pull system at 10GHz gave output power density of 4.69W/mm, linear gain of 11.8dB, and peak power-added efficiency (PAE) of 48%. The power density figure compares with AlGaN/GaN device performance of 41.4W/mm at



**Figure 1. Structure and energy band diagram of a schematic InAlN/GaN HEMT.**

4GHz and 3.65W/mm at 18GHz.

The maximum drain current density for the Hebei/Harbin device was 1.56A/mm at a gate potential



of +2V, a value “to our knowledge beyond the highest drain current density of any AlGaIn/GaN HEMT structure, especially for samples fabricated on sapphire substrates,” the researchers add. Higher current densities are expected from improved thermal management and reduced trap densities.

The devices (Figure 1) were grown on sapphire using low-pressure metal-organic chemical vapor deposition (LP-MOCVD). The In-content of ~17% was measured on a 100nm InAlN layer sample using x-ray diffraction techniques. Then a 13nm InAlN layer sample was grown for the production of HEMTs.

The ohmic source-drain contacts were titanium/aluminum/nickel/gold and the Schottky gate was nickel/gold. The source-drain electrodes were subjected to a rapid thermal anneal at 850°C for 30s in nitrogen. The source-drain contacts had resistances of 0.6Ω-mm. The gate length was 0.25μm. The gate width was 2x100μm.

Hall measurements of the performance of the two-dimensional electron gas at the InAlN/AlN/GaN interface gave a mobility of 1210cm<sup>2</sup>/V-s with a carrier concentration of 2.6x10<sup>13</sup>/cm<sup>2</sup>. The sheet resistance was 210Ω/sq. The sheet carrier density was about twice that typical for AlGaIn/GaN interfaces. The researchers attribute their high performance values to the optimized nature of their AlN and InAlN layers.

Unpassivated devices showed almost current-collapse-free performance with pulsed operation (Figure 2).

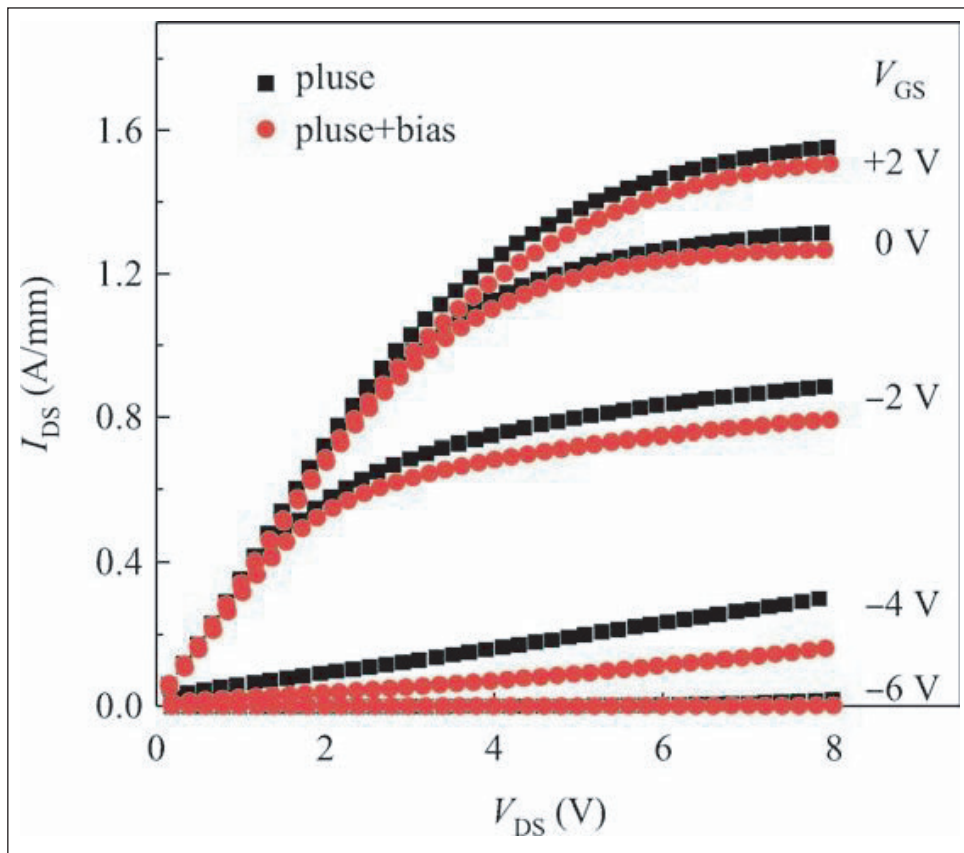


Figure 2. Pulse DC characteristics of unpassivated InAlN/ GaN HEMT.

AlGaIn/GaN-based devices tend to suffer from surface charging effects from trap states that cause the current response to decrease when the gate and drain potentials are pulsed.

The researchers comment on their results: “A much lower current dispersion was observed in our case, although these devices were still unpassivated, indicating a relatively stable surface in the case of the AlInN barrier material.” ■

<http://iopscience.iop.org/1674-4926/32/12/124003>

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# Speed and power from gallium nitride and silicon carbide

The International Electron Devices Meeting in December contained a wide range of compound semiconductor developments. Here, **Mike Cooke** reports on high-frequency and high-power research based on gallium nitride and silicon carbide.

These are interesting times for developers of compound semiconductor technologies. As the challenges of shrinking/scaling CMOS augur seismic changes in electronics, compound solutions are even being sought in the silicon heartland of logic. This strand of development was well represented at 2011's International Electron Devices Meeting (IEDM) and will be reported next issue.

Here, we report on the other great contenders for wide-ranging compound applications: high-speed and high-power electronics enabled by the wide-bandgap semiconductors in the III-nitride group and silicon carbide (SiC). The interesting properties of these materials include high critical electric fields before breakdown, the ability to operate at higher temperature, and high electron mobility. These parameters enable devices with lower power loss and higher frequency.

Schottky rectifiers and various transistors have been developed in these technologies and are in the process of commercialization. An important issue, however, is producing reliable devices at low enough overall cost to compete with silicon. Cost advantages for devices operating at higher temperatures than usual with silicon can include reduced size or even no cooling system.

Some recent work has focused on delivering high performance from nitride semiconductors grown on low-cost silicon substrates, creating also possibilities of the monolithic integration of high-performance power devices with scaled silicon CMOS-based ICs. Even without such integration, there are potential cost and economy-of-scale advantages in the larger substrates available and the existing infrastructure of tools and foundries.

## High frequency

At IEDM, HRL Laboratories and University of California San Diego (UCSD) reported a self-aligned gate process that can produce depletion- and enhancement-mode nitride semiconductor high-electron-mobility transistors (HEMTs) [session 19.1]. Devices with the world's shortest HEMT gate lengths of 20nm demonstrated records in terms of low on-resistance and high on-current (Table 1).

The different operating modes were obtained by varying the top barrier structure: gallium nitride/aluminum nitride (GaN/AlN) for D-mode and AlGaN/AlN for E-mode (Figure 1). An AlGaN back barrier was also implemented to increase carrier confinement, suppressing short-channel effects. The access resistance of the source/drain contacts was reduced with re-grown n<sup>+</sup>-GaN regions. The epitaxial material was grown using molecular beam epitaxy (MBE).

The self-aligned gate was formed using the sidewalls of a patterned silicon nitride surface passivation layer. The thickness of the passivation determined the gate-source and gate-drain distances at 40nm. Devices with gate lengths of 20nm and 35nm were produced. The gate material was platinum/gold. Source-drain electrodes were titanium/platinum/gold. ▶

**Table 1. Performance characteristics for HRL 20nm gate-length devices.**

Characteristic	D-mode	E-mode
On-resistance	0.29Ω-mm	0.33Ω-mm
On-current	2.7A/mm	2.6A/mm
Off-state breakdown	9.1V	11.6V
Threshold voltage	-1.44V	+0.47V
Peak extrinsic transconductance	1.04S/mm	1.63S/mm
Cut-off frequency	310GHz	343GHz
Maximum oscillation	364GHz	236GHz
Intrinsic RF transconductance	1148mS/mm	1725mS/mm

► The researchers attribute their results to aggressive scaling (i.e. reduction) of the gate length and source–drain distance. “The excellent RF performance was attributed to a significantly reduced electron transit time as a result of ultra-short gate length, suppressed drain delay, and enhanced electron velocity by an increased electric field confined in the very short  $L_{sd}$ ,” the team writes.

Separately, HRL reported on its second-generation millimeter-wave double-heterostructure field-effect transistors (DHFETs) that allowed the production of monolithic microwave integrated circuits (MMICs) with 1023mW output power and power-added efficiency of 19.1% at 95GHz [session 19.3]. Again, MBE re-growth of  $n^+$  ohmic regions was used to reduce parasitic resistance. An improved T-gate formation process reduced current-collapse effects.

Recent development has produced high-quality indium aluminum nitride material with some interesting properties for nitride devices, such as the ability to create material lattice matched with GaN. Researchers from MIT, IQE and the University of Notre Dame (UND) have studied the effect of channel thickness on high-frequency InAlN/GaN HEMTs with gate lengths in the range 30–230nm [session 19.2]. Thinner channels improve carrier confinement and thus ameliorate short-channel effects. However, as the channel becomes narrower, edge effects such as scattering from interfaces and alloy non-uniformities and diffusion into the GaN channel layer cause decreases in mobility and effective electron velocities, reducing performance with gate lengths scaled down to 30nm (Table 2).

The devices tested had a thin InGaN back-barrier. The indium diffusion into the GaN channel tended to increase the polarization difference between the channel and InAlN top-barrier. The increased electric field that resulted from the polarization contrast degraded the performance of the Schottky gate contact. The effects were particularly striking in devices with 4nm-thick channel layers, where complete pinch-off was not achieved.

The researchers comment: “In spite of this high gate leakage, the improved carrier confinement of the 4nm GaN channel structure shows 30–40% lower DC output conductance and threshold voltage roll-off than the thicker-channel structures, demonstrating its higher immunity to short-channel effects.”

The researchers add: “It should be noted that the intrinsic delay in 30nm-gate-length devices is comparable to the extrinsic and parasitic delays, which indicates that a reduction of these delays has as much impact as gate scaling in these deep-submicron devices.”

D-mode epi		
Ohmic regrowth layer	$n^+$ -GaN	50nm
Cap	GaN	2.5nm
Top barrier	AlN	3.5nm
Channel	GaN	20nm
Back barrier	$Al_{0.08}Ga_{0.92}N$	
Substrate	Semi-insulating SiC	
E-mode epi		
Ohmic regrowth layer	$n^+$ -GaN	50nm
Cap	$Al_{0.5}Ga_{0.5}N$	2.5nm
Top barrier	AlN	2.0nm
Channel	GaN	20nm
Back barrier	$Al_{0.08}Ga_{0.92}N$	
Substrate	Semi-insulating SiC	

**Figure 1. HRL’s vertically-scaled DH-HEMT epitaxial structures with (a) GaN (2.5nm)/AlN(3.5nm) top barrier for D-mode operation and (b) thinner  $Al_{0.5}Ga_{0.5}N$  (2.5nm)/GaN(2.0nm) top barrier for E-mode operation.**

Both the HRL/UCSD and MIT/IQE/UND works were sponsored by the Defense Advanced Research Projects Agency (DARPA) Nitride Electronic NeXt-Generation Technology (NEXT) program.

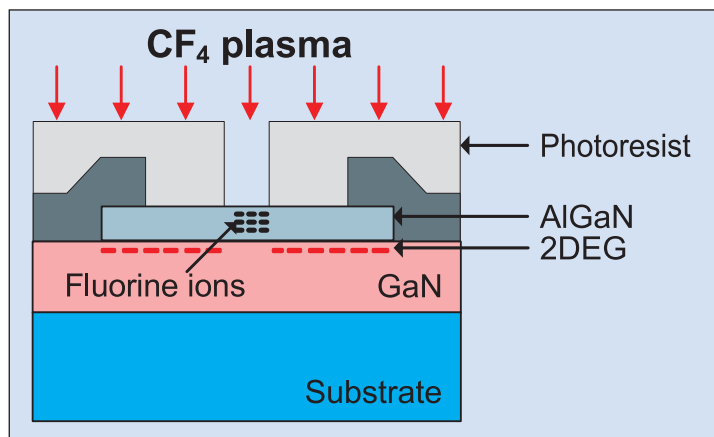
### Normally-off

Hong Kong University of Science and Technology (HKUST) reported on the development of fluorine ion implantation as a method for creating normally-off HEMTs [session 19.4]. The study included both atomistic theoretical models and experimental analysis using thermal diffusion, positron annihilation spectroscopy, photoconductivity and electroluminescence. Such devices are desired for

**Table 2. Performance of MIT/IQE/UND 30nm gate length devices with different channel thicknesses.**

Characteristic	26nm	12nm	4nm
Extrinsic transconductance	529mS/mm	491mS/mm	287mS/mm
Cut-off frequency	290–300GHz	290–300GHz	172GHz
Effective electron velocity	$1.45 \times 10^7$ cm/s	$1.32 \times 10^7$ cm/s	$1.16 \times 10^7$ cm/s





**Figure 2. Use of fluorine ion implantation to convert from normally-on to normally-off behavior.**

high-frequency and high-voltage power-switching applications that need fail-safe shut-off. Also, simplified circuit design can result from the use of normally-off devices.

The shifting of threshold voltages to the positive values needed for normally-off behavior is due to the strong electro-negativity of fluorine which becomes a fixed negative charge, modifying the electron band structure in the nitride semiconductor crystal and depleting the two-dimensional electron gas (2DEG) channel underneath (Figure 2).

The researchers see the technique as being a robust approach to fabricating normally-off AlGaN/GaN HEMTs or MIS-HEMTs with excellent stability under both thermal and electric field stresses.

The researchers comment: "The tight lattice structures of GaN and related materials provide a tailor-made environment for stable incorporation of F ions and the resultant reliable  $V_{th}$ ."

HKUST has also worked with Hebei Semiconductor Research Institute on  $Al_2O_3/InAlN/GaN$  MIS-HEMTs

with Schottky source and drain [session 33.4]. These demonstrated steep sub-threshold behavior (24mV/dec), on/off current ratios of 9 decades, and a drive current of 416mA/mm. The researchers propose a mechanism for the very steep sub-threshold behavior where dynamic interface charge-detraping processes result in positive feedback in drain current. Temperature-dependent characterization seems to validate the model.

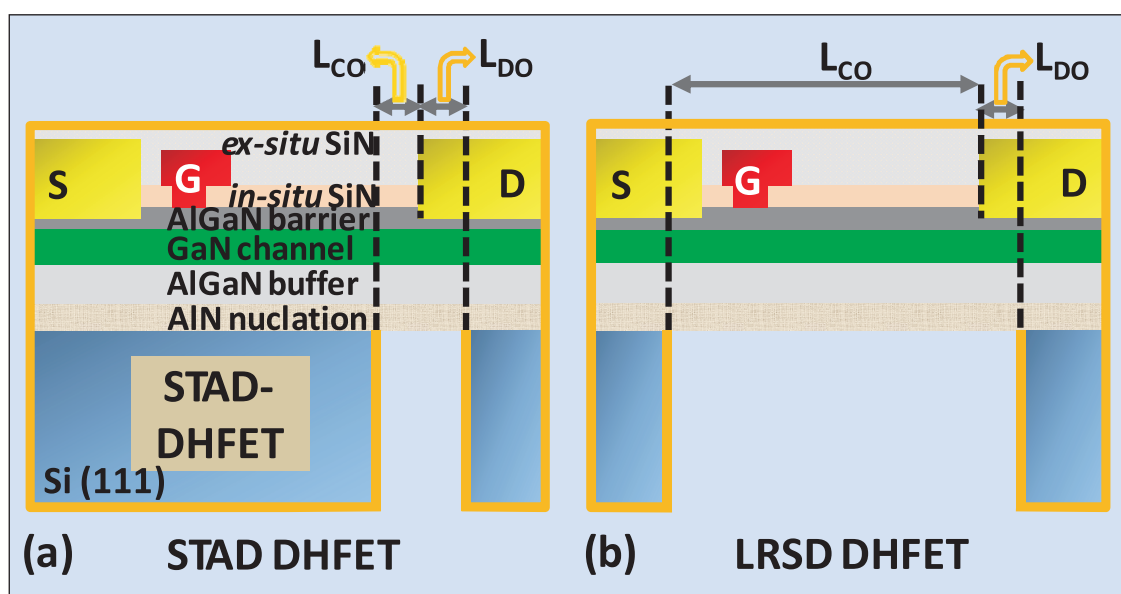
Hebei is a research body that has recently demonstrated mainland China's first high-performance InAlN HEMTs [www.semiconductor-today.com/news\_items/2012/JAN/HEBEI\_050112.html].

## Power

IMEC, Katholieke Universiteit Leuven (KUL) and Universiteit Gent (UG) have used silicon trenches around the drain (STAD) contacts of nitride semiconductor on a silicon DHFET to enhance breakdown voltages from 650V to more than 2kV [session 19.6]. The STAD contacts electrically isolate the gate and source from the drain by cutting the connection through the AlN/Si interface (Figure 3). An alternative approach where silicon substrate is removed locally between the source and drain (LRSD) was previously found to increase breakdown, but suffered from increased self-heating effects. This was because the silicon between the source and drain acts as a heat sink in the on-state.

The Schottky-gate devices were grown on Si(111) substrate. The resulting DHFETs operate in enhancement-mode (normally-off). To create the STAD structure, the silicon wafer is thinned to  $\sim 125\mu\text{m}$  and then a patterned etch is performed to remove the silicon trench around the drain contact. LRSD devices were also produced for comparison.

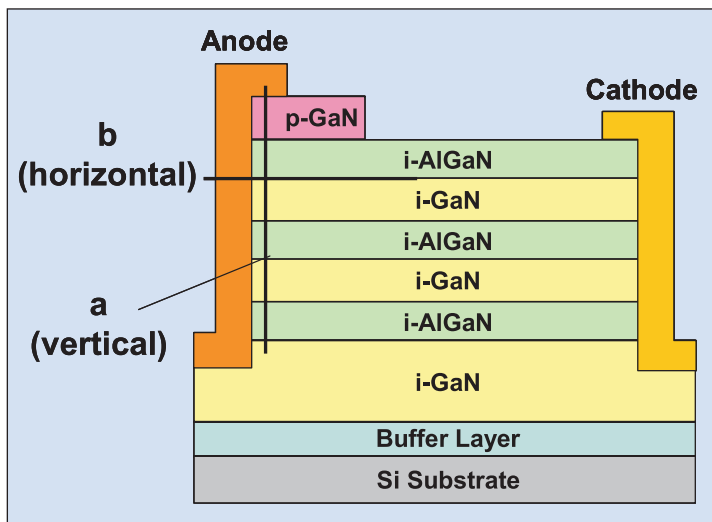
Wide-ranging experiments and simulations were carried out. The 2kV breakdown figure was obtained with



**Figure 3. Schematic diagrams of IMEC/KUL/UG's (a) STAD and (b) LRSD DHEFT devices.  $L_{DO}$  = trench overlap with drain contact;  $L_{CO}$  = trench overlap with channel.**

a device with gate-drain distance of  $20\mu\text{m}$ . The trench had an  $8\mu\text{m}$  overlap with the channel. High-temperature operation at  $100^\circ\text{C}$  showed three-orders-of-magnitude lower buffer leakage current with STAD, compared with devices that have no trench.

GaN and silicon carbide (SiC) diodes were also presented. Panasonic [session 26.2] has added a p-type barrier controlling layer (BCL) to its 'natural super junction' (NSJ) nitride semiconductor diode structure to



**Figure 4. Schematic cross section of Panasonic's GaN-based NSJ diodes with p-GaN BCL to suppress the reverse leakage current.**

reduce reverse leakage currents, allowing the breakdown voltage to be increased to 600V (Figure 4). Simulations suggest the effect of the BCL is to reduce carrier concentration in the channel near the anode sidewall at zero bias and to create complete depletion under reverse bias.

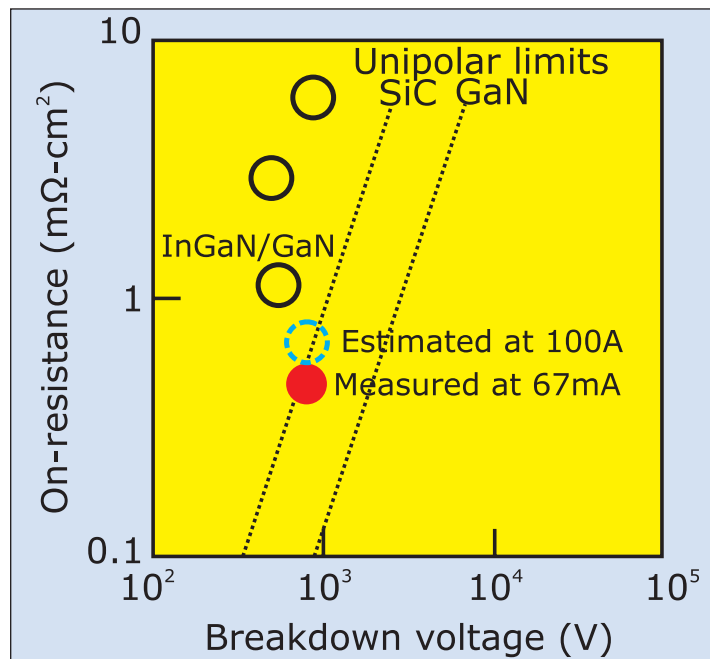
The diode material consists of three pairs of undoped AlGaIn/GaN layers grown on an undoped GaN/AlN buffer on silicon substrate. The deposition technique was MOCVD. The anode metal combination was nickel/gold and the cathode titanium/aluminum.

The forward current at 1.5V was 18A. The product of the on-resistance with the diode's capacitance was  $70\text{p}\Omega\text{F}$ , which is better than that of a comparison SiC Schottky barrier diode's  $95\text{p}\Omega\text{F}$ . The device has also less recovery loss compared with silicon fast-recovery diodes based on pn junctions.

The researchers combined their device with a gate-injection transistor (GIT) in a boost-converter circuit. The circuit demonstrated a peak conversion efficiency of 98% at 600W output power at 100kHz. This value beat that of GIT circuits using SiC or Si diode drivers.

Hitachi Ltd, Hosei University and Hitachi Cable Ltd have been developing more traditional GaN pn diodes with low on-resistance achieved through use of photon-recycling [session 26.3]. The breakdown voltage of a device with a  $20\mu\text{m}$ -radius anode was 700–800V and the on-resistance was extremely low, at about  $0.5\text{m}\Omega\text{-cm}^2$  at 5V over the 273–373K temperature range.

The photon recycling consists of using light generated in electron-hole recombination to regenerate hole densities, overcoming the poor p-type conductivity usually found with magnesium-doped GaN and thus enhancing conductivity. The light generation is encouraged by restricting the anode contact through constructing circular mesas, increasing current density. By constructing devices with arrays of anode contacts, the current handling can be increased, hopefully to beyond 100A.



**Figure 5. Comparison of measured and estimated on-resistances of Hitachi's fabricated GaN p-n diodes with reported on-resistances of GaN p-n diodes and p-InGaIn/n-GaN diodes formed on GaN free-standing substrates. Dotted lines show on-resistance limits of 4H-SiC and GaN unipolar diodes.**

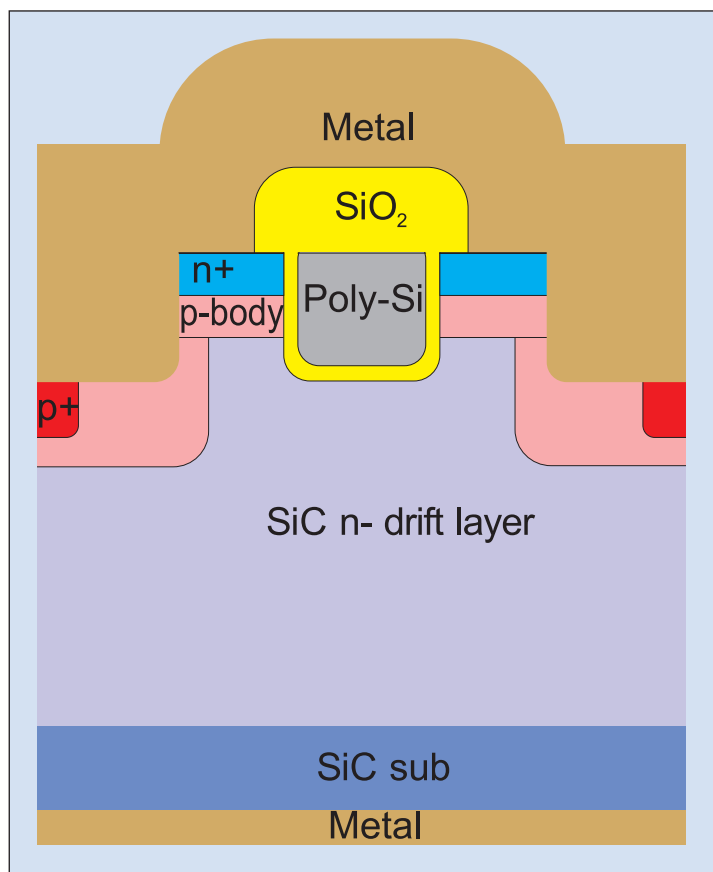
The measured devices had on-resistance and breakdown values near the unipolar 4H-polytype SiC limit (Figure 5). The researchers see potential application in fast, high-voltage freewheeling diodes.

Rohm presented research on SiC Schottky diodes and MOSFETs. In both cases, trench structures are used to improve performance [session 26.5].

To decrease the forward voltage of the diode, the barrier height was lowered. The trench is used to reduce the electric field at the Schottky interface, reducing the leakage under reverse bias. Devices without (planar) and with trenches were produced: the barrier without the trench was 1.31eV, which was reduced to 0.87eV with the trench. Under 600V reverse bias the leakage in the two devices was similar.

Double trenches (source and gate) were implemented with MOSFETs to address problems with single-trench (gate) devices where the oxide layer degrades at high drain bias (Figure 6). Simulation suggests that one of the effects of having two trenches is to reduce the electric field at the base of the gate trench, reducing oxide degradation. By varying the thickness of the epitaxial drift layer, different blocking voltages and specific on-resistances could be achieved with values approaching the theoretical limit for devices produced in 4H SiC.

Panasonic also reported on the first SiC MOSFET with an integrated unipolar diode (DioMOS) [session 26.6]. The company sees its DioMOS as the most suitable device for high-power circuit operation at elevated temperature without the need for an external inverse diode. ▶



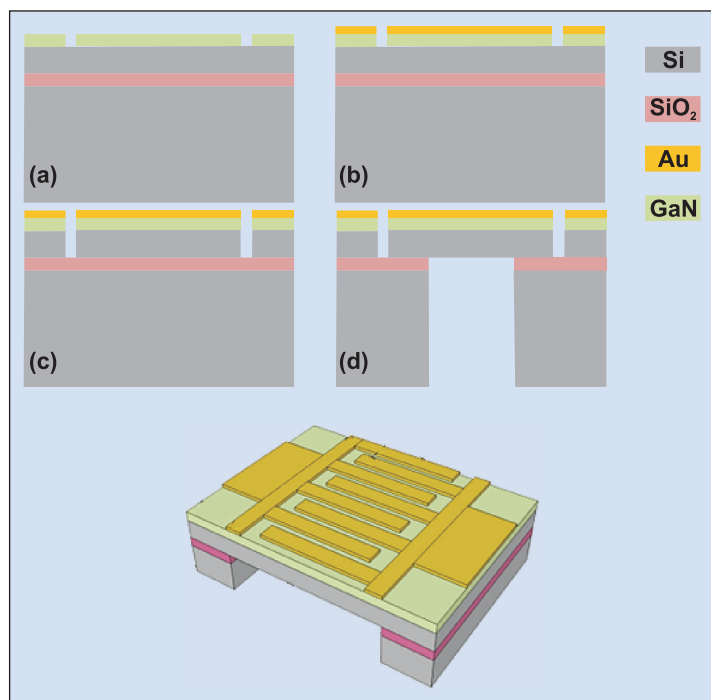
**Figure 6. Schematic cross section of Rohm's 4H-SiC trench MOSFET with source trench and gate trench. Source trench and gate trench are fabricated simultaneously.**

### ► Nitride semiconductor MEMS

In addition to its semiconductor properties, GaN is also highly piezoelectric due to the partly ionic nature of the bond between its components, raising the possibility of its use in micro-electro-mechanical systems (MEMS). Piezoelectricity is the effect of stress creating internal electric fields in a material. The reverse process is the application of electric fields to GaN epitaxial layers to induce mechanical changes.

University of Michigan and Nitronex Corp presented the first high-performance GaN-on-Si micromechanical resonators and filters [session 20.3]. A quality factor of 1850 was achieved at 802.5MHz, giving an  $fxQ$  of  $1.5 \times 10^{12} \text{Hz}$ , twice the highest value previously reported for such devices. "The effective coupling coefficient for the GaN resonator is extracted to be 1.7%, which is among the best reported in the literature," the researchers comment.

GaN has the advantage of an acoustic velocity close to that of silicon over other materials used for thin-film piezoelectric on silicon (TPoS) resonators such as AlN, zinc oxide or PZT (lead zirconate titanate). As with light, this means reduced sound reflection at boundaries. These devices are dominated by the silicon layer in terms of acoustic energy density and the material's low acoustic losses.



**Figure 7. Process sequence and schematic of University of Michigan's TPoS filter.**

The epitaxial GaN was metal-organic chemical vapor deposited on silicon-on-insulator (SOI) substrates. The use of SOI rather than bulk silicon results in less built-in stress in the GaN layers, giving a higher-quality film with fewer dislocations.

Fabrication of TPoS devices begins by plasma-enhanced chemical vapor deposition of 50nm silicon nitride that is patterned (Figure 7). Various etch and metal deposition

**University of Michigan and Nitronex Corp presented the first high-performance GaN-on-Si micromechanical resonators and filters. The effective coupling coefficient for the GaN resonator is extracted to be 1.7%, which is among the best reported in the literature... Since the etched sidewall profiles of the devices are not smooth, there are opportunities for performance improvement**

steps are carried out to create the TPoS structure.

Film bulk acoustic resonators (FBARs) were also fabricated on the same substrate that had an unloaded  $Q$  value of 424 at 2.1GHz, giving an  $fxQ$  of  $0.89 \times 10^{12} \text{Hz}$ .

The researchers believe that, since the etched sidewall profiles of the devices are not smooth, there are opportunities for performance improvement through process optimization. ■

*The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.*





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## Index

- |  |   |
|--|---|
| <b>1 Bulk crystal source materials p98</b>         | <b>14 Chip test equipment p102</b>              |
| <b>2 Bulk crystal growth equipment p98</b>         | <b>15 Assembly/packaging materials p102</b>     |
| <b>3 Substrates p98</b>                            | <b>16 Assembly/packaging equipment p102</b>     |
| <b>4 Epiwafer foundry p99</b>                      | <b>17 Assembly/packaging foundry p103</b>       |
| <b>5 Deposition materials p99</b>                  | <b>18 Chip foundry p103</b>                     |
| <b>6 Deposition equipment p100</b>                 | <b>19 Facility equipment p103</b>               |
| <b>7 Wafer processing materials p101</b>           | <b>20 Facility consumables p103</b>             |
| <b>8 Wafer processing equipment p101</b>           | <b>21 Computer hardware &amp; software p103</b> |
| <b>9 Materials and metals p101</b>                 | <b>22 Used equipment p103</b>                   |
| <b>10 Gas &amp; liquid handling equipment p101</b> | <b>23 Services p103</b>                         |
| <b>11 Process monitoring and control p101</b>      | <b>24 Consulting p103</b>                       |
| <b>12 Inspection equipment p102</b>                | <b>25 Resources p103</b>                        |
| <b>13 Characterization equipment p102</b>          |   |

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Tel: +1 215 784 6000  
Fax: +1 215 784 6001  
**www.kns.com**

**Palomar Technologies Inc**

2728 Loker Avenue West,  
Carlsbad,  
CA 92010,  
USA  
Tel: +1 760 931 3600  
Fax: +1 760 931 5191  
**www.PalomarTechnologies.com**

**TECDIA Inc**

2700 Augustine Drive, Suite 110,  
Santa Clara,  
CA 95054,  
USA  
Tel: +1 408 748 0100  
Fax: +1 408 748 0111  
**www.tecdia.com**



Tecdia is a **TECDIA** manufacturer of single-layer chip capacitors, chip resistors, DC boards, bias-Ts, diamond scribing tools and dispensing nozzles.

## 17 Assembly/packaging foundry

### Quik-Pak

10987 Via Frontera,  
San Diego, CA 92127,  
USA  
Tel: +1 858 674 4676  
Fax: +1 8586 74 4681  
[www.quikicpak.com](http://www.quikicpak.com)

## 18 Chip foundry

### Compound Semiconductor Technologies Ltd

Block 7, Kelvin Campus,  
West of Scotland, Glasgow,  
Scotland G20 0TH,  
UK  
Tel: +44 141 579 3000  
Fax: +44 141 579 3040  
[www.compoundsemi.co.uk](http://www.compoundsemi.co.uk)

### United Monolithic Semiconductors

Route departementale 128,  
BP46, Orsay, 91401,  
France  
Tel: +33 1 69 33 04 72  
Fax: +33 169 33 02 92  
[www.ums-gaas.com](http://www.ums-gaas.com)

## 19 Facility equipment

### MEI, LLC

3474 18th Avenue SE,  
Albany, OR 97322-7014,  
USA  
Tel: +1 541 917 3626  
Fax: +1 541 917 3623  
[www.marlerenterprises.net](http://www.marlerenterprises.net)

## 20 Facility consumables

### W.L. Gore & Associates

401 Airport Rd,  
Elkton, MD 21921-4236,  
USA  
Tel: +1 410 392 4440  
Fax: +1 410 506 8749  
[www.gore.com](http://www.gore.com)

## 21 Computer hardware & software

### Ansoft Corp

4 Station Square, Suite 200,  
Pittsburgh, PA 15219,  
USA  
Tel: +1 412 261 3200  
Fax: +1 412 471 9427  
[www.ansoft.com](http://www.ansoft.com)

### Crosslight Software Inc

121-3989 Henning Dr.,  
Burnaby, BC, V5C 6P8,  
Canada  
Tel: +1 604 320 1704  
Fax: +1 604 320 1734  
[www.crosslight.com](http://www.crosslight.com)

### Semiconductor Technology Research Inc

10404 Patterson Ave., Suite 108,  
Richmond, VA 23238,  
USA  
Tel: +1 804 740 8314  
Fax: +1 804 740 3814  
[www.semitech.us](http://www.semitech.us)

## 22 Used equipment

### Class One Equipment Inc

5302 Snapfinger Woods Drive,  
Decatur, GA 30035,  
USA  
Tel: +1 770 808 8708  
Fax: +1 770 808 8308  
[www.ClassOneEquipment.com](http://www.ClassOneEquipment.com)

### Brumley South Inc

422 North Broad Street,  
Mooresville,  
NC 28115,  
USA  
Tel: +1 704 664 9251  
Fax: +1 704 664 9246  
[www.brumleysouth.com](http://www.brumleysouth.com)

As an ISO 9001 registered global leader in the remanufacturing of wafer inspection systems, Brumley South Inc specializes in designing, installing and supporting upgrades for ADE, Nanometrics, Dryden and KLA-Tencor Surfscan tools, polystyrene latex sphere calibration standards, particle deposition systems, and semiconductor parts and service.



## 23 Services

### Henry Butcher International

Brownlow House, 50-51  
High Holborn,  
London WC1V 6EG,  
UK  
Tel: +44 (0)20 7405 8411  
Fax: +44 (0)20 7405 9772  
[www.henrybutcher.com](http://www.henrybutcher.com)

### M+W Zander Holding AG

Lotterbergstrasse 30,  
Stuttgart,  
Germany  
Tel: +49 711 8804 1141  
Fax: +49 711 8804 1950  
[www.mw-zander.com](http://www.mw-zander.com)

### TECDIA Inc

(see section 16 for full contact details)

## 24 Consulting

### Fishbone Consulting SARL

8 Rue de la Grange aux Moines,  
78460 Choisel,  
France  
Tel: + 33 (0)1 30 47 29 03  
E-mail: [jean-luc.ledys@neuf.fr](mailto:jean-luc.ledys@neuf.fr)

## 25 Resources

### SEMI Global Headquarters

3081 Zanker Road,  
San Jose, CA 95134, USA  
Tel: +1 408 943 6900  
Fax: +1 408 428 9600  
[www.semi.org](http://www.semi.org)

### Yole Développement

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[www.yole.fr](http://www.yole.fr)

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**7–9 February 2012**

## Strategies in Light 2012 Conference & Expo

Santa Clara Convention Center, CA, USA

**E-mail:** [LubaH@pennwell.com](mailto:LubaH@pennwell.com)

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

**7–9 February 2012**

## LED/SEMICON Korea 2012

COEX, Seoul, Korea

**E-mail:** [semiconkorea@semi.org](mailto:semiconkorea@semi.org)

[www.led-korea.org/en\\_eshim@semi.org](http://www.led-korea.org/en_eshim@semi.org)

**12–16 February 2012**

## SPIE Advanced Lithography 2012

San Jose, CA, USA

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)

<http://spie.org/advanced-lithography.xml>

**22 February 2012**

## LED Focus and Market Analytics (euroLED kicker event)

Birmingham, UK

**E-mail:** [info@euroled.org.uk](mailto:info@euroled.org.uk)

<http://ledfocusandmarketanalytics.eventbrite.co.uk>

**4–8 March 2012**

## Optical Fiber Communication Conference and Exhibition/National Fiber Optic Engineers Conference (OFC/NFOEC 2012)

Los Angeles Convention Center, CA, USA

**E-mail:** [info@ofcconference.org](mailto:info@ofcconference.org)

[www.ofcnfoec.org](http://www.ofcnfoec.org)

**18–19 March 2012**

## China Semiconductor Technology International Conference (CSTIC 2012)

Kerry Hotel Pudong, Shanghai, China

**E-mail:** [cstic@semi.org.cn](mailto:cstic@semi.org.cn)

<http://semiconchina.semi.org/cstic>

**19 March 2012**

## Oxford Instruments 'Nanoscale Plasma Processing' one-day workshop

Shanghai, China

**E-mail:** [process.news@oxinst.com](mailto:process.news@oxinst.com)

[www.oxford-instruments.com](http://www.oxford-instruments.com)

**20–22 March 2012**

## SEMICON China 2012

Shanghai New International Expo Centre (SNIEC), China

**E-mail:** [semichina@semi.org](mailto:semichina@semi.org)

[www.semiconchina.org](http://www.semiconchina.org)

**20–22 March 2012**

## LASER World of PHOTONICS CHINA

Shanghai New International Expo Centre (SNIEC), China

**E-mail:** [laser@mimi-shanghai.com](mailto:laser@mimi-shanghai.com)

[www.world-of-photonics.net/en/laser-china/start](http://www.world-of-photonics.net/en/laser-china/start)

## advertisers' index

Advertiser	Page no.	Advertiser	Page no.
Aixtron AG	5	Oxford Instruments-TDI	37
CrystAl-N	39	Plasma-Therm	19 & 21
EV Group	41	RIFF Company	53
Evatec	43	Tecdia	97
III/V-Reclaim	28	Temescal	45
Insaco	53	Veeco Instruments — MBE	15
IQE	25	Veeco Instruments — MOCVD	2
k-Space	61	Wafer Technology	31
LayTec	33	Wafer World	29
Oxford Instruments Plasma Technology	35		

**21–23 March 2012****7th Asia Solar Photovoltaic Industry Exhibition**

Shanghai Expo Theme Pavilion, China

**E-mail:** info@aexpo.com.cn**www.asiasolar.cc/en****25–30 March 2012****8th conference on Porous Semiconductors - Science and Technology (PSST-2012)**

Hotel Monte Malaga, Spain

**E-mail:** info@the-psst.com**www.the-psst.com****2–4 April 2012****Semiconductor and Integrated Opto-Electronics Conference (SIOE'12)**

Cardiff University, Wales, UK

**E-mail:** K.A.Shore@bangor.ac.uk**www.astro.cardiff.ac.uk/research/pm/events/?page=sioe****9–13 April 2012****2012 MRS Spring Meeting**

San Francisco, CA, USA

**E-mail:** info@mrs.org**www.mrs.org/spring2012****15–19 April 2012****IEEE International Reliability Physics Symposium (IRPS-2012)**

Hyatt Regency Orange County, Anaheim, CA, USA

**E-mail:** yuan.chen@nasa.gov**www.irps.org****15–20 April 2012****Light+Building 2012**

Frankfurt am Main, Germany

**http://light-building.messefrankfurt.com****16–18 April 2012****12th European Advanced Process Control and Manufacturing Conference (APCM 2012)**

MINATEC, Grenoble - France

**E-mail:** weber@apcm-europe.eu**www.apcm-europe.eu****16–18 April 2012****CPV-8 International Conference on Concentrating Photovoltaic Systems**

Toledo, Spain

**E-mail:** iinfo@cpv-8.org**www.cpv-8.org/cms****16–20 April 2012****SPIE Photonics Europe 2012**

The Square Conference Center, Brussels, Belgium

**http://spie.org/photonics-europe.xml****17–19 April 2012****7th Annual Photovoltaics Summit**

The Westin Hotel, San Diego, CA, USA

**E-mail:** info@pira-international.com**www.photovoltaicssummit.com****18–20 April 2012****16th European Conference on Integrated Optics (ECIO 2012)**

Hotel Melia Sitges, Barcelona, Spain

**E-mail:** ecio2012@icfo.es**www.ecio2012.com****19–20 April 2012****4th Photovoltaics Thin-Film Week, including:****4th Thin-Film Industry Forum (TIF 2012)**

Berlin, Germany

**E-mail:** info@solarpraxis.de**www.solarpraxis.de/en/conferences****23 April 2012****JEDEC's 27th Annual ROCS (Reliability of Compound Semiconductors) Workshop**

The Boston Park Plaza Hotel, Boston, MA, USA

**E-mail:** ptanner@jedec.org**www.jedec.org/home/gaas****23–26 April 2012****2012 CS MANTECH:****International Conference on Compound Semiconductor Manufacturing Technology**

The Boston Park Plaza Hotel, Boston, MA, USA

**E-mail:** csmantech@csmantech.org**www.csmantech.org****23–27 April 2012****SPIE Defense, Security, and Sensing 2012**

Baltimore, MD, USA

**E-mail:** customerservice@spie.org**http://spie.org/defense-security.xml****28 April – 3 May 2012****2012 SVC TechCon:****55th Society of Vacuum Coaters Annual Technical Conference**

Santa Clara Convention Center, CA, USA

**E-mail:** svcinfo@svc.org**www.svc.org/ConferencesExhibits/Future-Meetings.cfm****6–11 May 2012****221st Electrochemical Society (ECS) Meeting**

Seattle, Washington

**E-mail:** meetings@electrochem.org**www.electrochem.org/meetings/biannual/fut\_mtgs.htm**



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