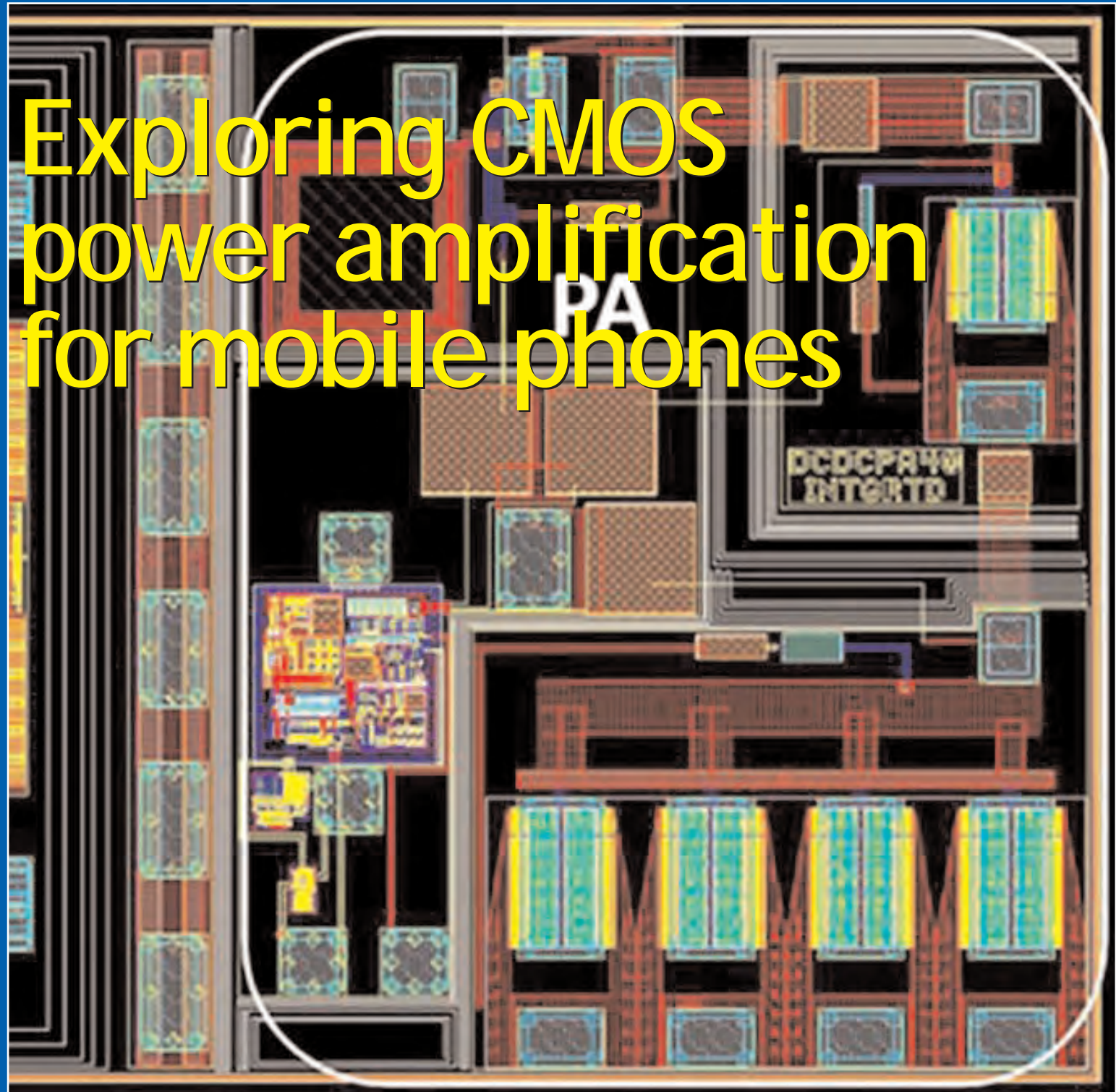


# semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

Vol. 8 • Issue 5 • June/July 2013

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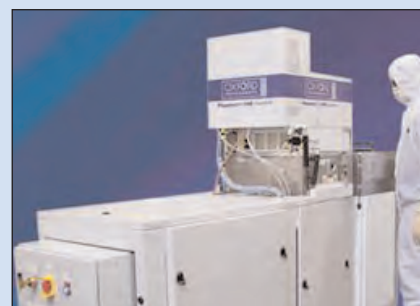
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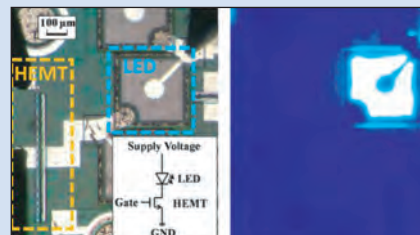
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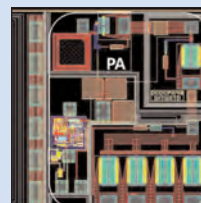
**p10** RF Micro Devices' UK GaAs fab in Newton Aycliffe, County Durham, which it is selling to Phoenix-based Compound Photonics.



**p36** OIPT has launched the PlasmaPro100 Sapphire single-wafer etch system for HBLED wafers up to 200mm in diameter.



**p54** Rensselaer Polytechnic Institute has demonstrated a monolithically integrated LED and HEMT on the same GaN chip, pictured with the LED off (left) and on (right).



Cover: Research at RFMD has produced a three-stage power amplifier (PA) in a CMOS silicon chip with integrated DC-DC buck converter measuring 3.2mm x 1.9mm (with the converter section measuring 1.15mm x 1.9mm).

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## Developments in RF CMOS, and LED market recovery

The feature article in this issue (pages 92–95) looks at how close CMOS silicon is to compound semiconductors in terms of performance for use in power amplifiers (PAs) for mobile phone applications.

RF CMOS on silicon-on-insulator substrates (RF SOI) has already been successful in making inroads into the formerly gallium arsenide-based preserve of the antenna switch function. According to market research firm Yole Développement, more than 65% of substrates used in fabricating switches for handsets are now SOI-based (see page 18). Indeed, such a trend has already been a factor in RF Micro Devices divesting its UK-based GaAs fab in Newton Aycliffe, which focused on GaAs pHEMTs (e.g. for switch applications). RFMD has now agreed to sell the fab to Phoenix-based Compound Photonics, which will use the fab to make diode lasers (see page 10).

More recently, CMOS-based firm Qualcomm caused a stir by announcing plans for a CMOS power amplifier. While this could be a threat to the incumbent GaAs-based PA manufacturers, it should be noted that many of the main GaAs PA makers have CMOS PA developments (as detailed in the article), some gained through acquisition of dedicated CMOS PA start-up companies.

Meanwhile, on page 15, we report how market analyst firm Research in China expresses the opinion that Qualcomm is developing its CMOS PA largely to complement and bolster its core baseband business, forestalling competition from Samsung over baseband business with 'white-box' mobile-phone makers such as those in China.

Meanwhile, in the LED sector, GaN LEDs (which now account for 85% of total LED revenue) will surpass shipments of 100 billion units in 2013, forecasts market analyst firm IMS Research (see page 6). In particular, according to LEDinside on page 8, the utilization rates of MOCVD reactors at Chinese LED makers has been recovering, driven by strong demand in the global LED lighting market in first-half 2013 (more than compensating for the slowdown of LED sales for display applications since 2012). LEDinside says that the growing MOCVD utilization rates are now boosting the confidence of makers to expand production, with manufacturers that had delayed expansion plans due to the poor market now having restarted their programs. The number of MOCVD systems in China reached 1013 in late 2012, and is estimated to rise by more than 100 new systems in 2013 (in terms of the number of chambers). Although MOCVD overcapacity still exists in China, many of the systems bought previously (and often unused) are now lagging behind more recent equipment in performance and efficiency. Such obsolescence will help to bring supply and demand back into balance, LEDinside reckons.

These recent market developments help MOCVD system makers Aixtron and Veeco to recover from their trough in orders over the last year or so. Indeed, as we close for press, their second-quarter 2013 financial results are being issued, accompanied by multi-reactor orders from Chinese LED makers. Such news will be detailed in our next issue.

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**Semiconductor Today covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices**

(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).

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- feature articles (technology, markets, regional profiles);
- conference reports;
- event calendar and event previews;
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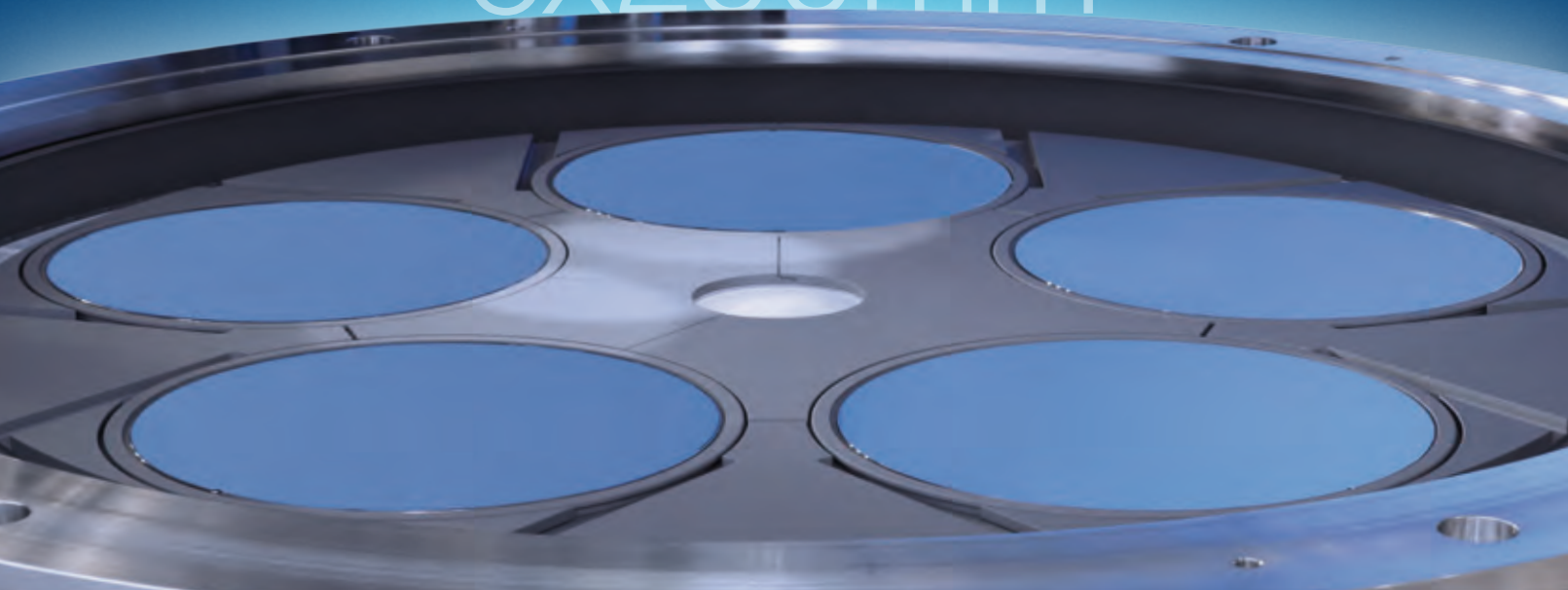
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## GaN LED shipments to exceed 100 billion units in 2013, tripling since 2009

**GaN accounts for 85% of total LED market; GaN LEDs to match \$10bn revenue achieved by entire LED market in 2010**

More than 100 billion gallium nitride light-emitting diodes will ship in 2013, according to the report 'Q2 GaN LED Supply and Demand' from IMS Research (now part of IHS Inc).

With mobile phones typically containing five or 10 LEDs and televisions incorporating LEDs numbering up to the hundreds, LED consumption is clearly accelerating, says the market analyst firm. In particular, GaN LEDs account for 85% of total revenue in the LED industry, dominating key applications such as TVs and lighting.

Revenue for GaN LEDs this year will pass the \$10bn mark, notes Jamie Fox, principal analyst for Lighting and LEDs at IHS. "If we consider the total LED market — including AlInGaP, GaN and other LED types — the \$10bn revenue and the 100 billion unit shipment levels were actually reached in 2010. But now in 2013, both of these thresholds are predicted to be attained by the GaN LED market alone, showing how large the segment has become," he adds.

The GaN LED market has grown tremendously in recent years. Revenue in 2013 is forecast to double from that of only four years ago, while unit shipments this year will have more than tripled since 2009.

However, growth on an annual basis has been fairly uneven.

In 2010, for instance, the annual revenue increase was the largest by far in the history of the LED industry, but revenue was flat the year after. Growth then returned in 2012, climbing 15%. This year, revenue

is forecast to be flat once again or see very little expansion, but the market can take comfort in industry total takings of \$10.2bn.

Another strong growth year is predicted in 2014 via general lighting along with other applications such as TVs and tablets. Then, growth will slow after next year, with the double-digit revenue increases typical of years past harder to come by, forecasts IMS Research.

Within the GaN LED space, the market this year for GaN LEDs in lighting is projected to reach \$3.4bn, on its way to \$6.7bn by 2016. In contrast, the market for GaN LEDs in TVs will start declining as manufacturers reduce the number of LEDs used per TV in the face of newer technology requiring fewer LEDs. From \$2.1bn this year, revenue for GaN LEDs in TVs will contract 7% on average each year during the next several years.

A number of challenges will be in store for the LED market moving forward, says IMS. Despite the strong annual growth of recent years, overcapacity, tough competition and declining profit margins at some companies have been nipping at the industry. Also, as the market matures, players will find it increasingly tougher to survive and thrive, even as good opportunities exist for those with the appropriate product and business model, the market research firm believes.

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

## Smartphones to account for nearly half of both 802.11ac and 802.11ad chipset shipments in 2018

For devices conforming to the IEEE standards 802.11ac and 802.11ad, with 802.11ac exploding into devices (including smartphones) from the start, while 802.11ad will see a more modest and staggered growth, forecasts ABI Research.

802.11ac is being pushed into smartphones by key carriers' device requirements in sync with hotspot plans for more robust Wi-Fi offloading. "The push towards 11ac adoption overpowers the minor additional cost of dual-band 11n/11ac chipsets," says ABI's Philip Solis. "We will likely see 2x2 802.11ac implementations in smartphones in a few years."

The proportion of 802.11ac-enabled products will remain steady, with smartphones making up 40% of those in 2013 and 46% in 2018, where over 3.5 billion Wi-Fi chipsets with 802.11ac will ship. The Wi-Fi Alliance is about to start certification of products using the protocol, yet shipments have started and should reach hundreds of millions this year. 802.11ac pushes Wi-Fi more towards the 5GHz spectrum, which is cleaner and allows the much larger channel sizes that enable greater speeds and capacity.

802.11ad will phase from larger to smaller products, starting from peripherals and larger non-handset mobile devices and shift to smaller and thinner devices over time. It will make its way into smartphones in 2015, changing the proportion of 802.11ad-enabled products.

Smartphones will account for nearly half of 802.11ad-enabled products in 2018, but with less than half the volume in smartphones compared to 802.11ac. Even so, over 1.5 billion chipsets with 11ad will ship in 2018. 802.11ad pushes Wi-Fi into higher-speed, lower-power personal area networking that will be used simultaneously with other Wi-Fi protocols.

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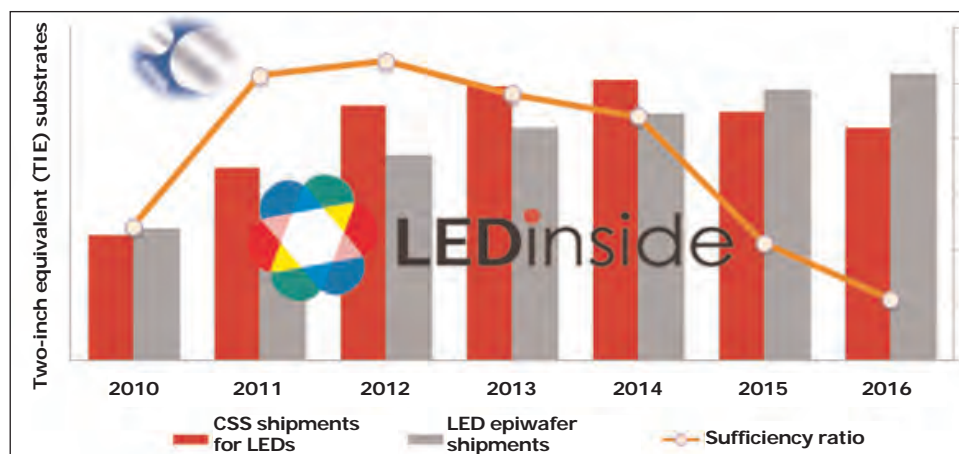
# Sapphire substrates to face another growth peak, driven by emerging demand from handset market

## Price declines slowed by rising demand from LED chip makers, but oversupply to be resolved by non-LED applications

According to the latest '2013 Global Sapphire Substrate Market Report' published by the LEDinside research department of market research institute TrendForce, sapphire substrate manufacturers are optimistic about the emerging demand for non-LED market applications in 2013 such as handset device applications, silicon-on-sapphire (SOS), and window films. With such prospects in the future, there are still many manufacturers fighting over the non-LED applications, with plans for production despite the low market prices, the firm adds.

Due to oversupply, sapphire substrate quality requirements from LED epiwafer manufacturers have risen, notes LEDinside. Existing LED makers are more willing to use sapphire ingots grown by the Kyropoulos (KY) method, so it has become even more difficult for most new-comers to enter the LED supply chain. Therefore, except for first-tier manufacturers, the utilization rates of most sapphire ingot manufacturers have been below 50%. However, since the introduction of sapphire for camera lenses in Apple's iPhone5, demand for sapphire substrates from non-LED applications has begun digesting part of the excess production, bringing the sapphire substrate industry into a virtuous cycle.

LEDinside estimates that the oversupply ratio for sapphire substrates in 2013 has been as high as 18% compared to demand from LED epiwafer manufacturers. However, it does show some sign of convergence compared to the 24% oversupply ratio in 2012. Looking ahead to the next few years, the issue of oversupply will not be solved anytime soon, says LEDinside, yet sapphire substrate manufacturers remain optimistic about non-LED market applications in 2013



Estimated gap between supply and demand for sapphire substrates for LEDs, in terms of two-inch equivalent (TIE) substrates.

(such as SOS, window films, and handset device applications) such that they have planned production expansions, with the hope that emerging non-LED applications can digest the production capacity. In addition to demand for camera lenses, if in the future the cover glass of smart-phones is replaced by sapphire, this will create enormous demand, which may lead to a shortage in sapphire substrate supply, reckons the firm.

### Sapphire substrate price decline slows as LED chip makers' utilization rates rise

Benefiting from demand from the lighting and backlight markets in first-half 2013, LED chip makers have raised their utilization rates, boosting demand for sapphire substrates. Price declines for 2-inch and 4-inch sapphire substrates have slowed in first-quarter 2013, while there are even some signs of certain low market prices rebounding slightly, says the report. For example, the price for 2-inch conventional sapphire substrate (CSS) has returned to US\$6.8–7, while the price for 4-inch CSS has stayed steady at US\$30–35. Although LED chip makers have consistently increased their 4-inch sapphire

substrate production ratio and hence increased the demand for 4-inch sapphire substrate, there is room for sapphire substrate manufacturers to make a profit, says LEDinside. The recent 4-inch sapphire substrate price has hence remained stable.

LEDinside comments that the sapphire substrate industry's large production expansion over the last two years caused the oversupply situation in the industry. However, it is still difficult to solve the oversupply problem in the short term if sapphire substrate capacity is digested only by LED applications. Non-LED market demand has hence generally been attracting much attention. As can be seen in the expansion plans of every sapphire substrate manufacturer in 2013, most are increasing capacity for non-LED applications. Generally speaking, mergers and acquisitions are still happening in the sapphire substrate industry, notes LEDinside. However, with non-LED market demand rising, there might be a chance of seeing another boom in the sapphire substrate market, as happened in 2010, the firm reckons.

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

# China's MOCVD activity rebounds with positive LED lighting market outlook

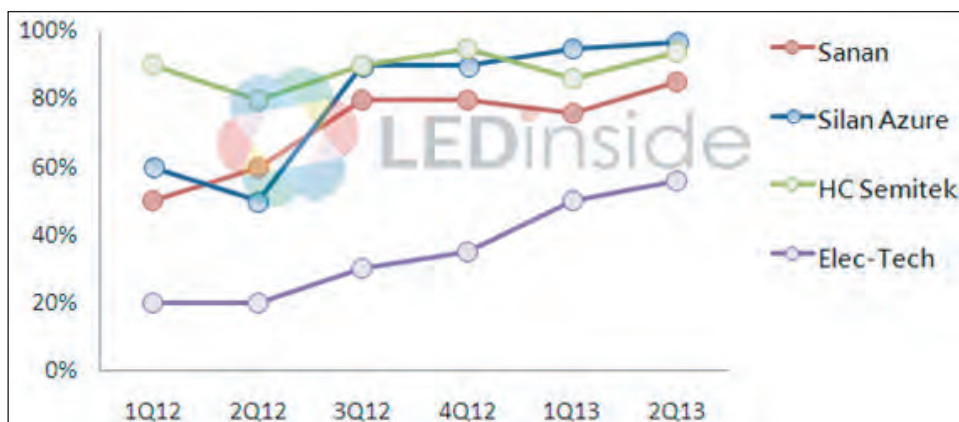
## Chip makers shifting from LED displays; 1013 systems in China to be boosted by more than 100 in 2013

Due to strong demand in the global LED lighting market in first-half 2013, the utilization rate of metal-organic chemical vapour deposition (MOCVD) systems that the major chip makers have installed and debugged is rising, according to statistics in the Gold membership reports of LEDinside (a division of market research firm TrendForce).

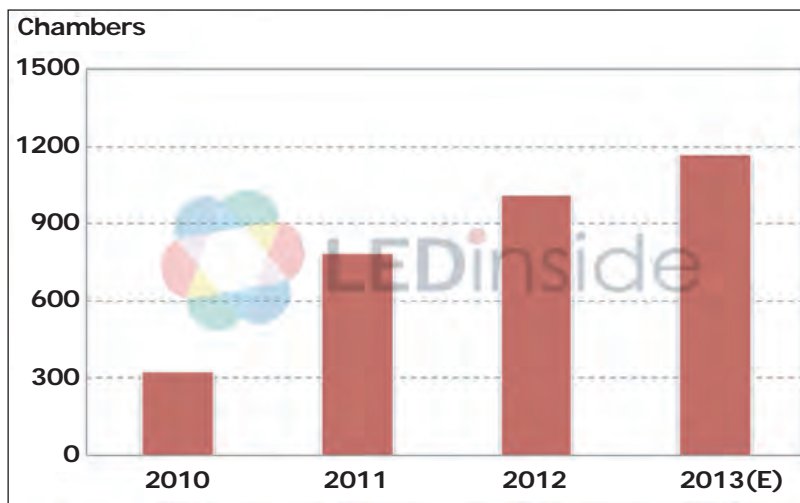
Chip prices have been stable this year but, with the increasing capacity of chip makers, it remains to be seen whether LED chip prices will fall in second-half 2013. However, in the long term, only the termination of invalid production capacity in China can help the LED industry return to a balance in supply and demand, says LEDinside.

The rise of the LED lighting market has directly stimulated rapid growth in demand in the upstream chip market this year, with Chinese chip makers that originally specialized in production for display applications actively adjusting their product strategies and boosting the ratio of lighting chips in the product segment. Both HC SemiTek and Silan Azure previously had chips for LED displays as their core business, but now they have adjusted production capacity in response to increasing market demand for LED lighting chips; all newly added MOCVD systems are put into use producing chips for lighting. Overall, growth in the display market has slowed since 2012, making it more competitive and more difficult for manufacturers to make profit, which is also one of the reasons why chip makers have switched to producing LED chips for lighting applications.

Sanan Optoelectronics owns 149 MOCVD systems in total. Currently, more than 90% of these have completed testing and have been put into operation, and the utilization rate exceeds 80%. As of first-half 2013,



MOCVD utilization rates trend (URT) for major Chinese LED chip makers.



Installed MOCVD volume (reaction chambers) in China.

Elec-Tech International (ETI) has 92 MOCVD systems, 45 of which have been put into use for mass production. The firm is second in China in terms of both the number installed and the number in mass production. Due to having fewer MOCVD systems, those of both HC SemiTek and Silan Azure have already fully come into use. Other chip vendors have also achieved growth in utilization rates for their equipment.

LEDinside says that the growth in MOCVD utilization rates is boosting the confidence of manufacturers to expand production; manufacturers that delayed expansion plans due to the poor market have restarted their programs. According to statis-

tics in LEDinside's Gold membership report, the number of systems in China reached 1013 in late 2012, and it is estimated that in 2013 China will

add more than 100 new MOCVD systems (calculated according to the number of chambers).

In view of the current total number of MOCVD systems in mainland China, overcapacity still exists, notes LEDinside. However, looking carefully, many manufacturers have not put their newly added equipment into operation since it was installed, and most systems are old; performance and efficiency are far lower than that for the new systems. These invalid capacities may exit the market after 2013, which will help the market return to a balance in supply and demand, concludes LEDinside.

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# RFMD selling UK GaAs fab to Compound Photonics

## Projection light engine producer to make green, red & infrared lasers

Radio-frequency component and compound semiconductor company RF Micro Devices Inc of Greensboro, NC, USA has agreed to sell its gallium arsenide (GaAs) fabrication plant in Newton Aycliffe, County Durham, UK (Europe's largest GaAs manufacturing facility) to Compound Photonics of Phoenix, AZ, USA. Terms of the transaction have not been disclosed.

In March, to "increase manufacturing flexibility, expand gross margin, and support aggressive growth", RFMD announced a new GaAs sourcing strategy involving phasing out manufacturing in its GaAs pseudomorphic high-electron-mobility transistor (pHEMT) fabrication plant in Newton Aycliffe and transition most GaAs manufacturing to its heterojunction bipolar transistor (HBT) fab in Greensboro. The Newton Aycliffe GaAs pHEMT fab had been RFMD's primary source for cellular switches, which RFMD has transitioned to higher-performance, lower-cost silicon-on-insulator (SOI). It said at the time that the transition would occur over the following 9–12 months to support existing millimeter-wave customer contracts.

The transaction and product transition related to the divestment of the Newton Aycliffe fab are expected to provide RFMD \$20m in annual cost savings (\$5m per quarter). The firm expects to realize the full benefit of savings beginning in the December quarter.

Compound Photonics says that it will use the 53 acre site and 50,000ft<sup>2</sup> GaAs wafer fab to manufacture wavelength-stabilized red and infrared laser diodes and green frequency-doubled lasers. The lasers will be used as illumination sources in the firm's miniature high-definition 1080p projectors for smartphones, tablets and other mobile devices, as well as ultra-high-definition 4K projectors and automotive head-up displays.



The Newton Aycliffe fab.

Wavelength-stabilized infrared lasers for emerging gesture recognition applications will also be manufactured using wafer-scale production methods.

The Newton Aycliffe fab complements Compound Photonics' 40,000ft<sup>2</sup> semiconductor processing facility in Phoenix, where it manufactures liquid crystal on silicon displays and optics systems for its laser projection light engines.

**Compound Photonics will soon release projector products for mobile devices that are three times brighter and smaller than current state-of-the-art... To achieve these next-generation levels of performance we need to vertically integrate the design and manufacture of the entire light engine. This acquisition will bring in-house the manufacturing capabilities for the lasers required to power these engines**

"Compound Photonics will soon release projector products for mobile devices that are three times brighter and smaller than current state-of-the-art," says president & CEO Jonathan A. Sachs, Ph.D. "To achieve these next-generation levels of performance we need to vertically integrate the design and manufacture of the entire light engine. This acquisition will bring in-house the manufacturing capabilities for the lasers required to power these engines," he adds. "The skilled and experienced people, the fab with its toolset, supply chain, mature processes, and a track record of high-volume production are ready-made for our laser production."

The addition of the systems, 6-inch wafer fabrication equipment and R&D capabilities as well as the manufacturing team (with experience supplying high-volume components to leading mobile phone manufacturers) expands Compound Photonics' capacity and flexibility to meet its aggressive growth plans, the firm says. "In time, this fab could become the largest manufacturer of laser diodes and purpose-built lasers in the world," Compound Photonics adds.

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

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# Anadigics expands small-cell power amplifier family for WCDMA, HSPA, and LTE applications

Broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has launched two power amplifiers (PAs) optimized for WCDMA, HSPA, and LTE small-cell applications, including picocells, enterprise-class femtocells, and high-performance customer premises equipment (CPE). The AWB7122 and AWB7124 operate in the 1805–1880MHz and 728–768MHz frequency bands, respectively.

“Carriers are facing mounting pressure to expand network capacity as wireless data consumption continues to increase rapidly,” says Glenn Eswein, director of product marketing for Infrastructure Products. “By offering a broad portfolio of high-performance ¼-Watt and ½-Watt linear power amplifiers optimized for the most widely used 3G



**Anadigics’ AWB7122 and AWB7124 small-cell power amplifiers.**

and 4G frequency bands, Anadigics enables wireless network equipment manufacturers to meet this infrastructure challenge. These PAs provide distinct design, performance and cost advantages for new infrastructure solutions that must deliver higher data throughput, support wider coverage areas, and consume less power.”

Anadigics’ complete family of

small-cell wireless infrastructure power amplifiers leverage the firm’s InGaP-Plus technology. The AWB7122 and AWB7124 PAs provide 16% and 14.5% efficiency, respectively, to minimize power consumption and offer greater flexibility in the choice of network power sources. Both the AWB7122 and AWB7124 deliver linearity of –47dBc ACPR at +24.5dBm output power and 30dB of RF gain to provide higher data rates with a greater coverage area. The complete family of small-cell power amplifiers is available in a compact, low-profile 7mm x 7mm x 1.3mm surface mount package with integrated RF matching to reduce PCB space requirements, says the firm. Engineering samples of the AWB7122 and AWB7124 are available now for qualified programs.

## ProEfficient-Plus PAs power Samsung’s new Galaxy S 4 Mini

Anadigics is shipping production volumes of its AWT6751 and AWT6755 dual-band ProEfficient-Plus WCDMA power amplifiers (PAs) to Samsung Electronics for multiple devices, including the new Galaxy S 4 Mini. This latest smartphone features a 4.3-inch Super AMOLED display and is more compact than the recently released flagship Galaxy S 4, which leverages Anadigics’ RF solutions for WiFi and cellular connectivity. The Galaxy S 4 Mini also has a 1.7GHz dual-core processor, 8-megapixel camera, and Android 4.2.2 Jelly Bean operating system.

Anadigics says that its ProEfficient-Plus solutions deliver high efficiency in low-power mode for greater talk-time and high-power mode for longer data application use, maximizing battery life in 3G mobile devices such as the Galaxy S 4 Mini. The power amplifiers are offered in highly integrated dual-band configurations that minimize



**Anadigics’ AWT6751 and AWT6755 dual-band ProEfficient-Plus WCDMA power amplifiers**

RF space requirements to provide greater design flexibility.

“Our dual-band ProEfficient-Plus power amplifiers have set the standard for 3G performance and integration by delivering the industry’s highest efficiency across all power levels in compact dual-band packages,” claims Jerry Miller, senior VP of Cellular Products.

“Through close collaboration with Anadigics, Samsung is leveraging these tremendous advantages in the design of the latest generation

of sleek, ultra-thin smartphones that offer exceptional battery life.”

Dual-band ProEfficient-Plus power amplifiers leverage Anadigics’ exclusive InGaP-Plus technology and patented design architectures to provide high performance and integration. The power amplifiers enable greater battery life in mobile devices by delivering high efficiency in low- and high-power modes, as well as low quiescent currents (of 6mA) without the use of a DC/DC converter. ProEfficient-Plus solutions are also compatible with average power tracking (APT) to further increase efficiency and reduce current consumption at medium and low operating powers.

The complete family of dual-band ProEfficient-Plus solutions are offered in compact 3mm x 4mm x 0.9mm packages that feature internal voltage regulation and integrated DC blocks on the RF ports to save valuable PCB space.

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



## Anadigics unveils pre-distortion-optimized PA for more power-efficient small-cell base-stations

GaAs-based broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has introduced a new style of RF power amplifier (PA) optimized to power 3G and 4G small-cell base-stations. Paired with digital or RF pre-distortion systems, the highly integrated designs create easy-to-use solutions that deliver very high efficiencies with the stringent linearity required for WCDMA, HSPA, and LTE networks, the firm claims. The new PAs are also packaged in compact (8mm by 14mm by 1.3mm) surface-mount modules that incorporate circuit components normally required separately.

The first Anadigics product to demonstrate this new power amplifier approach is the ASC7517. Operating in the 2100-2170MHz frequency band, the ACS7517 delivers 1.4W of power using only a 2.85V and 5V supply, while operating with a power efficiency of 28%. Used in a pre-distortion system, the PA supports the stringent adjacent channel level rejection (ACLR) requirements of WCDMA, HSPA, and LTE systems without compromising efficiency. The multi-stage PA also provides 42dB of RF gain, eliminating the need for driver amplifiers.

The ACS7517 uses a Doherty architecture, but does not require negative voltage supplies, separate control voltage for the integrated peaking amplifier, or critical supply sequencing. In addition, the PA does not require voltage adjustments to perform optimally over a wide operating temperature range of -40°C to +85°C. The package integrates both the RF matching and power combining circuit elements to save PCB space and provide a cost-effective solution that is much less complex than a traditional Doherty solution, it is claimed.

"Wireless data use continues to increase rapidly, placing tremendous demands on existing infrastructure networks," notes Glenn Eswein, director of product marketing for wireless infrastructure products at Anadigics. "Many operators are turning to small-cell base stations as a pragmatic solution for capacity-stressed 3G and 4G networks, but power consumption remains a significant concern, especially for multi-band and MIMO [multiple input, multiple output] applications," he adds. "Anadigics' new PA solution, demonstrated by the ASC7517, enables OEMs to develop simpler, smaller and more power-efficient designs using RF linearization techniques, without compromising data rate or linearity performance."

The ASC7517's performance is demonstrated for a Band 1 (2110-2170MHz) small-cell base-station application using the SC1894 adaptive RF power amplifier linearizer (RFPAL) made by Scintera of Sunnyvale, CA, USA. The combined solution delivers 1.25W of linear power, with the PA operating at 27% efficiency. With either a single 20MHz-channel LTE signal or four simultaneous 5MHz-channel-bandwidth WCDMA signals, the solution provides ACLR performance better than -48dBc at rated power.

Engineering evaluation samples of the ASC7517 are available now for qualified programs. Anadigics is also developing other pre-distortion-optimized power amplifiers that will support different frequency bands and output power levels.

Anadigics demonstrated the RF amplifier solution for Band 1 (using its ASC7517 power amplifier and Scintera's SC1894 RFPAL) at the 2013 IEEE MTT-S International Microwave Symposium (IMS) in Seattle, WA, USA (4-6 June).

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

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

### IN BRIEF

#### Samsung selects Anadigics' WiFi front-end ICs for Galaxy Tab 3 family

Anadigics is shipping production volumes of its AWL9280 and AWL9580 WiFi front-end ICs (FEICs) to Samsung Electronics for the new Galaxy Tab 3 family. Available in screen sizes ranging from 7.0" to 10.1", the tablets offer dual-core processors, front- and rear-facing cameras, and Android Jelly Bean operating system.

Anadigics' AWL9280 and AWL9580 FEICs are enabling 802.11a/b/g/n WiFi connectivity in the 7.0", 8.0" and 10.1" versions across multiple models and regions, powering both the 2.4GHz and 5GHz WiFi bands.

The 2.4GHz AWL9280 802.11b/g/n and 5GHz AWL9580 802.11a/n FEICs leverage Anadigics' exclusive InGaP-Plus technology and patented design architectures to combine a high-performance power amplifier (PA), low-noise amplifier (LNA), and Tx/Rx RF switch on a single die in a compact 2.5mm x 2.5mm x 0.4mm QFN package, with a high-accuracy integrated power detector and RF ports internally matched to 50Ω. This level of integration improves manufacturability and reliability, reduces PCB area, and simplifies RF front-end design to speed time-to-market.

The complete family of FEICs provides what is claimed to be outstanding error vector magnitude (EVM) and noise figure performance, enabling high modulation accuracy and hence high data throughput.

"Our front-end ICs have raised the bar in WiFi integration and performance, helping reduce space requirements while maximizing battery life and throughput," says Jonathan Griffith, VP of WiFi products.

# SEMATECH makes advances in post-epi-growth backside clean processing to enable high-volume III-V manufacturing on silicon

## New testing and analysis methods identify potential environmental, safety & health and contamination risks

SEMATECH (the international research consortium of semiconductor device, equipment, and materials manufacturers) claims that researchers have made significant advances in post-epitaxial-growth backside clean processing that will prepare III-V technology for high-volume manufacturing. The research leading to these accomplishments was conducted at SEMATECH's facilities at the College of Nanoscale Science and Engineering (CNSE) in Albany, NY, USA and presented at SEMATECH's Surface Preparation and Cleaning Conference in Austin, TX in late March.

Following a two-year effort to improve process parameters and validating III-V on 200mm silicon VLSI process flows, technologists have identified the key mechanisms to enable a robust backside cleaning process and made significant progress in reducing the likelihood of process cross-contamination that could impact a high-volume manufacturing line.

Furthermore, SEMATECH has developed systematic experiments to identify the key mechanisms of backside contamination, which were then used to engineer robust backside clean process using standard high-volume manufacturing toolsets. At the same time, researchers assessed the environmental, safety and health (ESH) risks of applying and processing compound semiconductor films on silicon dioxide wafers.

"To drive cost-effective compliance solutions, SEMATECH is developing new testing and analysis methodologies to evaluate ESH impacts of novel materials," says Hsi-An Kwong, SEMATECH's ESH Technology Center program manager.

"After conducting a process analysis of III-V manufacturing line, we were able to identify potential ESH risks, including generation of arsine and arsenic compounds, and develop protocols to help mitigate the impact to environment and safety."

Supported by CNSE's conventional Si CMOS processing capabilities, SEMATECH researchers are now working jointly with chipmakers, equipment and materials suppliers and universities on the ESH and contamination challenges of processing III-V materials in a 300mm fab in order to enable safe implementation of III-V technology for high-volume manufacturing.

III-V compound semiconductor are considered valid candidates as building blocks for the implementation of high-performance, low-power logic devices beyond the 10nm technology node, says SEMATECH. But, to be truly competitive, III-V-based technology must be monolithically

**III-V compound semiconductors are considered valid candidates as building blocks for the implementation of high-performance, low-power logic devices beyond the 10nm technology node... But, to be truly competitive, III-V-based technology must be monolithically integrated with silicon in order to benefit from existing Si-based semiconductor processing**

cally integrated with silicon in order to benefit from existing Si-based semiconductor processing, it adds. For successful introduction into a silicon manufacturing line, hetero-integrated III-V-on-Si wafers must be processed with a backside clean and capping processes.

"Through the success of our R&D efforts, SEMATECH is developing manufacturable solutions and practical implementation approaches to enable the fabrication of logic devices and systems on chips with diverse and improved functionalities," says Paul Kirsch, director of Front End Processes (FEP) at SEMATECH.

Silicon-based materials have been the basic layers used in manufacturing CMOS transistors for over half a century, but these staple materials (as well as materials derived from silicon such as insulators and contact metals) are reaching their limits, says SEMATECH, as the industry looks to lower power dissipation in CMOS devices and as scaling approaches the physical limits of silicon transistors. SEMATECH's FEP program is exploring innovative materials, new transistor structures and alternative non-volatile memories to address key aspects of system-level performance, power, variability and cost to help accelerate innovation in the continued scaling of logic and memory applications.

"The backside clean step is a key component of successful introduction of III-V material to a 300mm high-volume manufacturing line," says Chris Hobbs, SEMATECH's FEP program manager. "Success at this step is critical to ensure contamination control through subsequent toolsets."

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



# Qualcomm's CMOS power amplifier targeted at increasing competitiveness of firm's baseband

## Baseband chip firm aiming to enable white-box vendors to design mobile phones

In its latest report 'Global and China GaAs Industry Report, 2012–2013' market analyst firm Research In China summarizes that in first-half 2013 the biggest news in the gallium arsenide industry was Qualcomm's announcement in February of plans to introduce a CMOS silicon power amplifier (PA) targeting 4G LTE (long-term evolution) devices, once again initiating a war between CMOS and GaAs. However, most people believe that Qualcomm did that only to increase the competitiveness of its baseband, not to grab market from GaAs vendors, notes the market research firm.

CMOS PAs appeared before 2000, but have not been available in volume and are currently only used for 2G applications, due mainly to the difficulty in finding a balance between cost and performance, says the firm. Yet, it seems that Qualcomm's RF360 CMOS PA is aimed at breaking through this limitation. As a large mobile-phone baseband vendor, Qualcomm's revenue comes mainly from 3G and 4G telecom patents and baseband shipments, and is expected to reach \$24.5bn in 2013. Of that, baseband shipments are expected to reach 700 million units, worth about \$13.5bn.

Gross margin for mobile phone PAs is less than half of that of Qualcomm's baseband, and runs a very high market risk. The PA is the second most important part of a mobile phone, not only deciding the voice quality but also determining the stand-by time and talk time. Mobile-phone makers seldom changes PA suppliers, once they have been selected, notes the market report.

Qualcomm's RF360 is targeted mainly at dealing with MTK and Spreadtrum, targeting knock-off

digital product white-box vendors. White-box phones adopt the platform of MTK or Spreadtrum instead of Qualcomm, due to the simpler design and higher level of integration of the overall solution of the former two. In contrast, Qualcomm is expert in baseband design, not integrated solutions, hence it cannot enter the knock-off digital product market, which comprises more than 100 million sets. So, to set foot in this field, Qualcomm has introduced the RF360 chip, reducing the difficulty of mobile phone design to a large extent. Bundle sales of Qualcomm's RF360 chip and baseband aim to equip white-box vendors with the ability to design mobile phones independently.

On the other side, as the number 1 mobile phone vendor, Samsung contributes about \$5bn to Qualcomm annually, albeit unwillingly, since the baseband market for smartphones (except Chinese knock-off whitebox digital products) is monopolized by Qualcomm. So, Samsung is currently developing baseband technology, and some has already been used for the Galaxy S3. However, Qualcomm is introducing the RF360 to raise

the industry threshold and stop Samsung from developing its own baseband (and Samsung is very weak in the RF field — even weaker than Chinese vendors), notes Research In China.

Lots of start-ups are dedicated to replacing GaAs PAs with CMOS PAs, among which Axiom Microdevices has already realized shipments of over 10 million sets for 2G mobile phones, it is reckoned. Also, Javelin has announced its aim to mass produce 3G PAs using CMOS this June.

Unlike the start-ups, RF Micro Devices, Anadigics, Infineon and other existing PA suppliers have shown skepticism about CMOS PAs, believing that it is hard for CMOS PAs to strike the balance between cost and performance. Even PA maker Skyworks Solutions, which acquired Axiom, thinks that the application of CMOS PAs in high-end markets (i.e. 3G and 4G) is very limited.

Currently, the CMOS PA still has difficulties in achieving a balance between cost and performance, says the market research firm. It is inferior to GaAs in amplifier performance, and furthermore does not have an absolute advantage in cost. However, many large GaAs vendors have acquired CMOS PA firms — one after another — in order to gain a technical reserve. At the end of April, Avago Technologies completed the acquisition of Javelin Semiconductor. Last November, RFMD announced that it was acquiring CMOS PA start-up Amalfi. Skyworks acquired Axiom in 2009. Most recently, this Spring, Peregrine Semiconductor announced plans to cooperate with Murata in developing CMOS silicon-on-sapphire PAs for potential applications in front-end mobile phone modules, notes Research In China.

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

**RFMD, Anadigics, Infineon and other existing PA suppliers have shown skepticism about CMOS PAs, believing that it is hard for CMOS PAs to strike the balance between cost and performance... Skyworks thinks that the application of CMOS PAs in high-end markets is very limited**

# Nujira extends foundry partnership with TowerJazz

## Mass production of silicon-based envelope tracking IC prepared for 4G smartphone shipments in 2014

Fabless envelope tracking (ET) semiconductor firm Nujira Ltd of Cambridge, UK and specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) are extending their partnership agreement to include production of Nujira's latest NCT-L1300 Coolteq.L ET modulator chip for LTE handsets.

Envelope tracking technology is being developed to reduce the power consumption of 4G smartphones in order to extend battery life. ET dynamically adapts the power amplifier (PA) supply voltage to the signal amplitude, dramatically reducing the power consumption of the PA that transmits the signal to the antenna.

Anyone who uses 4G phones experiences an empty battery much earlier than with 3G, sometimes in the middle of the day, says Nujira. Several technologies are being developed to reduce power consumption of such phones, but recently ET interfaces have become standardized on LTE basebands, paving the way to a high adoption rate of the technology. Nujira reckons that it is well positioned to take a large proportion of the market. According to market research firm IHS, the annual revenue for analog application-specific ICs for 4G

mobile handsets is forecast to rise at a compound annual growth rate (CAGR) of 29% over the next five years, from \$827m in 2012 to \$2.9bn by 2017.

Nujira selected TowerJazz (the fifth largest foundry worldwide) as its manufacturing partner in early 2012. With the launch of the NCT-L1300 ET modulator IC in June, the partnership is being extended as the new chip is geared up for volume production to support 4G smartphone shipments in 2014. The NCT-L1300 is fabricated in TowerJazz's proven 0.18µm RF CMOS technology, which is used in hundreds of millions of RF front-end devices with additional uniquely fitted HV modules. The NCT-L1300 delivers power conversion efficiencies in excess of 80%, effectively doubling the efficiency of existing solutions, it is reckoned.

"Over the last year we've built an excellent relationship with TowerJazz; its processes offer us the ideal combination of high-performance analog and power management capabilities," says Nujira's CEO Tim Haynes. "Nujira's ET ICs have the highest bandwidth, widest voltage range, fastest slew rates, and lowest output impedance in the market, placing significant demands on the underlying process technology," he claims. "TowerJazz meets all of these stringent requirements and works closely

with us to ensure a high success rate and competitive time to market."

"As the world's largest specialty analog foundry, TowerJazz offers us the experience and capacity to address the high-volume smartphone market, and enables us to meet the price points demanded by the world's largest smartphone vendors," continues Haynes. "Moving our new IC into volume production is a critical step for our business, and with its process expertise, wafer capacity and security of supply across multiple fabs, TowerJazz is the right foundry partner," he adds.

"Nujira's technology has huge potential, with ET technology heading towards a 100% attach rate in LTE smartphones in 2014," says TowerJazz's CEO Russell Ellwanger. "Nujira's chips combine wireless communications and smart energy, which are two high-growth focus areas for TowerJazz," he adds. "As one of the world's largest foundries and with capacity on three continents, TowerJazz offers a unique combination of speciality processes and wafer capacity, enabling high-growth fabless IC companies like Nujira to rely on us as their silicon supplier."

The NCT-L1300 is packaged in a low-profile wafer-level chip-scale package, and started sampling to lead customers in June.

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

## TowerJazz raises \$22m in rights offering

TowerJazz has completed its rights offering to eligible security holders (announced at the end of May).

Gross proceeds were \$22m out of a maximum possible \$24m offered (a 90% participation rate). Major shareholder Israel Corporation Ltd exercised its rights in full (investing \$7m) and is also exercising all of its Series 8 warrants (an additional investment of about \$10m).

"We had opportunities to meet with multiple investors and discuss company strategies, tactics and performance," says CEO Russell Ellwanger. "There was an overall understanding, appreciation and belief in the direction the company is taking and of the strong traction within the strategic initiatives that the company has announced over the preceding years."

A total of 1.1 million rights were exercised in the offering. Each is exercisable for four ordinary shares, six short-term Series 8 warrants exercisable at \$5 per share, plus five Series 9 warrants exercisable at \$7.33 per share until 27 June 2017. Both the Series 8 and 9 warrants will be listed on the Tel Aviv Stock Exchange.

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



## Tektronix to adopt IBM's 9HP SiGe technology in 70GHz oscilloscopes

Test, measurement and monitoring equipment supplier Tektronix of Beaverton, OR, USA says that its next generation of high-performance real-time oscilloscopes will incorporate IBM's latest 9HP silicon-germanium (SiGe) chip-making process. The fifth generation of IBM's semiconductor technology — along with other advances such as patent-pending Asynchronous Time Interleaving announced previously — will result in oscilloscopes with bandwidth capability of 70GHz and improvements in signal fidelity, says Tektronix.

Operating at speeds up to 350GHz, 9HP is claimed to be the first SiGe technology in the industry featuring the density of 90nm BiCMOS, and delivers higher performance, lower power and higher levels of integration than existing 180nm or 130nm SiGe offerings. Tektronix has been a long-time adopter of SiGe for its oscilloscopes.

The next generation of oscilloscopes from Tektronix is due for availability in 2014. With real-time bandwidth of 70GHz (and the potential for more in future iterations), the new oscilloscope platform will deliver the performance and signal fidelity needed for applications such as 400Gbps and 1Tbps optical communications and fourth-generation serial data communications, says Tektronix.

"By extending our long-standing relationship with technology leader IBM, Tektronix is continuing to push the envelope on what can be achieved in high-fidelity, high-speed data acquisition systems," says chief technology officer Kevin Ilcisin. "Early adoption of 9HP has allowed our engineers to explore innovative architectures and performance thresholds once thought unattainable," he adds. "9HP SiGe BiCMOS technology provides the faster switching speeds, high integration levels, and low noise our next generation of performance instru-


mentation requires to meet customer requirements."

Tektronix' forthcoming oscilloscopes will also benefit from the use of Asynchronous Time Interleaving technology to improve signal-to-noise ratio beyond the frequency interleaving approach currently in use by some vendors, it is claimed. In traditional frequency interleaving, each analog-to-digital converter (ADC)

in the signal acquisition system only sees part of the input spectrum. With Asynchronous Time Interleaving, all ADCs see the full spectrum with full signal path symmetry. This offers the performance gains available from interleaved architectures but without the same impact to signal fidelity, says Tektronix.

[www.ibm.com/us/en](http://www.ibm.com/us/en)

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## IN BRIEF

### Microsemi and Future Electronics announce global distribution deal

Microsemi Corp of Aliso Viejo, CA, USA (which designs and makes analog and RF devices, mixed-signal integrated circuits and subsystems) has entered into a broad-based, global distribution agreement for Future Electronics (which distributes and markets electronic components) to provide worldwide sales, design support and fulfillment services for its complete line of semiconductor solutions (excluding certain government products and services).

"The addition of Future Electronics as a global channel partner marks yet another step forward in our strategy to enhance our worldwide distribution network to better support the expanding business and technical needs of our customers," says Michael G. Sivett III, Microsemi's VP of worldwide distribution sales.

Microsemi's product range includes mixed-signal analog RF power amplifiers (PAs) and front-end modules (FEMs) and power/RF discretes and modules.

"Microsemi has an extensive portfolio of unique, high-performance semiconductor systems solutions that are a great match with our current line card and our customer base, particularly in the industrial sector," comments Matthew Rotholz, director of marketing, Analog and Power Products, for Future Electronics. "Microsemi products are available from Future Electronics now, and we are currently holding a series of technical training programs to bring our applications engineering and embedded system designers up-to-speed on Microsemi's solutions."

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

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

## RF SOI now mainstream in mass production of smartphone switches

### Over 65% of substrates used in fabricating switches for handsets now SOI-based

At the SEMICON West trade show in San Francisco (9–11 July), Soitec of Bernin, France, which makes engineered substrates — including silicon-on-insulator (SOI) wafers and III-V epiwafers — as well as concentrating photovoltaic (CPV) solar systems, said that its silicon-on-insulator (SOI) technologies are now mainstream for manufacturing switches and antenna-tuners (key RF components used in all cell phones and tablet computers).

According to the market research firm Yole Développement, more than 65% of substrates used in fabricating switches for handsets are SOI-based, showing the massive adoption of RF SOI for this booming electronic market experiencing double-digit growth. Now, chip manufacturers are relying on SOI technology to offer the best price/performance ratio and enable next-generation smartphones.

Soitec says that its engineered substrates are at the heart of RF integrated circuits, enabling chip manufacturers to integrate various functions on the same die, reducing the overall system cost. An RF SOI substrate features an active layer on which CMOS transistors are built, isolated from a high-resistivity silicon base layer. This reduces noise and interference, helping the finished die to reach its target performance in terms of signal integrity, handling RF power and integration density. SOI technologies enable devices to reach a figure of merit for on-series resistance and off-equivalent capacitance ( $R_{on} \cdot C_{off}$ ) below 200fs (femtoseconds), with the potential for further reduction, reckons Soitec. This directly relates to improved device performance and smaller die size.

Another driver of SOI's growth is the evolution towards the greater performance required for overhaul-

ing wireless networks from 3G to 4G/LTE and further LTE Advanced using carrier aggregation. Soitec adds that SOI technologies exceed stringent linearity requirements such as intermodulation distortion (IMD) far beyond -110dBm, helping to avoid interference with other networks.

"RF SOI technologies enable the device integration, cost effectiveness and high performance needed for high-volume 3G and LTE applications," says Bernard Aspar, VP, Communication & Power business unit at Soitec. "RF, with over 100% revenue growth last year, remains

**Power amplifiers will likely be the next RF components based on SOI, as the technology enables highly tunable amplifiers to address multi-region requirements on a single platform**

a strategic market in which we have been continuously investing for more than a decade."

Soitec says that, on the strength of recent demonstra-

tions, power amplifiers will likely be the next RF components based on SOI, as the technology enables highly tunable amplifiers to address multi-region requirements on a single platform. The firm adds that its RF SOI substrates offer a path towards further integration, such as more mixed-signal and digital content.

Soitec also says that its broad offerings allow RF device manufacturers to select an engineered substrate that aligns best with their market strategies — from low-cost GSM handsets to multi-band, multi-mode LTE smartphones and tablets.

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



# RFaxis expands CMOS RF front-end portfolio with first pure-CMOS high-power 2.4GHz WLAN power amplifier

Fabless semiconductor firm RFaxis Inc of Irvine, CA, USA, which designs RF semiconductors and embedded antenna solutions for the wireless connectivity and cellular mobility markets, has begun mass production of its RFX240 high-power 2.4GHz power amplifier (PA) for wireless local-area network (WLAN) applications.

RFX240 is the first of RFaxis' pure-CMOS high-power CMOS PA series targeting the growing wireless access point (AP), router, set-top box (STB), home gateway, hot spot and other wireless infrastructure markets. The RFX240 is pin-to-pin compatible with incumbent solutions, including Skyworks' SE2576L, SE2604L and SE2605L, which are all based on compound semiconductor processes.

"The high-power Wi-Fi market has been served exclusively by costly gallium arsenide and silicon germa-

nium PAs," says RFaxis' chairman & CEO Mike Neshat. "We have proven to the RF industry once again that pure CMOS does deliver. In fact, the RFX240 not only delivers the same gain, output power level and excellent linearity, but also outperforms competitors in power-added efficiency," he claims. "After extensive evaluation, the feedback from our tier-1 ODM and OEM customers has been exceedingly positive." The firm aims to start volume shipment of the RFX240 this summer.

The RFX240 is a high-power, high-linear-

**The RFX240 not only delivers the same gain, output power level and excellent linearity, but also outperforms competitors in power-added efficiency**

arity PA built on industry-standard bulk CMOS, the lowest-cost semiconductor process ever to implement an RF device, says the firm. The RFX240 is optimized to provide the functionality of transmit power amplification for IEEE 802.11b/g/n applications in the 2.4GHz frequency range. It provides 30dB power gain, 26dBm linear output power for OFDM/64QAM with 5V power supply, and consumes 30mA less current than competing PAs of the same category, it is claimed. It integrates full-CMOS logic control, on-chip input and inter-stage impedance matching, RF decoupling, as well as a truly directional coupler-based power detector for accurate closed-loop power control. The RFX240 is assembled in a 3.0mm x3.0mm x 0.55mm 16-pin quad flat no-lead (QFN) package. Samples are now available.

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

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## IN BRIEF

### United Silicon Carbide chooses Silvaco's TCAD device simulators for SiC power device modelling

United Silicon Carbide Inc (USCi) of Monmouth Junction, NJ, USA has selected the TCAD simulators of Silvaco Inc of Santa Clara, CA, a provider of technology computer-aided design (TCAD), circuit simulation and electronic design automation (EDA) software tools, for the modeling of its silicon carbide (SiC) power devices. After an extensive evaluation and competitive bidding process, USCi says that it chose Silvaco for its unique capabilities to enhance the R&D of their SiC power devices.

"Silvaco's Athena process and Atlas device simulators offer the kinds of simulation capabilities that our engineers need to understand the manufacturing effects, and the electrical and thermal characteristics in our SiC power devices," says USCi's VP of engineering Anup Bhalla. "With these capabilities our engineers have the ability to develop and enhance our power device designs through simulation prior to manufacturing, and know that our devices are going to perform as we expect them to after manufacturing and with higher production yields. This allows USCi to get our product to market with minimal time and costs," he adds.

"Silicon carbide is a technology that Silvaco implemented into our simulators several years ago," notes Silvaco's CEO David Halliday. "The maturity of this capability has been extremely important and beneficial to our customers in the power industry."

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

### UK's first EPSRC National Centre of Excellence for Power Electronics Six-year, £18m research hub involves universities of Nottingham, Manchester, Newcastle, Greenwich, Bristol, Warwick and Imperial College London

The UK's capacity in power electronics has received an £18m boost from the UK's Engineering and Physical Sciences Research Council (EPSRC) with the opening of the first EPSRC National Centre of Excellence for Power Electronics. As well as silicon-based devices such as insulated-gate bipolar transistors (IGBTs), power electronics can use devices based on silicon carbide, gallium nitride and diamond.

"We have a leading power electronics industry in the UK, but we need to keep investing in research to ensure it remains globally competitive," said David Willetts MP, Minister for Universities and Science, on the opening of the centre. "This National Centre will bring together our excellent universities and businesses to ensure industry has access to the latest science and technology, as well as helping to maintain a supply of skilled people."

Investment in the EPSRC Centre will be spread as a series of grants, each involving multiple universities. These comprise a coordinating hub — led by professor Mark Johnson at the University of Nottingham, and involving the universities of Manchester, Newcastle, Greenwich, Bristol, Warwick, Nottingham and Imperial College London — and a series of four technical programs:

- **Devices** — led by professor Phil Mawby at the University of Warwick and involving the universities of Bristol, Cambridge, and Newcastle.

- **Components** — led by professor Philip Mellor at University of Bristol and involving the universities of Greenwich, Nottingham, Manchester, Warwick and Imperial College.

- **Convertors** — led by professor Andrew Forsyth at the University of Manchester and involving the universities of Strathclyde, Nottingham,

Bristol, and Imperial College London.

- **Drives** — led by professor Barrie Mecrow at the University of Newcastle and involving the universities of Manchester, Nottingham, Sheffield, and Bristol.

"This £18m investment in a six-year research initiative is part of EPSRC's response to the Government's 2011 BIS Strategy for Power Electronics in the UK," says EPSRC's CEO, professor David Delpy. "We will invest an initial tranche of £12m with a further £6m being released subject to a future review of progress," he adds. "Power Electronics was also a priority area in our recent call for new Centres for Doctoral Training."

The new centre's opening comes two months after the launch of the PowerelectronicsUK Forum, which is an industry-led collaborative network facilitated by NMI (the UK trade association for electronic systems, microelectronics and semiconductors) and backed by industry, academia and the government that aims to boost the number of people within the power electronics industry.

"The new EPSRC Centre for Power Electronics will be key to the future success of UK power electronics," reckons Steve Burgin, chairman of PowerelectronicsUK and UK president of Alstom. "It will help to keep UK industry and academia at the forefront of next-generation power electronics technologies."

PowerelectronicsUK's Steering Group (with the role of ensuring the success of the PowerelectronicsUK initiative and driving external communications) is chaired by Stephen Burgin and vice-chaired by Dynex Semiconductor's CEO Paul Taylor, assisted by a secretariat from NMI — Derek Boyd (CEO) and Alastair McGibbon (R&D Policy Director).

[www.epsrc.ac.uk](http://www.epsrc.ac.uk)



## ARPA-E to award up to \$25m for work on WBG power devices

The US Department of Energy's Advanced Research Projects Agency — Energy (ARPA-E) has issued two new Funding Opportunity Announcements (DE-FOA-0000941, DE-FOA-0000942) for high-current wide-bandgap (WBG) power semiconductor devices called 'Strategies for Wide Bandgap, Inexpensive Transistors for Controlling High Efficiency Systems (SWITCHES)'.

Both FOAs seek to fund transformational advances in WBG semiconductor materials, device architectures, and device fabrication processes that promise to enable increased energy density, increased switching frequencies, enhanced temperature control, and reduce power losses in a range of power electronics applications, including high-power electric motor drives and automotive traction drive inverters.

The goal of the SWITCHES program is to enable the development of high-voltage (1200V+), high-current (100A) single-die power semiconductor devices that, upon ultimately reaching scale, would have the potential to reach functional cost parity with silicon power transistors while also offering breakthrough relative circuit performance (low losses, high switching frequencies, and high temperature operation).

These transformational technologies would have promise to reduce the barriers to ubiquitous deployment of low-loss WBG power semiconductor devices in stationary and transportation energy applications.

ARPA-E is allocating up to \$25m for both SWITCHES FOAs, with \$15m in funding being made available specifically to small businesses under ARPA-E's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program and \$10m being made available to all applicants.

Recent research results indicate that new materials advances, device architectures, and device fabrication processes could substantially accelerate progress towards WBG devices that achieve both higher current ratings and functional cost parity with silicon-based devices, thus gaining ubiquitous deployment. These approaches have, as of yet, received relatively little attention from industry and the research community since they are perceived to be technically unproven and high risk.

The following technical areas are of interest to the FOA:

- Wide-bandgap power semiconductor devices utilizing novel fabrication processes or device structures not previously supported by ARPA-E, other governmental agencies or previously developed for commercial application; such technologies might include vertical GaN device structures, approaches to device fabrication that are compatible with substrate re-use (i.e. device liftoff), and novel structures compatible with far lower-cost fabrication processes and high die current ratings. New approaches to fast, high-quality thick-film epitaxial growth that enables rapid fabrication of high voltage devices are also of interest.

- Investigation of technologies with the potential to enable extremely low cost and highly scalable free standing wide bandgap substrate fabrication. Such technologies might include, but are not limited to, new GaN, ZnO, SnO<sub>2</sub>, sapphire, or other wide bandgap substrate growth techniques. Approaches that enable larger substrate sizes and substantially reduced defect densities are required. These may include advances in new chemistries for epitaxial growth or substrate refining techniques.

<https://arpa-e-foa.energy.gov>

### IN BRIEF

#### Cree's 2nd-gen SiC MOSFETs used in Delta's latest supplies

Cree Inc of Durham, NC, USA says that its newly expanded portfolio of 1200V SiC MOSFETs is being incorporated into the latest power supplies from Netherlands-based Delta Elektronika BV. Consequently, Delta has demonstrated a 21% decrease in overall power supply losses and a reduction in component count by up to 45% compared with power supply products using traditional silicon technology, it is reckoned.

Cree's new SiC transistor improves both the efficiency and power density of the power supplies, comments Delta's director Job Koopmann. "The switching behavior is outstanding and controlling the MOSFET is simple and straightforward," he adds. "This device is helping us to continue developing more reliable products."

Since 1959, Delta Elektronika has produced power supplies for industrial applications such as specialized equipment used in factories, automation and industrial power conversion. "Delta Elektronika BV has a half-century legacy of producing some of the most reliable, efficient and compact power supplies on the market," says Cengiz Balkas, general manager, Cree Power and RF. "The industrial power supply market, which values efficiency, reliability and power density, is a key market for SiC MOSFET technology," he adds.

Cree says its second-generation SiC MOSFETs (launched in March, and now including a 160mΩ MOSFET for the 5–10kW market) are experiencing an increasing rate of adoption in key applications, including a design-in at a major manufacturer's next-generation PV inverters.

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

# US government honors Raytheon for completing Title III GaN production improvement program

## Manufacturing Readiness Level 8, exceeding requirement for insertion into production military systems

Raytheon Company of Waltham, MA, USA has been honored by the Office of the Secretary of Defense (OSD) for successful completion of a Defense Production Act (DPA) Title III gallium nitride (GaN) production improvement program, culminating more than a decade of government and Raytheon investment in GaN radio-frequency circuit technology.

"Raytheon has been at the forefront in advancing the maturity and production-readiness of GaN technology, and this recognition reflects our mutual collaboration and achievement, having worked closely with our customers," says Joe Biondi, VP of Advanced Technology for Raytheon's Integrated Defense Systems (IDS) business in Tewksbury, MA. "The limitless benefits of GaN in performance and

reliability deliver enhanced capability and affordability," he adds.

Raytheon also demonstrated that the reliability of its GaN technology exceeded the requirement for insertion into production military systems. This maturation of GaN resulted in a Manufacturing Readiness Level (MRL) production capability of '8', the highest level obtained by any organization in the defense industry for this technology. MRL is a measure used by the OSD and many of the world's major companies to assess the maturity of manufacturing readiness.

**GaN yield was improved by more than 300% and cost was reduced more than 75% for MMICs**

Raytheon says that GaN technology extends the warfighter's reach into the battlespace by increasing radar ranges, sensitivity and search capabilities. Through the Title III program, GaN yield was improved by more than 300% and cost was reduced more than 75% for monolithic microwave integrated circuits (MMICs). Such devices (operating at microwave frequencies, i.e. 300MHz to 300GHz) typically perform functions such as microwave mixing, power amplification, low-noise amplification and high-frequency switching.

GaN technology also supports a reduction in the size of a system's antenna, which can provide flexibility, improve transportability and reduce acquisition and lifecycle costs without sacrificing performance, says Raytheon.

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

# Hittite launches GaN MMIC power amplifiers delivering 25W at 2–6GHz and 8W at 2–20GHz

Hittite Microwave Corp of Chelmsford, MA, USA (which designs and supplies analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) has launched four new gallium nitride (GaN) MMIC power amplifier products that offer performance, size and durability advantages for communications, test instrumentation and radar systems operating in the 2–20GHz frequency range.

The HMC1086F10 is a 25W GaN MMIC power amplifier that operates at 2–6GHz, and is provided in a 10-lead flange-mount package. The amplifier typically provides 23dB of small-signal gain, +44dBm saturated output power, and delivers +46dBm output IP3 at +33dBm output power per tone. The amplifier

draws 1100mA quiescent current from a +28V DC supply. The HMC1086 is the die version of the HMC1086F10. This 25W GaN MMIC power amplifier also operates at 2–6GHz and provides 22dB of small-signal gain, +44dBm of saturated output power, and +48dBm output IP3 at +33dBm output power per tone. Both feature RF I/Os that are DC blocked and matched to 50Ω for ease of use.

The HMC1087F10 is an 8W GaN MMIC power amplifier that operates at 2–20GHz, and is provided in a 10-lead flange-mount package. The amplifier typically provides 11dB of small-signal gain, +39dBm of saturated output power, and +43dBm output IP3 at +28dBm output power per tone. The amplifier draws 850mA quiescent current from a

+28V DC supply. The HMC1087 is the die version of the HMC1087F10. This 8W GaN MMIC power amplifier also operates at 2–20GHz and provides 11dB of small-signal gain, +39dBm of saturated output power, and +45dBm output IP3 at +29dBm output power per tone. Both feature RF I/Os matched to 50Ω.

Both the HMC1086 and the HMC1087 have compact die sizes, high-output-power capability and simplified biasing, making them suitable for integration into high-power-density multi-chip module (MCM) and subsystem applications.

All four GaN MMIC power amplifiers complement Hittite's line of microwave power amplifiers, which provide continuous frequency coverage of 0.01–86GHz.

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



## RF-Lambda selects TriQuint's gallium nitride HEMTs for new line of high-power amplifiers

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA says that RF-Lambda of San Diego, CA, USA, which makes and distributes RF components for analog wireless networks in North America, Europe and Asia-Pacific, has developed a new line of high power amplifiers based on TriQuint's gallium nitride (GaN) power transistors. RF-Lambda's new products are currently being qualified in commercial 4G systems, a defense flight system, and other defense/aerospace projects.

Reducing part counts and maintaining performance was central to RF-Lambda's decision. "We formerly supplied a key customer with two separate GaAs amplifiers to cover two bands. By using TriQuint GaN, we were able to replace those with a single GaN high-electron-mobility transistor (HEMT) and cover the full frequency range," says R&D director Michael Liu. "This increased design flexibility while decreasing production variation," he adds. "Our customers also benefit by using

software to switch bands rather than physically changing hardware, while still achieving necessary power."

TriQuint says its new GaN HEMT devices offer optimized power and efficiency at high drain voltage operating conditions. RF-Lambda chose the T2G6001528-Q3, which offers typical power-added efficiency (PAE) of greater than 50% at 15dB gain; its performance can reduce the number of transistors in a design, which also benefits heat management. These advantages can lower part counts, reduce board space and lower overall system costs, notes TriQuint. The T2G6001528-Q3 is offered in a low-thermal-resistance, flangeless 4mm x 5mm package. Samples and evaluation boards are available.

RF-Lambda is also developing other new power amplifiers based on TriQuint GaN transistors, including a 1–18GHz, 50W device and 20W/40W solutions for 0.1–6GHz as well as the RFLUPA0706GE (0.7–6GHz) 7W amplifier.

"TriQuint GaN products offer important size, weight and power advantages that the defense industry was fast to appreciate," says James L. Klein, TriQuint VP & general manager for Infrastructure and Defense Products. "We now see more commercial applications using GaN thanks to its advantages, and we look forward to supporting RF-Lambda's new programs," he adds.

"While defense supported GaN in many applications, communication infrastructure utilization is growing fast," comments market research firm Strategy Analytics, which foresees significant growth for GaN. "Sat-com, power and other infrastructure markets are ramping to higher revenues. Strategy Analytics forecasts that the market for GaN microelectronic devices will grow with a compound average annual growth (CAGR) rate of over 34% to approximately \$186m by 2015," says Eric Higham, director of Strategy Analytics' Semiconductor Practice.

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

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

## Raytheon wins contract for Technology Development phase of US Navy's Next Generation Jammer program

Raytheon Company of Waltham, MA, USA has been awarded a \$279.4m cost-plus-incentive-fee contract by the US Navy to conduct the Technology Development phase of the Navy's Next Generation Jammer (NGJ) program.

"The Navy's choice validates Raytheon's leadership in advanced electronic attack systems and technologies," says Rick Yuse, president of Raytheon's Space and Airborne Systems business. "Raytheon looks forward to building on our long-standing relationship with the US Navy as we provide the warfighter with innovative and reliable Next Generation Jammer solutions."

Raytheon says that it is leveraging its knowledge and experience as a tactical weapon systems integrator to provide an affordable, low-risk, comprehensive NGJ solution to the US Navy. Raytheon also leveraged its gallium nitride-based AESA (active electronically scanned array) technologies to provide warfighters with enhanced electronic attack capabilities.

"Raytheon provided the US Navy with an innovative and efficient design capable of jamming current and future threats," says Yuse. "Our technology approach met the program requirements and leveraged our industry team's extensive

experience in combat-proven, high-reliability agile-beam RF systems designed for demanding carrier-based aircraft environments."

NGJ will replace the ALQ-99 tactical jamming system currently on the Navy's EA-18G Growler tactical airborne electronic attack aircraft.

Raytheon's Space and Airborne Systems business, in McKinney, Texas, will lead the Technology Development phase of the NGJ program with collaboration from Raytheon facilities in El Segundo, California; Forest, Mississippi; Dallas, Texas; Fort Wayne, Indiana; Largo, Florida; and Andover, Massachusetts.

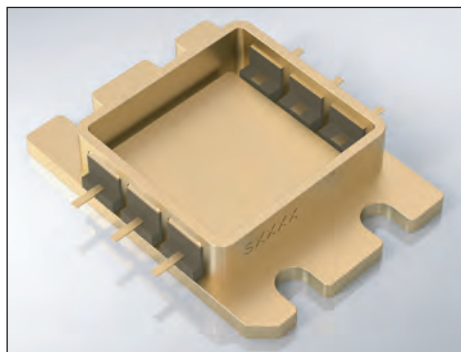
[www.raytheon.com](http://www.raytheon.com)

# Hermetic GaN power amplifier package developed by SCHOTT & Tesat-Spacecom used aboard Proba-V satellite HTCC multi-layer ceramics used as high-frequency feedthroughs

The Electronic Packaging business unit of SCHOTT technology group of Mainz, Germany and Tesat-Spacecom GmbH of Backnang, Germany (a manufacturer of systems and equipment for telecoms via satellite) have developed a hermetically sealed package for use in space, and has been supporting the European Space Agency's mini-satellite Proba-V for performing Earth observations since the beginning of May.

Specifically, for the first time the housing contains a gallium nitride (GaN) power amplifier monolithic microwave integrated circuit (MMIC) chip. SCHOTT and Tesat-Spacecom developed the optimum composition and geometry for the package's heat-sink. In addition, the package features hermetically sealed HTCC (high-temperature co-fired ceramic) multi-layer ceramics as high-frequency feedthroughs that allow only minimal insertion loss and reflection of high-frequency waves.

The communication system for Proba-V weighs 140kg, is 1m<sup>3</sup> in size and contains a special microwave amplifier based on gallium nitride (used for the first time ever in a European satellite). This is being used to transmit photos (taken at a height of about 800km) in the X-band (at a frequency of 8GHz) to monitor



**New type of hermetic packaging for GaN power amplifiers in the Proba-V satellite. Source: Tesat-Spacecom.**

vegetation on Earth. GaN is capable of improving signal strengths and data transmission by 5–10 times and will be used as a high-performance material in communication systems, reckons SCHOTT. The MMIC amplifier chip delivers its performance via a surface area just a few square millimeters in size and hence requires innovative packaging concepts, the firm adds.

The MMIC amplifier chip has been installed inside a hermetically sealed package co-developed by SCHOTT and Tesat-Spacecom. Due to the design of the ceramic-to-metal feedthrough, the high-frequency waves are able to pass the wall of the housing with very low attenuation, so the loss of power (insertion loss) is minimized. In addition, reflection

losses of the high-frequency waves along the housing wall are also minimized.

"Simulations of electromagnetic waves have enabled us to determine the best possible geometries and designs for this special type of feedthrough in close coordination with manufacturing technology," explains Dr Thomas Zetterer, development engineer at SCHOTT Electronic Packaging.

The second key property of the package is the high thermal conductivity of its base, allowing dissipation of the heat generated inside the MMIC amplifier. To achieve this, the development teams at SCHOTT and Tesat-Spacecom came up with the optimum material composition and geometry for a heat-sink for this particular application. Materials and material compounds that allow for even higher thermal connectivity still need to be developed in the near future and tested for use in applications with even higher microwave power, say the firms.

"Working together with SCHOTT enables us to obtain the high-thermal-conductivity packages that are urgently needed for future GaN amplifiers," says Eberhard Möss, group leader at Tesat-Spacecom.

[www.tesat.de](http://www.tesat.de)

[www.schott.com/epackaging](http://www.schott.com/epackaging)

## RFMD launches 500W pulse power gallium nitride L-band amplifier for radar applications

RF Micro Devices Inc of Greensboro, NC, USA has launched the RFHA1027, a GaN matched power transistor (MPT) delivering pulsed power of 500W in a compact flanged package at L-band frequencies.

Operating at 1.2–1.4GHz and provides 500W of pulsed RF power from a 50V supply, the new amplifier is optimized for pulsed power applications requiring efficiency and

compact size. Offering high gain of 16.5dB and high efficiency of 55%, the RFHA1027 is housed in a small-form-factor 24mm x 17.4mm package and is input and output matched to 50Ω, minimizing external components. Also, the package uses RFMD's heat-sink and power-dissipation technologies to deliver what is claimed to be excellent thermal stability and conductivity.

The RFHA1027 targets new and existing radar architectures requiring ruggedness and reliability. Its launch follows the release in late 2011 of RFHA1020 (280W L-band) and RF3928 (280W S-band).

RFMD showcased its RF components at the IEEE MTT-S International Microwave Symposium (IMS 2013) in Seattle, WA, USA (4–6 June).

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



# Fujitsu to ship samples of WLCSP-packaged GaN-on-Si HEMT-based power device with 150V breakdown

## Volume production due in 2014, targeting switches for more efficient, more compact power supplies

Fujitsu Semiconductor Ltd of Yokohama, Japan has released the MB51T008A, a silicon-substrate-based, gallium nitride (GaN) power device with a drain-source breakdown voltage ( $V_{(BR)DSS}$ ) of 150V.

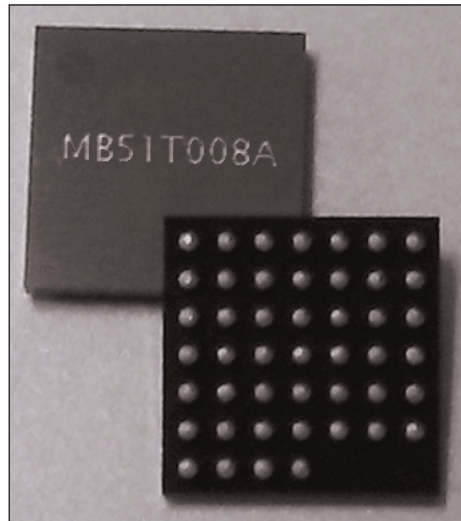
The MB51T008A features include: (1) drain-source on-state resistance ( $R_{DS(on)}$ ) of  $13m\Omega$  and total gate charge ( $Q_g$ ) of 16nC, which enables roughly half the FOM of silicon-based power devices with an equivalent breakdown voltage; (2) minimal parasitic inductance and high-frequency operation through the use of wafer-level chip-scale packaging (WLCSP); and (3) a proprietary gate design that enables normally-off operation.

The new device is suitable for high-side switches and low-side switches in DC-DC converters employed in power supplies for data communications equipment, industrial products, and automobiles. In addition, because it supports a higher switching frequency in power supply circuits, power supplies can achieve improvements in overall size and efficiency.

Fujitsu Semiconductor plans to begin sample shipments in July, with volume production scheduled to begin in 2014.

The firm says that, with the new addition to its lineup, it will be able to offer GaN devices that contribute to smaller, more efficient power supplies for a wide range of fields, from home appliances and ICT equipment to automotive applications.

In addition to the 150V-breakdown MB51T008A, Fujitsu Semiconductor is also developing models with breakdown voltages of 600V and 30V, helping to enable enhanced



**Fujitsu's new MB51T008A GaN-on-Si power device in wafer-level chip-scale package.**

power efficiency in a wide range of product areas. The GaN power devices are based on high-electron-mobility transistor (HEMT) technology, in which Fujitsu Laboratories has led development since the 1980s, the firm claims. Building on its IP portfolio in the technology, Fujitsu Semiconductor aims to rapidly bring its GaN power devices to market. Also, to expand business further, it plans to build partnerships with customers across a wide range of industries.

The MB51T008A and other GaN products are on display at the 'TECHNO-FRONTIER 2013' trade show at Tokyo Big Sight, Japan (17-19 July). The firm plans to highlight performance improvements in its GaN power devices with 600V breakdown voltages, as well as prototypes and test data for a 2.5kW power supply employing a GaN power device, a high-frequency PFC (power factor correction), and a high-frequency DC-DC converter.

<http://jp.fujitsu.com/fsl/en>

## IN BRIEF

### Nitronex adds ceramic- and plastic-packaged 48V HEMTs

Nitronex LLC of Durham, NC, USA has developed a family of products based on a new 48V GaN-on-Si process technology.

The NPT2000 Series discrete HEMTs support power levels of 12, 25, 50 and 100W, and come in both plastic and ceramic packages. Targeting defense and high-volume commercial markets, they address competing demands for low cost and high performance.

"These products provide higher gain, higher efficiency, and wider bandwidths," says president & CEO Greg Baker. "We see many interesting opportunities with our core customer and market base with the 48V ceramic package offering, and even more opportunities with the lower-cost plastic package line. Our thermally enhanced plastic package offering will allow us to be very price competitive in new commercial markets for GaN such as land mobile radio and small-cell base stations."

The NPT2000 Series is the culmination of three efforts:

- iterative design improvements based on Nitronex's 28V product line, enhancing ruggedness, thermal performance and breakdown voltage;
- expanded product range by including low-cost, easy-to-use plastic packages for all devices, from lowest to highest power;
- reliability testing, qualifying the new 48V operating voltage.

The new family includes the NPT2010 and NPT2020 (with outputs of 100W and 50W) in AC360 ceramic packages, the NPT2018 and NPT2019 (with outputs of 12W and 25W) in 3x6 DFN plastic packages, and the NPT2021 and NPT2022 (with outputs of 50W and 100W) in TO272 plastic packages.

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

# Xilinx and Sumitomo Electric collaborating to reduce broadband radio network CapEx and OpEx

## Xilinx radio SmartCORE IP and Sumitomo Electric's GaN power amplifier transistors to boost power efficiency over 50%

Xilinx Inc of San Jose, CA, USA, which provides all-programmable field-programmable gate arrays (FPGAs), systems-on-chip (SoCs) and 3D ICs, and Japan's Sumitomo Electric Industries Ltd are collaborating to reduce capital expenditure (CapEx) and operational expenditure (OpEx) through the use of Sumitomo Electric's gallium nitride (GaN) power amplifier transistors and Xilinx's SmartCORE IP, resulting in higher radio unit efficiencies. Wireless system designers using Xilinx's SmartCORE IP can scale to support small cells to high-end macro cells, as well as active antenna systems (AAS), offering customers time-to-market advantages, lower development costs, high efficiency, lower SWaP (size, weight and power), and lower total cost, it is reckoned.

Xilinx radio SmartCORE IP such as digital up- and down-converters

(DUC/DDC), crest factor reduction (CFR) and digital pre-distortion (DPD) IP cores, coupled with generation-ahead 28nm Zynq-7000 all-programmable SoCs, offers a single-chip implementation of the entire digital radio as well as board-level control and calibration typically found in an external processor.

"By collaborating with Sumitomo Electric, we are able to provide our customers with a smarter solution that is scalable to support the needs of broadband microcells, and up to the highest performance multi-antenna broadband macros and AAS installations," says David Hawke, director of wireless product marketing at Xilinx. "Additionally, our radio IP, coupled with Sumitomo Electric's power amplifier transistors, allow OEMs to design equipment that ultimately save operator CapEx and OpEx, as well as reduce device cost and power."

The high breakdown voltage and saturation velocity characteristics of GaN devices suit high-power and high-temperature base-station applications. The higher power density of GaN also allows for smaller devices, reducing size and cost.

"Sumitomo Electric's GaN-based power devices, combined with Xilinx's SmartCORE IP, will demonstrate the world's next generation of highly efficient solutions for the wireless market," says Nobu Kuwata, general manager of Technology and Marketing Strategy Department at Sumitomo Electric Device Innovations Inc (SEDI).

A live demonstration of the Sumitomo Electric GaN and Xilinx DPD IP core was given at the IEEE MTT-S International Microwave Symposium (IMS 2013) in Seattle, WA, USA (4–6 June).

[www.xilinx.com/esp/wireless/refdes\\_listing.htm](http://www.xilinx.com/esp/wireless/refdes_listing.htm)

## Sumitomo Electric's first Ku-band GaN HEMT for satcoms

At IMS 2013, Sumitomo Electric Device Innovations USA Inc (SEDU) of San Jose, CA, USA launched its first Ku-band GaN HEMT power amplifier (PA) for satcoms.

Sumitomo Electric notes that GaN technology allows significantly higher output powers — 50W, versus

30W for GaAs. Tuned for operation at frequencies of 13.75–14.5GHz, the SGK1314-50A PA is internally matched for the extended Ku satcom band to provide optimum power and gain in a 50Ω system.

"The new GaN PAs provide the ability to simplify the design by

reducing the number of required transistors," says Sumitomo Electric Device Innovations USA's president John Wyatt. "For example, the 50W GaN HEMT replaces two GaAs FETs and also provides higher gain [8dB typical] and efficiency [lower power consumption]," he adds.

## 500W single-ended GaN power amplifiers launched for S-band radar

SEDU has launched two 500W single-ended GaN power amplifiers (PAs) with broadband operation, between them covering the entire S-band, for radar applications.

Frequency ranges are 2.7–3.1GHz for the 2731-500W device and 3.1–3.5GHz for the 3135-500W. Operating from a high voltage of 50V, both devices are internally

matched to provide optimum power and gain for 50Ω systems. The minimum target gain is 12dB and the typical target efficiency is as high as 60%. Typically, pulse width is 150μs and duty is 10%. Low thermal resistance enables superior heat dissipation, says SEDU.

The devices are said to be the first in their class housed in a

space-saving IV package (with a footprint of 17.4mm x 24mm x 5mm, about half that of current PAs) while offering high efficiency and gain to radar manufacturers.

Sumitomo's overall range of GaN PAs for radar applications span from L-band to X-band, with power levels up to 600W.

[www.sei-device.com](http://www.sei-device.com)



## Toshiba adds high-gain 200W C-band GaN HEMT power amplifier for weather radar

Toshiba America Electronic Components Inc (TAEC) — a subsidiary of Tokyo-based semiconductor maker Toshiba Corp — has added a 200W C-band GaN HEMT to its power amplifier product family. The new device was exhibited at the IEEE MTT-S International Microwave Symposium (IMS 2013) in Seattle, WA, USA (4–6 June).

The 200W TGI5254-200P is Toshiba's first commercial C-band GaN HEMT optimized for pulsed operation to support C-band radar applications. Operating at 5.2–5.4GHz, typical output power is 53.0dBm with 43dBm input power, power gain is 10.0dB and drain current is 2.4A, with a supply voltage of 24V at 25°C (nominal pulse width 200µs; duty ratio 10%). The device enables increased output power and, housed in a 7-AA06A package, helps to reduce size and

weight in solid-state power amplifiers (SSPAs) for radar applications.

"Although this is our initial entry into this specific type of C-band GaN HEMTs, Toshiba has long been a leading manufacturer of solid-state power amplifiers for radar applications in the Japanese domestic and international markets," says Homayoun Ghani, business development manager, microwave devices, for TAEC's Discrete business unit. "Our GaN HEMTs have been one of the technological foundations helping to accelerate the modernization of radar technology from a tube-based to a solid-state-based design," he claims. "In fact, solid-state weather radar systems using Toshiba devices are currently in operation at several sites in Japan."

Samples of the C-band GaN HEMT are available in third-quarter 2013.

## Toshiba expands high-power C-band GaN HEMT product line to support SatComs

Toshiba has expanded its GaN HEMT lineup with the addition of three new devices optimized to support extended C-band SatCom applications. Housed in 7-AA06A packages, the TGI5867 broadband GaN HEMT family is targeted at block up-convertors (BUCs) and solid-state power amplifiers (SSPAs) and was exhibited at IMS 2013.

With available power ratings of 25W, 50W and 100W, the TGI5867 family supports extended C-band (5.85–6.725GHz frequency range) satcoms, enabling satellite operators to offer more service and data traffic capacity. The TGI5867-100L has an output power at 100W or 50.0dBm (typical), with an input power of 20W or 43dBm (nominal), linear gain at 11.0dB (typical) and power-added efficiency (PAE) of 38%. The TGI5867-50L and -25L

have output power at 50W and at 25W, linear gain at 13.0dB and PAE of 40% and 45%, respectively.

"The expansion of our GaN HEMT product family brings high-gain, high-power and broadband features that help designers build energy-efficient SSPAs and BUCs," notes Homayoun Ghani, business development manager, microwave devices, for TAEC's Discrete business unit. "By adding the 100W, 50W and 25W lineup to our GaN HEMT product family, Toshiba is now able to provide a full GaN HEMT-based SSPA design solution for extended C-band SatComs," he adds. "This solution will help microwave designers eliminate multiple power supply rails and reduce the number of parts in their overall system."

[www.toshiba.co.jp/index.htm](http://www.toshiba.co.jp/index.htm)

### IN BRIEF

#### API expands power amplifier line with GaN technology

API Technologies Corp of Orlando, Florida, USA, a provider of RF/microwave, microelectronics and security solutions, has expanded its range of power amplifiers (PAs) to include the GaN-technology-driven designs. The expanded line is intended particularly for electronic warfare (EW), radio-controlled improvised explosive device (RCIED) counter-measures, and national security jammer applications, where rugged and highly reliable power amplifier designs are mission critical. The firm's power amplifier product line was exhibited at June's IEEE MTT-S International Microwave Symposium (IMS 2013) in Seattle, WA, USA.

API's strategy is to create strategic partnerships with leading defense firms to provide both standard and custom solutions for broadband power amplification, says Richard Graham, director, sales & marketing, RF/Microwave & Microelectronics. "API's successful heritage in amplifier design includes both broadband, high linearity amplifiers, as well as high-frequency, narrowband, higher-power amplifiers to 100W with strict attention to size."

API says it optimizes package configurations to address thermal conditions to meet system-level integration challenges. API provides compact, lightweight power amplifiers with what are claimed to be excellent thermal characteristic. Engineering high-power GaN power amplifiers to predict junction-to-case temperatures and thermal profiles during the design stage helps to eliminate the need for cumbersome heat-sinks, reducing cost and providing for more accurate results, says the firm.

<http://micro.apitech.com>

# IR and EPC reach settlement, ending litigation

## EPC to pay royalties to International Rectifier on sales of GaN-on-silicon power devices from 2015–2023

Power semiconductor device maker International Rectifier Corp (IR) of El Segundo, CA, USA has entered into a settlement agreement with El Segundo-based Efficient Power Conversion Corp (EPC) — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) used in power management applications — that will result in the payment of royalties to IR on the sale of gallium nitride on silicon (GaN-on-Si)-based power devices from

2015–2023, subject to an offset in certain cases.

The settlement resolves all disputes between EPC and certain of EPC's principals (including co-founder & CEO Dr Alex Lidow) and IR without judicial determination of the merits of any party's claims or defenses.

IR brought the suit against EPC, Alex Lidow and others in 2009 for misappropriation of trade secrets associated with its GaN-on-Si program. Lidow had also sued IR

for wrongful termination as its CEO. When the settlement occurred, the matter was awaiting trial in the Los Angeles Superior Court.

"This resolution is positive for IR and will allow the company to put this dispute behind us," believes IR's president & CEO Oleg Khaykin. "We will continue to direct our attention and resources to the commercialization of our GaN-on-silicon technology platform."

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

[www.epc-co.com](http://www.epc-co.com)

## EPC redesigns website to include GaN power transistor library

Efficient Power Conversion Corp has redesigned its website to include a gallium nitride (GaN) transistor library, providing searchability and access to GaN transistor technology, educational materials and product information.

"All new technologies have a learning curve that engineers must climb prior to implementing a new technology effectively and efficiently," says co-founder & CEO Dr

Alex Lidow. "At EPC we recognize our responsibility to the design community to make certain that engineers know the benefits and understand the intricacies of working with gallium nitride technology," he adds. "We have taken this education responsibility seriously and have generated and collected a vast amount of materials on GaN transistor technology and applications. Now these materials are

concentrated in a single location."

Since the founding of EPC in 2007, the firm's design and applications team has published over 50 articles in professional journals, delivered more than 30 presentations at industry and academic conferences, and published the only textbook available on the subject 'GaN Transistors for Efficient Power Conversion'.

[www.epc-co.com](http://www.epc-co.com)

# EPC launches 96%-efficient, 1MHz buck converter demonstration board featuring EPC2015 eGaN FETs plus Texas Instruments gate driver

EPC has introduced the EPC9107, a fully functional buck power conversion demonstration circuit. The board is a 9–28V input to 3.3V, 15A maximum output current, 1MHz buck converter. It uses the EPC2015 enhancement-mode gallium nitride (eGaN) field-effect transistor (FET) in conjunction with the LM5113 100V half-bridge gate driver from Texas Instruments (TI).

EPC says that the EPC9107 demonstrates the reduced size and performance capabilities of high-switching-frequency eGaN FETs when coupled with this dedi-

cated eGaN driver.

The EPC9107 demonstration board is 3" square and contains a fully closed-loop buck converter with optimized control loop. The complete power stage including eGaN FETs, driver, inductor and input/output caps is in an ultra-compact 0.5" x 0.5" layout to showcase the performance that can be achieved using the eGaN FETs with the LM5113 eGaN driver. Despite its small size, the board has peak power efficiency of more than 96% and is capable of delivering 15A of current at 3.3V.

The firm says that the EPC9107 demonstration board is easy to set up and contains various probe points to facilitate simple waveform measurement and efficiency calculation. A Quick Start Guide (containing set-up procedures, circuit diagram, performance curves and a bill of material) is included for reference and ease of use.

EPC9107 demo boards are priced at \$195.94 each and are available from the distributor Digi-Key.

<http://digikey.com/Suppliers/us/Efficient-Power-Conversion.page>

<http://epc-co.com>





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## IN BRIEF

### Suntron offers EMS services for semiconductor capital equipment firms

Suntron Corp of Phoenix, Arizona, USA, a supplier of integrated electronics manufacturing systems (EMS), says it is offering a variety of manufacturing services, including large-scale integration, for semiconductor capital equipment firms.

Suntron's manufacturing facilities offer cycle-time reduction, advanced manufacturing services, and electromechanical assembly with high-mix, low- to medium-volume manufacturing capabilities. Testing capacities include interlock safety, controls testing, AC/DC verification of all signals, pressure testing of all cooling lines, ground bond measurements, and helium vacuum leak.

Suntron says it is especially experienced in quality-sensitive and challenging large-scale assemblies. The firm's integration teams manage highly complex and extensive bills of materials, reducing total cost of ownership for customers. In particular, the firm says it has developed unique procedures and infrastructure for handling the extremely large part count bills-of-material that are typical of semiconductor processing products.

A single-source supplier for all major semiconductor equipment platforms, Suntron has experience with many different applications, including lithography systems, PVD systems, wafer metrology and inspection systems, power management systems, PECVD producer SE systems, and high-voltage transformer systems.

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

## Element Six expands microwave CVD synthetic diamond manufacturing capacity by 60%

### Growth driven by demand for thermal management and high-power optics for EUV lithography

At the SEMICON West 2013 event in San Francisco (9–11 July), Luxembourg-registered synthetic diamond materials firm Element Six (a member of the De Beers Family of Companies) said that it has expanded its global manufacturing capabilities for microwave chemical vapor deposition (CVD) synthetic diamond by 60% compared to last year. Driven by growth in the firm's semiconductor and optical business segments, Element Six has effectively ramped production capacity to meet emerging demand for thermal management solutions including gallium nitride (GaN)-on-diamond substrates and high-power-resistant optical windows for extreme ultraviolet (EUV) lithography systems.

"Our bookings have seen a 30% increase in compound annual growth over the last two years, and we attribute the majority of our expansion to new applications in the semiconductor market," says Adrian Wilson, head of the technologies division. "We are seeing more interest from packaging designers and manufacturers as the industry comes to recognize the numerous properties and benefits of synthetic diamond, which offer our customers a distinct competitive advantage to further differentiate and strengthen their solutions," he adds.

Element Six has expanded its high-volume manufacturing capabilities across its facilities in Silicon Valley, California, USA and Ascot, UK (with the latter already serving as the world's largest CVD diamond manufacturing site). The three key areas of production supported at the built-out sites include:

- CVD diamond thermal material — delivering thermal conductivity of 1000–2000W/mK, synthetic diamond is integrated into semiconductor modules to serve as an effective heat spreader — driving to more than a 20 degree temperature decrease to quadruple a device's lifetime.

- Synthetic diamond optical windows — an enabler for laser-produced plasma (LPP) EUV lithography system, Element Six's large CVD synthetic diamond optical windows (71–80mm in diameter) withstand the power levels necessary to produce EUV light (reducing system downtime and improving wafer throughput).

- GaN-on-diamond wafers — one of the most thermally conductive materials, GaN on free-standing polycrystalline CVD diamond is up to five times more conductive than copper at room temperature (enabling rapid, efficient and cost-effective heat extraction that lowers operating temperature and overall system level costs, and increases the power of RF devices).

Element Six says that, to consolidate and strengthen its innovation capabilities, it has also opened a new Global Innovation Centre (GIC) in Harwell, near Oxford, UK. Building on the firm's 50 years of R&D heritage, the GIC should enable Element Six to rapidly design, manufacture and test market-ready solutions in one location.

[www.e6.com/electronics](http://www.e6.com/electronics)

**We attribute the majority of our expansion to new applications in the semiconductor market**



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# IQE's first-half revenue increases by 80% year-on-year to nearly £63m

**Growth driven by wireless division via RF Micro Devices' MBE epi and Kopin Wireless acquisitions**

In a trading update for first-half 2013, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says it expects first-half performance to be ahead of market expectations, with revenue approaching £63m, EBITDA (earnings before interest, taxes, depreciation, amortization, share-based payments and exceptional items) in excess of £10m and net debt below £39m.

This represents revenue growth of over 80%, and EBITDA growth of over 150% compared with first-half 2012. Sales growth was driven primarily by the wireless division, which included contributions from acquisitions including the MBE epiwafer manufacturing unit of RF Micro Devices Inc of Greensboro, NC, USA as well as the Kopin Wireless MOCVD-based heterojunction bipolar transistor (HBT) epiwafer manufacturing business of Kopin Corp of Taunton, MA, USA.

The wireless market has continued to grow in line with expectations, driven by the increasing adoption of more sophisticated communication devices including 4G and LTE smartphones and tablets, and newly launched dual-band WiFi (802.11ac). IQE says that these advanced products demand the highest levels of RF performance, which can only be delivered by compound-semiconductor-enabled front-end solutions.

The integration of the RFMD and Kopin acquisitions has been completed as planned, and work to realise the projected synergies is progressing well, says the firm. The board will provide a full update on this progress with the group's half year results.

IQE adds that its photonics business is also making good progress, with several applications in transi-

tion from R&D into production. Notably, these include a number of vertical-cavity surface-emitting laser (VCSEL) products for consumer, industrial and medical applications such as: optical communications devices for short-range optical links; data centers and broadband delivery; optical devices for gesture recognition; gaming and cosmetic applications; and lasers for projection, medical and defence applications.

Advanced concentrated photovoltaic (CPV) solar technology, acquired through the investment in CPV cell maker Solar Junction Corp of San Jose, CA, USA and the exclusive seven-year license agreement, is now in the final stages of qualification. IQE remains on track for this business to achieve end-customer qualification and move into volume production during second-half 2013.

The development of advanced products including gallium nitride (GaN) materials and the IQE's compound semiconductors on silicon

**The wireless market has continued to grow... driven by the increasing adoption of more sophisticated communication devices including 4G and LTE smartphones and tablets, and newly launched dual-band WiFi (802.11ac)**

projects are progressing well, says the firm. These are building a platform for further diversified growth in the rapidly growing markets for energy-efficient devices such as LEDs and power semiconductors over the next few years, says the firm.

"Our key markets have continued to demonstrate robust growth, driven predominantly by high levels

**Transactions with Solar Junction, RFMD and Kopin, over the last 18 months, represent significant milestones in the execution of our overall strategy and have significantly enhanced both our short- and long-term growth potential**

of demand for 4G and LTE enabled smartphone and tablet products, along with accelerating requirements for photonic products and advanced sensor applications," says chief executive Dr Drew Nelson. "Additionally, requirements for energy-efficient third-generation CPV solar products, solid-state lighting (SSL) and power-efficient GaN devices continue to increase strongly," he adds.

"Our transactions with Solar Junction, RF Micro Devices and Kopin, over the last 18 months, represent significant milestones in the execution of our overall strategy and have significantly enhanced both our short- and long-term growth potential," Nelson continues. "They are highly complementary, extending our critical mass and global leadership in wireless, and bringing additional capacity to service the emerging high-growth CPV market."

IQE expects to report its interim first-half 2013 results around mid-September. The board adds that it is confident the firm remains on track to achieve market expectations for the full year.

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



## Air Products joins SEMATECH's Front End Processes program to assess materials for sub-10nm III-V devices

Air Products of Lehigh Valley, PA, USA (which provides atmospheric, process and specialty gases, performance materials, equipment and technology) has joined the Front End Processes (FEP) program of SEMATECH (the international research consortium of semiconductor device, equipment, and materials manufacturers). Air Products will work with SEMATECH to assess advanced materials and technologies for the development of sub-10nm-node III-V devices.

Continued scaling will require the use of new materials and chemistries to keep pace with the International Technology Roadmap for Semiconductors (ITRS), says SEMATECH, noting that III-V channels offer power and performance benefits (e.g. higher mobility, enhanced drive current and supply voltage scaling) enabling continued device scaling and performance boosts.

The goal of SEMATECH's FEP program is to provide novel leading-edge materials, processes, structural modules and electrical and physical characterization methods to support the continued scaling of logic and memory applications.

As a member of the program, located at the College of Nanoscale Science and Engineering (CNSE) of the State University of New York (SUNY) in Albany, NY, Air Products will collaborate with SEMATECH's engineers and leverage its activities in advanced materials to enable better understanding of the underlying principles responsible for the deposition of III-V structures. The team's goal will be to help guide the development of new chemical products that address a wide variety of needs for next-generation semiconductor devices.

"Air Products will be cooperating

with SEMATECH to accelerate the introduction of innovative products to the marketplace," says Dr John Langan, the Global Director of Electronics Technology for Air Products. "By leveraging the capabilities of SEMATECH, we are accelerating new product development to fulfill the requests we are receiving for electronics materials from our industry partners," he adds.

"Air Products' long-standing and deep expertise in specialty materials will complement our own device and process expertise," comments Paul Kirsch, director of SEMATECH's FEP program. "We will work together to develop practical and promising manufacturable solutions to address the emerging needs of the advanced transistor markets."

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

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

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## IN BRIEF

### Taiwan's EpiLEDs orders further Aixtron CRIUS II-L MOCVD systems

Aixtron has announced another repeat order (made in first-quarter 2013) from EpiLEDs Co Ltd of Tainan Science Park, Taiwan to support its ramp-up of GaN-based LED production for lighting applications. The order for two CRIUS II-L 69x2" MOCVD systems is due for delivery in third-quarter 2013. EpiLEDs is producing the LEDs exclusively using MOCVD equipment from Aixtron.

EpiLEDs designs and manufactures blue, green, red and white light LED epiwafers and chips with a full range of wavelengths (from 365nm to 940nm), suitable for applications such as indicators of consumer electronics, light source of fax machines and scanners, indoor or outdoor display boards, automotive lightings, traffic signals and illuminators.

"We want a smooth ramp-up of production based on existing, proven technology," says EpiLEDs' president MingSen Hsu. "The CRIUS II-L meets our requirements for high throughput enabled by semi-automated loading and best cost-of-ownership in class," he comments. "Further, the system is already fully qualified for production of EpiLEDs' high-end LED power chips... we plan to continue to work closely with Aixtron in meeting our future MOCVD needs," he adds.

The CRIUS II-L systems are delivered with Aixtron's ARGUS Topside Temperature Control (TTC) system. The method eliminates temperature variation within each run and run-to-run, boosting production yields, says Aixtron.

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

### Veeco's request for continued NASDAQ listing granted

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that on 17 July the NASDAQ Listing Qualifications Panel informed it that its request for continued listing on The NASDAQ Stock Market until 4 November had been granted.

As reported on 17 May, Veeco is not in compliance with NASDAQ Listing Rule 5250(c)(1) because it did not file on time its quarterly report on Form 10-Q for first-quarter 2013, its annual report on Form 10-K for 2012 and its quarterly report on Form 10-Q for third-quarter 2012. This was because the firm was reviewing the timing of recognition of revenue and related expenses on the sale of certain metal-organic chemical vapor deposition (MOCVD) systems and related upgrades to these systems. The accounting review was announced on 15 November 2012.

On 24 May, Veeco received a letter from NASDAQ saying that, since it had not regained compliance, its

common stock would be subject to delisting unless it requested a hearing before the NASDAQ Listing Qualifications Panel. On 18 June, the panel granted its request to extend the stay of suspension of trading in its stock pending a final determination regarding the firm's listing status following a hearing before the panel on 27 June.

At the hearing, Veeco requested additional time to satisfy the NASDAQ listing requirement for it to be current in its filings with the US Securities and Exchange Commission (SEC).

Now, NASDAQ says that, on or prior to 4 November, Veeco must regain compliance with all applicable requirements for continued listing on The NASDAQ Stock Market including filing its outstanding annual and periodic reports with the SEC. Veeco says it is working, together with its auditors, towards becoming current with its SEC reports earlier than the November date.

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

### Aixtron delivers 3x2" CCS MOCVD system to University of Illinois for developing solar nanowires

In second-quarter 2013 deposition equipment maker Aixtron SE of Herzogenrath, Germany delivered a Close Coupled Showerhead (CCS) metal-organic chemical vapour deposition (MOCVD) reactor (ordered in fourth-quarter 2012) to the University of Illinois at Urbana-Champaign, USA. The 3x2"-wafer system will be used for the development of III-V compound semiconductor based materials and devices, including nanowire-based solar cells and transistors.

"We needed a flexible research platform that can support a variety of programs at the university,"

says professor Xiuling Li of the Department of Electrical and Computer Engineering and Micro and Nanotechnology Laboratory (MNTL) at Illinois. "The critical issues for us are cost of ownership and process flexibility, which is essential for materials research in a multi-user environment," he adds.

The MNTL at University of Illinois contains more than 8000 square feet of Class 100 and Class 1000 cleanroom space and recently underwent an \$18m expansion that added faculty and student office space.

<http://mntl.illinois.edu>  
[www.aixtron.com](http://www.aixtron.com)

## SolR monitors 50nm thin layers

LayTec AG of Berlin, Germany, which makes in-situ metrology systems for thin-film processes, says that a successful application of its SolR in-line metrology tool by an industrial customer has proven its extreme sensitivity.

The Figure shows in-line measurements of thickness homogeneity over seven modules directly after deposition of a thick copper indium gallium diselenide (CIGS) absorber layer (upper part) and a thin cadmium sulphide (CdS) buffer layer of less than 50nm (lower part).

The measurement is based on spectroscopic reflectance and is taken by two optical heads installed at two different positions perpendicular to the transport direction of the modules (white and green transients in the screenshot). The characteristic patterns of the film thickness line-scans across the modules show that the thickness is inhomogeneous. However, all modules have a similar pattern of thickness distribution. The CIGS layer is typically thinner in the center than



**Thickness transients of CIGS and CdS layers by SolR.**

at the edges. The CdS layer has an S-shaped thickness distribution.

In the CdS layer, a certain systematic variation of the production line has been identified by statistical process analysis: the mean CdS thickness (median) increases with process time (dash line in Figure). The standard deviation for both CIGS and CdS layer thickness measurements was found to be under 1nm.

LayTec says that these high-precision measurements are now used by the customer to improve the process toward higher yield and maximum cell efficiency.

[www.laytec.de/solr](http://www.laytec.de/solr)

## University of Wroclaw starts up second 3x2" CCS MOCVD system

### Technological center TECHNOPOLIS to develop multi-junction solar cells

Deposition equipment maker Aixtron SE of Herzogenrath, Germany says that the University of Wroclaw in Poland has started up a 3x2" Close Coupled Showerhead (CCS) MOCVD system to create optoelectronic devices, in particular high-efficiency multi-junction solar cells, based on gallium arsenide related materials.

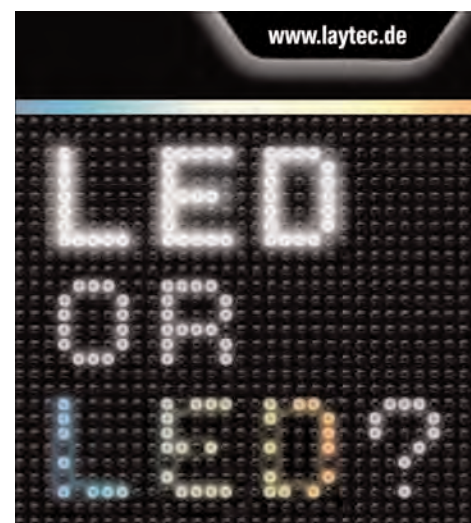
"We decided to purchase the Aixtron system based on our good experience with the performance of our existing CCS 3x2" GaN tool in the Faculty of Microsystem Electronics and Photonics," says professor Marek Tlaczala. "The new Showerhead reactor is destined for the

University's Interuniversity Didactic-Technological Center 'TECHNOPOLIS' in Wroclaw," he adds. The center is co-funded by the European Union from the European Regional Development Fund (ERDF) within the framework of the Infrastructure and Environmental Programme and Poland's national budget.

"The Close Coupled Showerhead (CCS) concept is recognized as a robust route to uniformity and scalability," says Dr Frank Schulte, VP of Aixtron Europe. "We are looking forward to continue our close collaboration."

[www.uni.wroc.pl](http://www.uni.wroc.pl)

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



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## IN BRIEF

### OIPT's iPhone/iPad app adds interactive periodic table

OIPT has updated its iPhone/iPad application, which allows users to look up process chemistries in order to etch or deposit any material through an easy periodic table interface.

The free-to-download application provides an interactive periodic table of elements, with detailed plasma, ion beam and atomic-layer deposition (ALD) processing information. The firm says that the application can be used as a teaching device to demonstrate individual element properties and electron configurations.

This App is available for immediate download at:

[www.oxford-instruments.com/businesses/nanotechnology/plasma-technology/campaigns/periodic-table-of-elements-app](http://www.oxford-instruments.com/businesses/nanotechnology/plasma-technology/campaigns/periodic-table-of-elements-app)

## OIPT launches PlasmaPro100 Sapphire single-wafer etch system

UK-based etch, deposition and growth system maker Oxford Instruments Plasma Technology (OIPT, part of Oxford Instruments plc) has introduced the PlasmaPro100 Sapphire single-wafer etch system.

"The PlasmaPro100 Sapphire is designed specifically to address the harsh chemistries required for HBLEED materials, delivering fast etch rates uniformly on wafers up to 200mm in diameter," says Michelle Bourke, Production Business Group director at Oxford Instruments. "At Oxford Instruments we strive to provide the most innovative, cost-effective and reliable process solutions for our customers. This latest system is

designed to encompass all these requirements," she adds.

Key system features and benefits include: Electrostatic Clamp technology capable of clamping sapphire, GaN-on-sapphire and silicon; a high-power ICP source producing a high-density plasma; magnetic spacer for enhanced ion control; and a high-conductance pumping system delivering maximum gas throughput at low pressures.

[www.oxford-instruments.com](http://www.oxford-instruments.com)



PlasmaPro100 Sapphire single wafer etch system.

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[www.oxford-instruments.com/plasma](http://www.oxford-instruments.com/plasma)





# SPTS acquires XACTIX to expand etch offering

## Acquisition strengthens SPTS' MEMS vapor release etch intellectual property and product portfolio

Plasma etch, deposition and thermal wafer processing equipment maker SPTS Technologies Ltd of Newport, Wales, UK (a Bridgepoint portfolio company) has acquired XACTIX Inc of Pittsburgh, PA, USA, which is claimed to be the market-leading provider of xenon difluoride ( $\text{XeF}_2$ )-based release etch technology.

Manufacturing micro-electro-mechanical systems (MEMS) devices such as microphones, inertial sensors and RF switches, often requires a release etch step to remove a sacrificial layer in order to allow free movement of specific parts of the mechanical structure. By adding the XACTIX product line to its HF vapor phase release range, SPTS now supports release technologies for silicon/molybdenum/germanium

and silicon oxide sacrificial layers. The firm says that both processes offer advantages over traditional wet etch solutions because they eliminate stiction between moving parts, which can make precision MEMS devices inoperable.

SPTS and XACTIX jointly developed the CVE single-wafer  $\text{XeF}_2$  release etch module and have shared sales/marketing channels over a number of years.

**SPTS now supports release technologies for silicon/molybdenum/germanium and silicon oxide sacrificial layers**

"Bringing XACTIX's technology and product portfolio into the SPTS family is a natural and logical

step for us," says SPTS' president & CEO William Johnson. "This expands our product offering in MEMS release etch and adds to our MEMS toolbox," he adds.

"This evolution of the long-standing relationship between SPTS and XACTIX will expand our opportunities in the MEMS market, and provide our customers with an enlarged and comprehensive sales and support infrastructure," comments XACTIX's founder & chief technology officer Kyle Leboutiz.

XACTIX operations and personnel will now become part of SPTS' Release Etch Division, also based in Pennsylvania.

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

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



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# ClassOne Equipment expands Wet Processing Division with new subsidiary

## ClassOne Technology to focus on new product design and development

ClassOne Equipment (which supplies refurbished wafer fabrication equipment) says that, in response to increased market demand, it has made significant investments in the growth and expansion of its Wet Processing Division.

A Design and Development Center has been opened in Kalispell, Montana, staffed with several industry veterans (representing over 200 years of cumulative industry experience), who will focus on new product design and development. Corporate and refurbishment activities will remain at ClassOne's headquarters in Atlanta, Georgia.

"We have expanded the division to enhance our sales and support of legacy Semitool equipment worldwide as well as to design and manufacture new state-of-the-art upgrades and platforms that address

emerging markets such as MEMS, nanotech, LED and RF power devices," says ClassOne's president Byron Exarcos. "Semitool's acquisition [by Applied Materials, in December 2009] left a void in the market for mature fabs and emerging technologies that use 75–200mm substrates," he adds. "ClassOne is meeting the growing demand for cost-effective, reliable and long-term support for popular tools such as the Spray Solvent, Spray Acid and Equinox tools. The wide-spread adoption of our lift-and-rotate and robot refurbishment programs gives testimony to that fact."

The new facility in Kalispell will be operated under the name of ClassOne Technology as a subsidiary of ClassOne Equipment. The executive team includes: Win Carpenter (a 33-year veteran in the semicon-

ductor industry), VP Wet Process Division; Tim McGlenn (with 26 years experience, including leading the software and electronics development of Semitool's 101, 102, 202, 302, 402 and 502 controllers), VP of Operations; and Kevin Witt (25 years focused on the development and commercialization of new wet chemical processing platforms), VP Technology — all of whom previously held leadership positions at Semitool. ClassOne says that their appointments strengthen the division, positioning it for enhanced growth.

ClassOne Technology's first product, the Polaris controller, is a PLC-based, field-retrofitable control system that replaces the aging 302 control system used in many Semitool legacy tools.

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

## ClassOne Equipment unveiling PLC controller upgrade for Semitool 302-based platforms

At the SEMICON West 2013 event in San Francisco (9–11 July), ClassOne Equipment demonstrated its all-new Polaris PLC controller upgrade for its remanufactured Semitool product line, shown installed in a fully refurbished Semitool Spray Solvent Tool.

The new Polaris control system has been developed as a field-upgradeable replacement for the aging Semitool 302 control system. Polaris features electronics with fully configurable software for real-time control, data-logging, and communications, driven by an intuitive graphical user interface, designed and developed by former Semitool veterans at the new subsidiary ClassOne Technology.

The Polaris PLC upgrade offers the following benefits:

- significantly extended life for existing 302-based systems (SST, SAT and Equinox), reducing fab

capital expenditure (CapEx);

- a new Quad-Core CPU with Windows, replacing the obsolete 486-based processor and proprietary software;
- flexible reconfiguration of the system (such as adding tanks and changing pumps);
- dual hard drives and RAID configuration for hot-swapping and backup for increased uptime;
- Ethernet network connectivity (allowing remote data logging, real-time chemical consumption monitoring, predictive maintenance functions, e-mail notifications and reporting);
- reversible cassette rotation for enhanced process capability; and
- integration of off-the-shelf electronics with fully configurable software.

"Semitool's Spray Solvent and Spray Acid tools have been the work-horses of the industry for

decades, with hundreds of units installed around the world. Because of this, refurbished tools continue to be highly sought after," says ClassOne's president Byron Exarcos. "The Polaris control system brings all the advantages of a modern control system to a time-tested platform while maintaining and enhancing the key elements of performance and cost-effectiveness. Not only does this upgrade offer additional and useful features to the user, it eliminates the concerns over the age of a core component in tools based upon the aging Semitool 302 controllers," he adds. "This competitively priced, critical update will breathe new life into an industry-standard platform and extend its useful life for years."

The Polaris will be offered as a stand-alone field upgrade and as an optional upgrade for tools remanufactured by ClassOne.

# SSEC adds WaferEtch and WaferStorm platforms to single-wafer wet processing product portfolio

At the SEMICON West 2013 event in San Francisco (9-11 July), Solid State Equipment LLC (SSEC) of Horsham, PA, USA, which makes single-wafer wet processing equipment, introduced its WaferEtch and WaferStorm product lines. These platforms are specifically configured to meet the process needs of leading-edge applications in advanced packaging, MEMS and compound semiconductor manufacturing, with an emphasis on improved process control and reduced chemistry consumption, which translates to higher throughput and lower cost of ownership (CoO).

One key CoO reduction driver was enabled by an engineering breakthrough that makes the chambers more compact and stackable. This results in 50% more process chambers within the same small footprint of the legacy products.

The WaferEtch platform is configured for aqueous-based etch processes such as through-silicon via (TSV) reveal. The WaferStorm platform is configured for solvent-based processes such as resist strip, metal lift-off, and TSV cleaning.

"Superior performance, improved yields, and increased throughput at a lower CoO are the cornerstones of SSEC's single-wafer wet processing approach," says chief technical officer Laura Rothman Mauer.

"We have worked closely with our customers to develop practical solutions to some of the industry's toughest manufacturing challenges in 2.5D and 3D ICs, MEMS, and compound semiconductors," she adds. "The launch of these preconfigured product lines is the culmination of this work."

## WaferEtch

The WaferEtch platform is an aqueous-based, customizable platform uniquely configured to meet the needs of specific etch applications for 3D ICs, MEMS, and compound semiconductor processes. The systems use a wet etch

process chemistry that demonstrates optimal etch rate and in-situ cleaning.

The flagship of the WaferEtch platform, the TSV REVEALER, is specifically configured to address the requirements of TSV reveal (where the backside of the wafer is thinned to reveal the copper interconnects), which has become a target area in the manufacture of 2.5D and 3D IC packaging for process control and cost reduction. The TSV REVEALER replaces three tools required for the dry etch approach: plasma etch, silicon thickness measurement, and clean. An optical end-point detection system with advanced algorithms determines when vias are revealed. Integration of a wafer thickness measurement sensor in the etch system provides closed-loop control of the etching process. The TSV REVEALER achieves a significant reduction in CoO making 3D TSVs more economically feasible.

## WaferStorm

The WaferStorm platform is a solvent-based platform, initially available in three unique configurations: TSV CLEANER, METAL LIFTER, and DRY FILM REMOVER. All WaferStorm systems are based on SSEC's unique soak and spray technology, which provides improved performance at lower CoO than conventional wet bench-only or spray-only approaches. The process combines equal soak time in the wet buffer tank for each wafer, followed by spray, and then a final step depending on the process being performed. This unique combination minimizes both spray time and chemistry use, and adds a significant level of process control. The reduction in spray time results in increased throughput.

### ● WaferStorm TSV CLEANER

TSV clean is a critical process step that is essential to reliability. The deep reactive ion etch (DRIE) process leaves behind a polymer residue which can lead to defects

and voids in the barrier, seed, and fill steps that follow. SSEC's WaferStorm TSV CLEANER is proven to remove residues in high-aspect-ratio holes that wet bench-only or spray-only tools leave behind. The tool features equal-time soak software for process control.

### ● WaferStorm METAL LIFTER

Metal lift-off consists of the sequential steps of photolithography, metal deposition, and solvent lift-off of both metal and non-metal substances in MEMS and compound semiconductor applications. The SSEC WaferStorm METAL LIFTER is configured specifically to perform the sequential soak and spray combinations unique to the process. The immersion station operates in a low-oxygen atmosphere, which maintains the bath longer. Following a soak in the immersion tank, lift-off takes place in a spray station using a high-pressure chemical spray, which translates to increased throughput. The tool features a lift-off material filtration station and strainers for separating metal films, resulting in the complete removal of the metal.

### ● WaferStorm DRY FILM REMOVER

Removal of dry film resists used in advanced microbumping processes for 3D ICs and wafer level packaging (WLP) applications is a challenge due to the film thickness and composition. The SSEC WaferStorm DRY FILM REMOVER combines heated chemistries and proprietary soak and spray at high pressure for rapid and complete removal of stubborn dry film residue. The soak step uses heated solvents throughout the buffer cycle time. After being softened by the soak, the wafers are transferred to the single-wafer spray station where they are exposed to high-pressure fan sprays with heated solvents for rapid removal of dry film residue. This combination ensures thorough removal and increased throughput.

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



## EVG and Dynaloy co-develop single-wafer cleaning

Wafer bonding and lithography equipment supplier EV Group (EVG) of St Florian, Austria and Eastman Chemical Company subsidiary Dynaloy LLC (which makes chemicals for the electronics industry) have introduced CoatsClean, a single-wafer photoresist and residue removal technology designed to address thick films and difficult-to-remove material layers for the 3D-ICs/through-silicon vias (TSVs), advanced packaging, microelectromechanical systems (MEMS) and compound semiconductor markets.

"Increasing wafer processing challenges associated with the adoption of new materials, device architectures and packaging schemes requires a new, holistic view of wafer cleaning, where the chemistry, process and equipment are all critically important and must be addressed in combination," says Dynaloy's business director Steven Dwyer. "We're pleased to be working with EV Group on developing and commercializing CoatsClean technology to meet the needs of our customers for a more cost-effective, flexible approach to thick-film resist removal."

CoatsClean incorporates features to boost performance and productivity, as well as reduce CoO, compared to

wet bench and other traditional wafer cleaning approaches. The process and chemical formulation are engineered to perform at higher temperatures, yielding faster stripping rates and cycle times. This enables CoatsClean to operate as a single-wafer process for thick resist films and difficult-to-remove resists, resulting in improved performance, consistency, reproducibility and repeatability. The engineered formulation also enables selective stripping of the resist.

CoatsClean is claimed to be unique in its ability to dispense a small amount of material on the top of the wafer, and then activate it with direct heat. This direct utilization of the material and heat dramatically reduces the strip material used. Compared to other techniques that use an immersion bath, CoatsClean uses fresh solution for each processed wafer, resulting in greater process efficiency and eliminating cross contamination. The highly selective application of resist strip material eliminates damage to the wafer backside. The entire process is performed in a single bowl, reducing tool footprint.

"CoatsClean applies the right chemistry at the right process con-

ditions to provide optimal cleaning results," says EVG's executive technology director Paul Lindner. "By combining our respective strengths, EV Group and Dynaloy can now offer our customers a complete wafer cleaning solution that significantly reduces their CoO and achieves superior performance."

The CoatsClean tool series, which includes EVG's EVG301RS and EVG320RS XT platforms, leverage EVG's core competences in controlled dispense, heating and temperature control, fluid rinse and wafer handling technologies. The EVG301RS system targets R&D, as well as low-volume production on substrates up to 300mm in diameter. The EVG320RS XT has up to eight process modules to address high-volume production requirements on substrates up to 300mm.

EVG will sell the CoatsClean systems and provide customer support. Dynaloy will sell the CoatsClean resist stripping materials. Systems have already been installed for customer demonstrations, and EVG and Dynaloy are now accepting orders for the systems and resist stripping materials.

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

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

## EVG introduces LowTemp room-temperature debonding platform

EVG has introduced its LowTemp debonding platform, featuring three different room-temperature wafer-debonding processes and an extended material supply chain.

The platform includes two new debonding processes qualified for EVG's high-volume production temporary bonding/debonding (TB/DB) systems (UV laser debonding and multilayer adhesive debonding) in addition to EVG's ZoneBOND technology (already implemented into production across the compound semiconductor and advanced packaging sectors). EVG's LowTemp debonding platform is complemented by a supply chain of seven material

suppliers, with a choice of qualified adhesives that support a variety of bonding applications and offer more process flexibility, says the firm.

"The experience and know-how that we've built up from our numerous installations in high-volume manufacturing has taught us that one solution doesn't fit all applications when it comes to temporary bonding/debonding," says executive technology director Paul Lindner. "EVG offers highly flexible and modular equipment, a wide choice of qualified materials to support customers' individual requirements and multiple source policies, and process development and imple-

mentation support through our worldwide application labs and cleanroom infrastructure across a range of applications — including interposers, stacked memory, memory on logic, power devices and compound semiconductors."

The LowTemp platform is available on EVG's full range of TB/DB systems including the recently launched EVG850TB/DB XT Frame production platform, which can reach throughput of over 40 wafer stacks per hour and features an optional, integrated in-line metrology module that takes up to 300,000 measurement points to enable real-time monitoring of the bonding/debonding process.

## Leti and EVG launch common lab on wafer bonding

Micro/nanotechnology R&D center CEA-Leti in Grenoble, France and 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, have launched a three-year common lab to optimize temporary- and permanent-bonding technologies related to 3D TSV (through-silicon via) integration and all direct bonding heterostructures.

The lab, which continues more than 10 years of collaboration between the two organizations, is focusing on hardware, software and process development.

"Temporary- and permanent-bonding equipment and process solutions are key product offerings for EVG," says Markus Wimplinger, EVG's corporate technology development & IP director. "This project leverages CEA-Leti's global leadership in wafer-bonding research and EVG's unparalleled expertise in developing wafer bonding equipment and process technology," he adds.

"Like all common labs that Leti creates with its partners, this project is designed to produce specific, practical solutions that address current and future market requirements," notes CEA-Leti's CEO Laurent Malier. "This collaboration is targeting results that will make 3D TSV

integration more efficient and cost effective and open new areas of wafer bonding using covalent bonding at room temperature," he adds.

"Bringing these approaches to high-volume manufacturing with reliable wafer bonding requires innovative fabrication processes," says Fabrice Geiger, head of Leti's Silicon Technology division.

"The new equipment and process technology developed within the common lab will allow exciting possibilities, especially for heterogeneous materials stacks, that require very low-temperature wafer bonding."

[www.leti.fr](http://www.leti.fr)

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

## Revenue growth and new manufacturing process solutions

Wafer bonding and lithography equipment maker EV Group of St Florian, Austria says it has achieved strong revenue growth and expanded its headcount in first-half 2013. The firm attributes this to continuing demand for its flexible process solutions designed to address high-volume manufacturing (HVM) needs across multiple markets, including compound semiconductors, 3D-ICs, MEMS, and power devices.

EVG showcased its latest technology at July's SEMICON West 2013 in San Francisco. As well as unveiling a series of new solutions, EVG also says that it continues to expand its wafer processing services and process development consultation capabilities worldwide as part of the firm's long-term growth strategy.

"2013 has been a strong year for EV Group as we continue to invest in new technologies and capabilities to support our customers' ability to ramp next-generation devices to volume production quickly and cost-effectively at high yields," says Dave Kirsch, VP & general manager of EV Group North America. "This requires not only leading-edge

process equipment but also world-class global support and process development services. EVG's local teams work hand in hand with our corporate headquarters to provide increased flexibility and capability for our customers. That includes our ability to offer small-scale and pilot-production services at our global applications labs, which is a key differentiator for us and a key value proposition for customers."

In first-half 2013, EVG achieved 10% growth in sales and a more than 10% increase in staff. To support its customers' roadmaps, EVG continues to invest in R&D (about 20% of sales) in several key efforts. Among these, EVG has invested in new cleanrooms and application labs with in-house process demo capability on fully automated systems at its headquarters in Austria, as well as its regional headquarters in Japan and North America.

EVG recently unveiled several new platform developments in both fusion bonding and temporary bonding/debonding applications. At SEMICON West, it unveiled the latest version of its EVG40NT automated measurement system,

which features improved specifications to achieve the highest wafer-to-wafer alignment accuracies needed for the production of next-generation 3D integrated image sensors and stacked memory devices. The EVG40NT is integrated with EVG's GEMINI FB automated production fusion bonding system to enable closed-loop control facilitating customers' ramp to volume production across multiple markets and applications. EVG also introduced its LowTemp debonding platform, which features three high-volume-production room-temperature debonding process types and is supported by a supply chain of seven qualified adhesive suppliers to enable greater manufacturing flexibility.

Recently, the firm introduced its EVG120 automated resist processing system, which integrates spin/spray coating and wet processing, and suits applications including high-topography coating and spray coating for MEMS, thick-film resists and bumping for advanced packaging. It is also suited for passivation, dielectrics and thick-film processing for compound semiconductor devices.



## Kyma extends 2" n-type GaN substrates from government/internal use to commercial availability

### Round 2" wafers key to enabling bulk GaN to penetrate device markets

Kyma Technologies Inc of Raleigh, NC, USA, which provides crystalline gallium nitride (GaN), aluminum nitride (AlN) and aluminum gallium nitride (AlGaIn) materials and related products and services, has announced the commercial availability of 2-inch diameter n-type c-plane GaN substrates.

During its 15 year history, Kyma has produced free-standing GaN products in a variety of form factors, including c-plane substrates of 10mm squares, 18mm squares, and 30mm diameter rounds, and rectangular non-polar and semi-polar substrates of 5mm x 10mm and larger. However, 2" c-plane GaN substrates were typically held back from commercial sales for use in government contract programs or internal R&D. Improvements in the availability of 2" substrates has allowed the firm to release more of the product to commercial customers.

"GaN device manufacturers making devices on sapphire or silicon are constantly striving to improve the performance of their devices," says chief marketing officer Ed Preble. "GaN substrates allow for GaN-on-GaN growth, which results in devices that have double the thermal conductivity and 100–1000 times fewer crystal defects," he adds. "Improvements to these two material properties are critical for boosting device performance and reliability."

For most GaN-based device manufacturers, 2" round substrates are a critical form factor. Most LED manufacturers currently use 2" sapphire wafers in metal-organic chemical vapour deposition (MOCVD) GaN epitaxy systems and also in a number of post-epitaxy wafer processing systems. Providing this wafer shape is therefore critical to enabling bulk

GaN wafers to penetrate into the existing GaN device markets, says Kyma.

"We are very pleased to begin shipping 2" wafers, an important entry point for our customer's production requirements," comments CEO Keith Evans. "Kyma has long sought to improve the availability of GaN substrates for our many customers asking for this material every day, and this is a critical step for us to take."

Kyma notes that, in addition to the thermal conductivity and defect-related benefits of GaN-on-GaN device growth, there are several other benefits, including: (a) shorter, simpler epitaxy recipes; (b) higher current density and/or smaller device footprint; (c) no wafer bow after epitaxy; and (d) simpler designs for vertical device geometries.

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

## GT introduces 100mm silicon carbide production furnace

### New product line targets growth opportunities in power electronics

GT Advanced Technologies Inc of Nashua, NH, USA (a provider of polysilicon production technology as well as sapphire and silicon crystal growth systems and materials for the solar, LED and electronics markets) has introduced a silicon carbide (SiC) production furnace.

GT says that the SiClone100 uses a sublimation growth technique capable of producing high-quality semiconducting bulk SiC crystal that can be finished into wafers up to 100mm in diameter. In its initial offering, the SiClone100 is targeted at users that have developed their own hot zone, qualified a bulk crystal production recipe, and are looking to begin volume production.

"GT's new SiClone100 furnace addresses the need in the power electronics industry for more high-quality SiC material for use in

advanced, high-power, high-frequency devices," president & CEO Tom Gutierrez says. "The SiClone100 lays the foundation for our SiC product roadmap that is expected over time to provide customers with access to a complete production environment including recipes, hot zones and consumables capable of producing up to 8-inch SiC wafers," he adds.

GT says that it has leveraged its deep domain expertise in crystal growth technology to offer customers who are looking to move from 'the lab to the fab' a reliable and proven platform to begin volume production of SiC bulk crystal. The SiClone100 is equipped with a control system that helps to automate the growth process by integrating the furnace electronics into the human-machine interface (HMI)

control. The furnace uses a bottom-loading design, making it easy to load the hot zone, the firm says. The control system provides increased flexibility for users to customize process recipes and control key production parameters such as temperature, profile, ramp and gas flow, which improves run-to-run control repeatability and thus helps to lower manufacturing costs, GT adds. Also, the firm's onsite engineering and support can help users to ramp to volume production quickly.

GT expects SiC furnace sales to contribute less than 1% of its 2013 revenue, and the SiC revenue ramp in 2014 and beyond to develop at a gradual pace, given the lengthy design cycle associated with new power devices.

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

## Brooks adds four new MFCs and a technology development center for semiconductor processing applications

Brooks Instrument LLC of Hatfield, PA, USA, a provider of flow, pressure, vacuum, level and vapor delivery solutions, says it has expanded its commitment to the semiconductor industry with the introduction of four products and a new technology development center in Irvine, CA, USA.

The new products include the GF135 diagnostic mass flow controller (MFC) and three MFCs (the GF101, GF121 and GF126) for high-flow applications. The MFCs, which expand Brooks' GF100 Series product line for semiconductor processing applications, are all built on a common platform and interface, enabling an entire system to use one product platform.

"Our strategic focus for the technology center will be to strengthen our relationships with semiconductor end-users and equipment manufacturers so we can translate customer needs into product requirements," says chief technology officer Bill Valentine.

The GF135 is claimed to be the first 'smart' pressure transient insensitive (PTI) MFC that can perform self-diagnostics – including integral rate-of-decay flow measurement – without stopping the flow of process gas. The firm says that semiconductor makers can now verify accuracy, check valve leak-by, and monitor sensor drift in real time without removing the flow controller from the gas line. The new diagnostic technology allows uninterrupted production of wafers and hence potentially daily cost savings.

The GF101, GF121 and GF126 are high-flow thermal MFCs that suit LED and semiconductor process and purge applications requiring ultra-high purity and flow rates up to 300slpm, says Brooks. As well as delivering good accuracy, response time and reliability, the MFCs have a small footprint, adds the firm.

The new products were showcased at the SEMICON West trade show in San Francisco (9–11 July).

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



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## IN BRIEF

### Bridgelux appoints Future Electronics as global distributor

Bridgelux Inc of Livermore, CA, USA has signed a global distribution agreement with Future Electronics. Its lighting division Future Lighting Solutions will provide global sales, design support and fulfillment services for Bridgelux's portfolio of LED products sold through distribution.

"With a world-class web platform, deep lighting application knowledge and leading global distribution capabilities, Future Lighting Solutions has distinguished itself as an innovative and extremely customer-focused organization, with strong demand creation programs," says Max Hong, executive VP of sales & marketing for Bridgelux. "Combining Future Lighting Solutions' leading-edge selling, marketing and technical support strengths with Bridgelux's high-performance LED technology portfolio will produce an alliance to accelerate the worldwide transformation to solid-state lighting."

"Bridgelux's innovative product offering targets the rapidly increasing demand for high-quality, energy-efficient internal and external LED lighting solutions for retail, commercial and residential environments," says Jamie Singerman, corporate VP, worldwide of Future Lighting Solutions. "The partnership with Bridgelux presents Future Lighting Solutions with significant growth opportunities by delivering access to an even broader base of customers. Innovative new Bridgelux products, such as the Vero array platform, complement our SSL product line, increasing our ability to deliver design solutions across a wider range of applications and markets for our global customers."

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

## Bridgelux's Vero Series LED arrays shipping with higher efficacy and tighter color binning

Bridgelux Inc of Livermore, CA, USA says that its Vero series of LED array products (made available commercially in April) are now shipping with what is claimed to be industry-leading luminous efficacy of 120lm/W (nominal) and 110lm/W (minimum average), yielding lumen output ranging from 240lm to 16,400lm. This performance enhancement delivers energy savings of about 11% over the prior product generation and provides a significantly accelerated return on investment, adds the firm.

As well as a broad range of correlated color index (CCT) options from 2700K to 5000K and color rendering index (CRI) options including the 70, 80, 90, and 97 CRI Décor products, the Vero Series arrays are also now available with both 2SDCM and 3SDCM (2-step and 3-step Standard Deviation Colour Matching) MacAdam ellipse binning options for color control precision and uniformity (3SDCM standard for 2700–4000K CCT, with 2SDCM options now available). The 120lm/W efficacy is an average performance across all form factors in the Vero Array Series based on 3000K 80CRI configurations driven at nominal currents. With some Vero configurations driven at lower currents, users can achieve efficacies up to 140lm/w. The Vero arrays also deliver what are claimed to be industry-leading average minimums of 110lm/w and provide designers with best-in-class design and manufacturability flexibility, claims the firm.

The Vero platform enables plug & play connectivity for lighting manufacturers, streamlining production processes for lighting manufacturers, says Bridgelux. These capabilities lead to shorter product development times, lower inventory requirements, reduced costs and more light with



**Bridgelux's Vero Series LEDs.**

less energy, the firm adds. Also, the more precise standard color control options of either 2SDCM or 3SDCM improves the quality of light by providing greater consistency and uniformity between adjacent light sources, enabling consistent lighting installations with both high-quality color rendering and appearance, says Bridgelux.

The Vero Series also exceeds the California Energy Commission (CEC) requirements for a R9 saturated red level of greater than 50 for luminaires and lamps.

Vero arrays are compatible with a wide variety of standard drivers (350mA increments) and optical components, providing lighting manufacturers with greater flexibility and a wide range of options (shortening product development times, lowering inventory requirements and reducing costs), Bridgelux claims. Electrical connections can be established with thermally isolated solder pads (reducing manufacturing time and complexity) or by using a solder-less on-board connector port (simplifying manufacturing processes, reducing production time/cost, and eliminating the potential for solder failures, as well as enabling plug & play connectivity and field upgradability).

Vero Series Arrays are available now in four different sizes with performance specifications to fit a broad spectrum of residential, commercial, industrial and interior/exterior applications.

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

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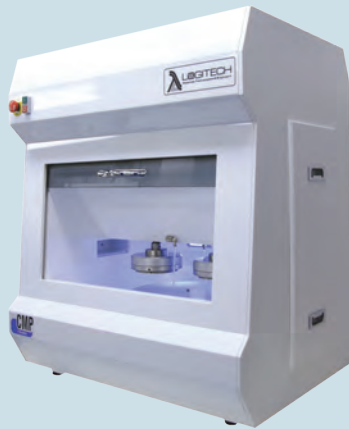
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## IN BRIEF

### Plessey releases 350mW LEDs

Plessey Semiconductors Ltd of Plymouth, UK says that samples of a 350mW gallium nitride-on-silicon LED are now available.

The entry-level lighting products (part number PLB010350) are manufactured on Plessey's 6" MAGIC (Manufactured on GaN I/C) line. They are targeted at solid-state lighting and entertainment-type lighting products including accent lighting, wall washing, wall grazing, strip-lighting and pulse lighting applications.

Plessey announced the first commercially available GaN on large-diameter silicon LEDs in April. "The MAGIC LED product range is expanding in both light output and efficacy," says Plessey's chief operating officer Barry Dennington. "The PLB010350 is our first high-current device, operating at anywhere from 350mA through to 2A in pulse applications," he adds.

"We have also been able to demonstrate the versatility and the potential of the Plessey GaN-on-Si technology by constructing an LED with a relatively large die area," continues Dennington. "This new 350mW product demonstrates the inherent flexibility we have for the manufacture of LEDs with a 6" GaN-on-Si substrate in an integrated circuit manufacturing line," he adds.

"We are seeing continual improvements in output efficiencies in the lab, which means we will continue to launch new products in line with our product release plan."

The use of the MAGIC GaN line — which employs standard semiconductor manufacturing processing — provides yield entitlements of over 95% and fast processing times, providing a cost advantage over standard LEDs of similar quality, reckons the firm.

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

## Tyndall's Brian Corbett wins Intel Outstanding Researcher Award

Brian Corbett of Ireland's Tyndall National Institute, University College Cork (UCC) has received an Intel Outstanding Researcher Award for 2013. He is the third Tyndall researcher to win the annual honor. Tyndall has now won three of the 11 Intel Outstanding Researcher Awards given to date.

The award is in recognition of outstanding contributions that Corbett and his team have made in photonics and material science over a number of years funded by Intel's Semiconductor Technology Council.

Corbett's research aims to investigate the critical light source for fiber connections to the CPU in a computer. Tyndall says that he and his team have delivered practical results consistently over the last few years and the team's expertise in device fabrication and characterization have enabled the project to meet its milestones. In addition, through regular contact with Intel experts in Portland, OR, USA, Corbett has provided insight and understanding into the behavior of fabricated photonic devices and associated assembly challenges, while working on ways to improve the design and process flow, the institute adds.

The award was presented by Dr Keln Kuhn (an Intel fellow and director of Advanced Device Technology at the Technology Manufacturing Group), joined by Anita McGuire (VP of Research at UCC). "In making these awards we give careful consideration to both the excellence of the research and its practical applications... Corbett has excelled in both categories," Kuhn commented. The award is "a strong endorsement of the quality and breadth of the research in the Cork facility," adds Intel Ireland's research manager Leonard Hobbs.

In 2009 Corbett also won the Enterprise Ireland Commercialisation Award for his work on the applications of photonics devices. In particular,



Keln Kuhn with Brian Corbett.

research by Corbett and his III-V Materials and Devices group on Micro LEDs ( $\mu$ LEDs) led in 2010 to the formation of InfiniLED, an LED development and production portfolio company of ScienceWorks Ventures plc (a London-based IP commercialization company with an operations centre in Cork). InfiniLED develops LED light source modules based on patented  $\mu$ LED technology (licensed from Tyndall), which is said to have performance benefits over conventional LEDs (mainly a significant reduction in the illumination area and in battery power required to run the LED).

"He has made substantial contributions to both the fundamental understanding of photonic materials and the applications of photonic devices," commented InfiniLED's chief commercial officer Bill Henry. "The range of both academic and industrial collaborators that the III-V Group has worked with over the years highlights the breadth of their work," he adds.

InfiniLED maintains a strong on-going relationship with Corbett's research group and Tyndall. As well as an access agreement with Tyndall, InfiniLED has research projects focused on new developments and industrial applications of the  $\mu$ LED technology, as well as development contracts with international customers. Applications range from diagnostic testing devices to consumer products.

[www.tyndall.ie](http://www.tyndall.ie)

## Cambridge Nanotherm delivers first order for its Chip-on-Heatsink technology in partnership with design & assembly firm Optocap

In partnership with contract microelectronic and optoelectronic packaging design & assembly firm Optocap Ltd of Livingston, Scotland, UK, Cambridge Nanotherm Ltd of Haverhill, UK says the first commercial order for its Chip-on-Heatsink modules have been shipped to a customer in the LED industry.

"As a design and assembly service provider we need to ensure we specify materials that will enhance our customers' products," says Optocap's CEO David Ruxton. "We specified Cambridge Nanotherm's technology due to the outstanding thermal performance it enables," he adds. "It also means a reduced bill of materials, simplified supplier management and easier assembly for our customer."

Established in 2010 to commercialize proprietary nano-ceramic technology for the electronic industry, Cambridge Nanotherm was supported by grants from the UK Technology Strategy Board (TSB), East of England Development Agency (EEDA) and European Regional Development Fund (ERDF) and was a member of the Carbon Trust Fast-track Entrepreneur Programme. Since 2011 it has been financially backed by Enso Ventures. The firm was the UK winner of the 2011 Clean Tech Open Competition, sponsored by Silicon Valley Bank.

Cambridge Nanotherm's core IP is a unique process for converting aluminium into alumina. The process allows the surface of any aluminium object to be converted into a dielectric layer. In the case of the Chip-on-Heatsink approach, an extruded heat-sink or heat-pipe can be coated and then metallized with the end-user's circuit design. Nanotherm's technology enabled Optocap to utilize its advanced manufacturing processes, allowing direct assembly of die and surface-

mount components onto the heat-sink, creating a fully integrated module.

For LED lighting customers using conventional PCB materials and heat-sinks, the advantages are three-fold:

- (1) a cost reduction is seen through the removal of both the MCPCB and thermal interface material (TIM) components;
- (2) the removal of these layers gives the most efficient thermal path between component and heat-sink;
- (3) as a result of minimizing thermal resistance, denser component layouts can be realised.

For those using thick-film or thin-film metallized alumina and aluminium nitride ceramic heat-sinks, the cost reduction is even more significant, while bulk thermal performance of the aluminium heat-sink matches one made from aluminium nitride.

**Nanotherm's technology enabled Optocap to utilize its advanced manufacturing processes, allowing direct assembly of die and surface-mount components onto the heat-sink, creating a fully integrated module**

"We are very pleased to have Optocap as the world's first commercial customer for the first ever Chip-on-Heatsink product," says Cambridge Nanotherm's CEO Dr Pavel Shashkov. "Working with Optocap we were able to demonstrate that our product has clear technological advantages as well as real commercial benefits," he adds.

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

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

### IN BRIEF

#### Demand for Soraa's GaN-on-GaN LED MR16 lamps spurs expansion of its sales team

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has appointed George Stringer as senior VP of North America Sales and Nick Faraway as senior VP of International Sales, both reporting to president & chief operating officer Dr Tom Caulfield. The firm says that the appointments are due to a surge in demand for its full-visible-spectrum GaN-on-GaN LED MR16 lamps.

Stringer joins Soraa following 16 years in senior level sales and sales management roles with Acuity Brands Lighting, most recently as VP & general manager for Corporate Accounts, Renovation, and Government. He brings to Soraa considerable expertise in all sales channels and motions; direct, distribution, manufacturer's representatives, and national and regional accounts, says the firm.

With over 30 years of global industry experience, Faraway brings a wide range of expertise in lamps, fixtures and applications to Soraa. He previously held senior executive roles at Sylvania, Thorn and Zumtobel Lighting, working through all channels from international project specification to general wholesale distribution and retail. He led the successful bid teams on several prominent international projects, including London Heathrow Airport Terminal 5 and Wembley International Football Stadium. Faraway holds a BEng from Middlesex University.

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



## Cree extends its series of LED bulbs to meet growing consumer demand

Just four months after introducing Cree LED light bulbs in March, LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has introduced the Cree LED BR30 flood light, which the firm says looks and lights like a traditional incandescent BR30 but uses 85% less energy and is designed to last 25 times longer than comparable incandescent flood lights.

Featuring the same shape, same glass dome and same color light of the typical incandescent flood it replaces, the new Cree LED flood

light blends with existing BR flood lights and gives consumers the flexibility to upgrade one or multiple bulbs without any noticeable difference — especially in recessed-lighting applications. The new LED BR30 flood lights are backed by Cree's 10-year limited warranty and are available exclusively at The Home Depot. The BR30 has a retail price of \$19.97 for the soft-white (2700K) 65-watt incandescent replacement and \$21.97 for the daylight (5000K) color version.

The BR30 is suitable for use in most common track, recessed and hard-to-reach fixtures, says the firm. The LED bulbs turn on instantly and are dimmable with most standard incandescent dimmers. Both versions of the new Cree bulbs deliver 650 lumens and consume only 9.5W.

"Cree is committed to solving consumer problems by delivering products that are better than those being replaced, while maintaining the experience people expect," says chairman & CEO Chuck Swoboda.

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

## LED street luminaire for challenging environmental requirements

Cree has introduced the XSP IP66 LED street luminaires, which are optimized for European and other global environmental requirements. Providing metropolitan and other municipal areas with a durable luminaire that protects critical electrical components from dust, water jets and other potentially damaging environmental factors, the XSP is claimed to be the first real alternative to high-pressure sodium (HPS) street lights with better payback, better performance and better price. Compared to its outdated predecessor, the XSP IP66 uses nearly 50% less energy and is designed to last more than three times longer.

Beyond saving energy and reducing maintenance due to longer life-

time, Cree says that it achieves better control over luminaire output through its NanoOptic Precision Delivery Grid technology compared to a traditional street light. The new XSP IP66 features similar aesthetics to a traditional HPS street light while achieving what is claimed to be unmatched target illumination.

"XSP IP66 is the ideal choice for metropolitan and other municipal areas looking to save money and reduce maintenance costs," comments Massimo Targetti, managing director, Cree Europe S.r.l. "Designed to meet the demanding needs of global markets, the XSP IP66 represents the perfect combination of high-performance design and advanced LED technology," he

adds. "The optimized LED street luminaire design makes it easy for municipalities to upgrade from incumbent technologies for both retrofit and new construction applications."

The XSP IP66 offers a ten-year warranty and is available in both single and double module configurations. The luminaire also features thermal management and electronics critical to high-reliability operation in the most challenging applications. The result is a high-performance luminaire that does not compromise longevity or light quality at the cost of performance. The new luminaire delivers a range of lumen packages and distributions optimized for the most common street-light applications.

## Cree adds UK and Nordic lighting sales manager

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has appointed Darren Marsh as lighting sales manager of Cree Europe for the UK and Nordic regions. In the newly created role, Marsh will closely collaborate with Cree's strategic lighting allies in the UK and Scandinavia to help strengthen and grow the local business in these regions.

"The UK is a key market for our strategic growth plans in Europe," says Alessandro Targetti, commercial director, Cree Europe S.r.l. in Florence, Italy. "Darren has gained a wealth of experience in the lighting market during his career, which will serve as a significant asset to helping strengthen our business in the UK."

Marsh has more than 25 years of

experience in the lighting industry in a business development role, as well as in the OEM lighting and electrical wholesale business channels.

"With LED lighting now in the mainstream, the differential will be in delivering customers consistent quality through continual innovation," comments Marsh.

[www.Cree.com/Lighting](http://www.Cree.com/Lighting)

## Cree expands CXA LED product family

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has expanded its CXA product family with new 95-CRI options and two new LEDs. Delivering up to twice the efficacy of equivalent-CRI LED light sources, the new CXA CRI options deliver halogen-like color and push the boundaries of lighting-class performance by combining high-quality light with unmatched light output and efficacy, says the firm. Cree's extended family of CXA LED Arrays include the XLamp CXA1304 and CXA1816.

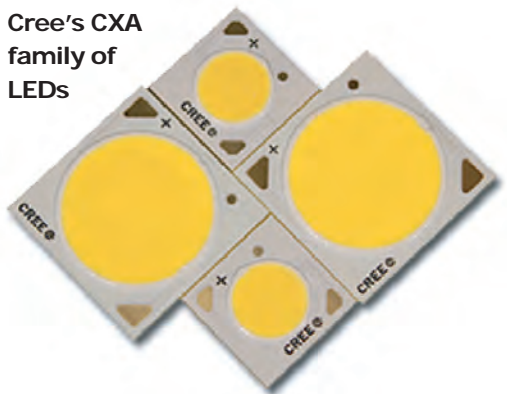
The XLamp CXA1304 LED Array is the most compact member of the family, delivering up to 1034 lumens in a 6mm optical-source size, and enabling lighting manufacturers to rapidly address small-form-factor lighting applications. The XLamp CXA1816 LED Array can enable LED replacements for up to 70-watt ceramic-metal-halide in spot lighting or for 2000 lumen downlights with a 12mm optical-source size.

"The family of CXA LED Arrays appeals to us because of the wide range of lumen options available, all at very high efficacy levels," says Michael Lin, CEO of Buckingham Industrial Group. "Regardless of the lighting application that we want to address, there is a CXA LED Array offered that is optimized for it."

Customers are looking for LED-based halogen replacements that do not have the current trade-off between light quality

and output with energy efficiency," says Paul Thieken, Cree director of marketing, LED components. "With Cree's high-CRI CXA LED Arrays, lighting manufacturers finally

**Cree's CXA family of LEDs**



have an LED solution that can deliver high quality-of-light combined with high performance."

All the LEDs in the CXA family offer 6000 hours of LM-80 data published and are designed to support TM-21 reported L90 lifetime of over four years, even at 105°C. Available in 5000K through 2700K CCTs, the high-CRI CXA LED Arrays deliver a typical CRI of 95 with a typical R9 value of 85 at 3000K. All CXA LED Arrays are available in EasyWhite color temperatures. The new family of CXA LED Arrays now delivers from 300 to over 10,000 lumens.

XLamp CXA1304 (9V and 37V options available) and CXA1816 LED samples are available now, and production quantities are available with standard lead times.

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



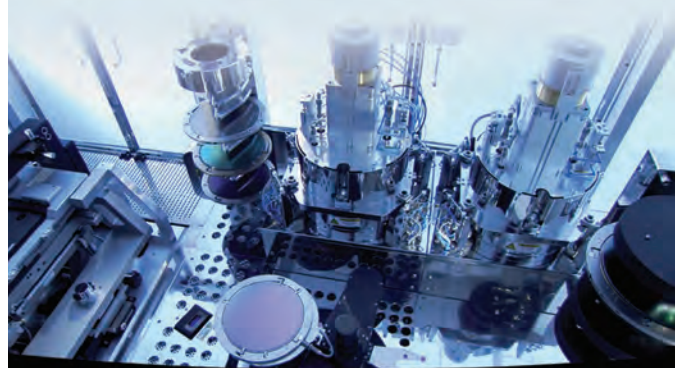
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## Seoul Semiconductor achieves efficacy of 180lm/W and cuts cost by 50% with new mid-power LEDs

South Korean LED maker Seoul Semiconductor has introduced two mid-power packaged LED lighting products, the 5630C and the 3030.

With luminous efficacy of 180lm/W (claimed to be a world best), the 5630C is an extension of the mid-power LED lighting family that Seoul Semiconductor released as one of the first mid-power LEDs for solid-state lighting products, and targets high-growth LED lighting applications including bulbs, tubes and panel lights in the USA,

Japan, and Europe.

The 3030 LED extends the firm's mid-power offering up to the high-power 1 watt range by enhancing both the LED chip and package in terms of heat resistance. As opposed to traditional 3030 packaged LEDs for mid-power applications only, these new versions can also be used in high-power applications, with the additional benefit of reducing costs by up to 50%, says the firm.

"The 3030 and 5630 packages are

LED products which focus on both price competitiveness (lm/\$) and luminance efficiency (lm/W)," says VP of marketing Marten Willemsen. "We have already sold billions of pieces in China, USA, and Europe for various LED lighting products," he adds. "If you use these two LEDs properly, you can chase two rabbits at the same time in terms of 'lm/W' and 'lm/\$' which most lighting designers consider the most important factors."

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

## Cree introduces 750lm integrated LED module for residential downlighting

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has announced commercial availability of its 750-lumen LMR2 LED module, which combines light source, driver, optics and primary thermal management in a single, compact system, simplifying retrofit and new installation.

The new LMR2 LED module shares the same form factor of the commercial LMR2 yet is optimized for the performance, dimming and cost requirements of the residential market, providing manufacturers the investment protection of a single platform for all applications, says the firm. The LMR2 LED module series shares the same optical and mechanical interface as Cree's LMH2 LED modules, which enables

lighting manufacturers to leverage existing luminaire designs to help speed product development and shorten time to market.

"We worked closely with Cree to design a cost-effective system, while still maintaining the high product quality Nora is known for," says Fred Farzan, president of Nora Lighting. "With the new Cree LMR2 LED module, we are able to deliver higher lumen output and efficacy in a single-unit design that more easily integrates into existing single-piece incandescent downlight design.

With the help of Cree's technology, Nora is able to meet market demands and keep our customers competitive with the highest quality products."

Featuring Cree EasyWhite technology, the LMR2 delivers 750 lumens

at 72 lumens-per-watt, 80-CRI and is available in color temperatures of 2700K, 3000K, 3500K and 4000K. Designed for 35,000 hours of operation and dimmable to five percent and compatible with most standard dimmers, the LMR2 comes with Cree's three-year warranty. The LMR2 is UL-recognized, and luminaire makers seeking ENERGY STAR and California Code of Regulations Title 24 qualification will have access to specification and performance data, including LM-80 reports, which can speed regulatory approvals.

Cree EasyWhite technology allows lighting manufacturers to deliver consistent lumen output across all available color temperatures while maintaining a tight color consistency.

[www.cree.com/lmr2](http://www.cree.com/lmr2)

## Osram Opto wins Yazaki's 'Green Supplier of the Year'

LED maker Osram Opto Semiconductors GmbH of Regensburg, Germany has been named 'Green Supplier of the Year' by automotive supplier Yazaki North America at its annual awards ceremony (on 5 June to honor World Environment Day). Yazaki also recognized Osram Opto as the Best in Class Green supplier

for 2012-2013. Osram was chosen from Yazaki's top 103 suppliers in North and Central America.

"At Osram Opto Semiconductors, we follow a responsible, sustainable and careful environmental policy," says chief operating officer Frank Tillner. "Our programs to save energy, protect water and avoid

chemical waste are improving every day... not only in production, but also within our products."

Yazaki recognized Osram for its contributions to the preservation of the environment through its manufacturing, production, and delivery processes.

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## IN BRIEF

### Siemens spin-off Osram goes public, becoming an independent firm

The spin-off of Osram Licht AG from parent firm Siemens AG of Munich, Germany became effective on 5 July with its final entry into the Commercial Register, making Osram an officially independent firm. With this move, the world's largest pure-play lighting firm has gone public. Osram says that, as an integrated lighting firm, it offers the entire spectrum from LED chip to lamp, luminaire and all the way to complex lighting solutions.

The spin-off is made on the basis of the Spin-Off and Acquisition Agreement of 28 November 2012 (authorized by the general meetings of Siemens on 23 January 2013 and of Osram Licht AG on 21 January 2013). Now, all shares of Osram Licht have been admitted to the regulated market of the Frankfurt and Munich Stock Exchanges, as well as to the sub-segment of the regulated market with additional post-admission obligations (Prime Standard) of the Frankfurt Stock Exchange. Trading of Osram Licht shares commenced on 8 July, under the ticker symbol OSR. Osram Licht's overall capital stock is divided into more than 100 million shares, of which 80% are allotted to existing Siemens shareholders at a ratio of 10:1 (i.e. the given shareholder will receive one new Osram share for every ten Siemens shares).

Osram says that it generates more than 70% of its revenue via energy-efficient products, with LED-based products already accounting for more than 25% of its overall revenue.

[www.siemens.com](http://www.siemens.com)  
[www.osram.com](http://www.osram.com)

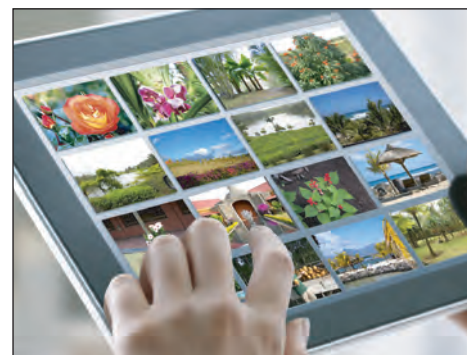
## Osram launches LEDs with high efficiency, constant brightness and good color rendering for display backlighting in portable devices

Osram Opto Semiconductors GmbH of Regensburg, Germany says that, even at high temperatures and high currents, its new MicroSideled 3806 ensures stable light conditions on the display. The brightness of the light-emitting diode, which is available in white and blue, remains constant throughout its lifetime. They also offer high efficiency, so the light sources suit portable devices such as tablets and smartphones.

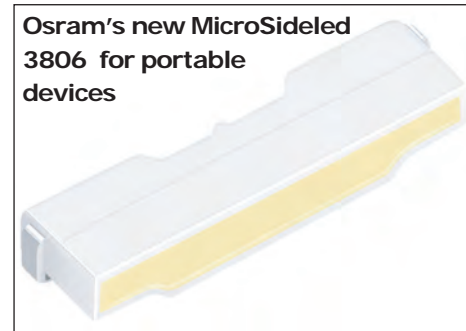
Multifunctional devices such as tablets, ultrabooks and even smartphones need high brightness levels and good color rendering without draining the batteries too quickly. Osram Opto says that the MicroSideled 3806 has been designed specifically to meet these requirements. It is very efficient in white and also in blue, offers constant brightness throughout its lifetime of 15,000 hours, and can withstand high temperatures and high currents. At the end of its rated life, half of the LEDs will still provide 70% of their initial brightness (L70/B50).

The white version is a classic LED with chip and converter, achieving high luminous efficiency of 150lm/W. "For white in particular we offer very fine binning, so there is always a uniform color over the entire backlit surface," says Matthias Winter, marketing director, consumer. The color temperature range is 2700–10,000K.

The blue MicroSideled has 55% external quantum efficiency (EQE, the ratio of the electrical power used to the optical power emitted). The LED is designed for display technology that uses quantum dots (nano-particles) in the conversion material. This conversion technology features a thin sheet containing quantum dots (a quantum dot sheet) in the backlighting. This



A tablet PC containing Osram's new MicroSideled 3806 LEDs.



sheet is illuminated by the blue LEDs. This in turn leads to a very narrow-band emission spectrum that accurately hits the color filters of the backlighting unit. Light losses are therefore kept to a minimum and the colors are more vibrant, says the firm. System efficiency is hence 10–15% greater than with classic white LED solutions, it is reckoned. Also, coverage of the color space is 33% better than with classic white LED systems.

Both versions are compact, measuring only 3.8mm by 1.0mm (by 0.6mm high), and have good thermal conductivity with a thermal resistance of 66K/W.

"The new MicroSideled offers extraordinarily high efficiency, constant brightness and brilliant color rendering, irrespective of which technology is used to create white light," summarizes Winter.

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

## Lawsuit against SemiLEDs alleges securities violations

An investor who purchased shares of LED chip and component maker SemiLEDs Corp has filed a lawsuit in the US District Court for the Southern District of New York over alleged violations of Federal Securities Laws by SemiLEDs in connection with certain allegedly false and misleading statements made between 9 December 2010 and 12 July 2011.

On behalf of purchasers of SemiLEDs' common stock during that time, the plaintiff alleges that SemiLEDs and certain of its officers violated the Securities Exchange Act, specifically that defendants failed to disclose that: SemiLEDs was experiencing known, but undisclosed, pricing pressures for its products which were reasonably likely to have a material adverse effect on SemiLEDs' future revenues and operating income, that known events or uncertainties — including the reduction in demand for SemiLEDs' products, the likely (and ultimate) loss of a large customer, and the decline in the value of SemiLEDs' inventory — were reasonably likely to cause SemiLEDs' financial information not to be indicative of future operating results; that SemiLEDs' disclosure controls were materially deficient and its representations concerning them were materially false and misleading; that the certifications issued by defendants associated with the company's disclosure controls were materially false and misleading; and that, based on the foregoing, defendants lacked a reasonable basis for their positive statements about SemiLEDs, and its then current business and future financial prospects.

SemiLEDs reported that revenue rose from \$11.55m for the 12 months to end-August 2009 to \$35.76m for the 12 months to end-August 2010, and that its net loss of \$3.69m for 12 months to end-August 2009 turned into a net income of \$10.83m for the 12 months to end-August 2010. SemiLEDs' shares traded in December 2010 at \$29.50 per share.

SemiLEDs reported its results for fiscal Q3/2011 on 7 July 2011 and

for fiscal Q4 and full-year 2011 that November. Shares fell from almost \$30 at the end of 2010 to under \$3 at the end of 2011. On 12 July 2012, NASDAQ:LEDS shares were \$1.33.

Law firm Shareholders Foundation of San Diego, CA, USA says that investors who bought shares between 9 December 2010 and 12 July 2011, and those who bought NASDAQ:LEDS

shares prior to December 2010 and currently hold any of those shares, have certain options and, for certain investors, there are strict deadlines. NASDAQ:LEDS investors can e-mail [mail@shareholdersfoundation.com](mailto:mail@shareholdersfoundation.com) or call +1(858)-779-1554, by 9 September.

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

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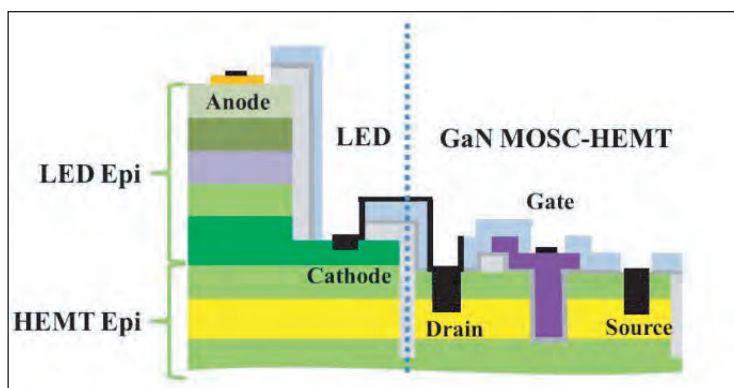
# RPI's Smart Lighting ERC demos first monolithic integration of LED and HEMT on GaN chip

**Light-emitting integrated circuit promise more efficient LED lighting and new smart lighting applications**

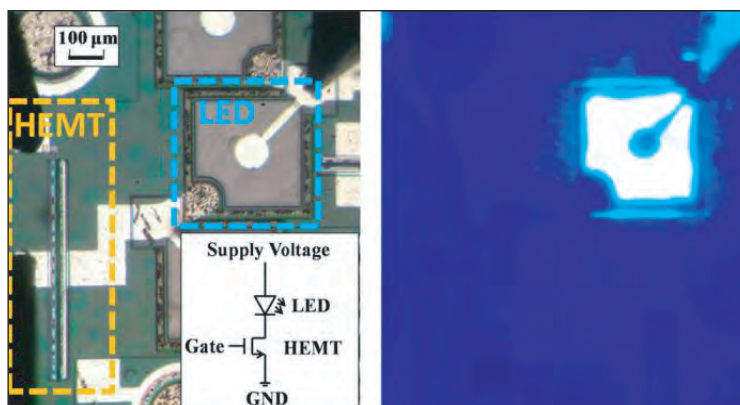
The Smart Lighting Engineering Research Center at Rensselaer Polytechnic Institute (RPI) in Troy, NY, USA has demonstrated what is said to be the first monolithically integrated light-emitting diode (LED) and high-electron-mobility transistor (HEMT) on the same gallium nitride (GaN) chip. It is reckoned that the development could open the door to a new generation of LED technology which is less expensive to manufacture, much more efficient, and which enables new functionalities and applications beyond illumination.

In existing LED lighting systems, for the LED to function, external components — such as inductors, capacitors, silicon interconnects, and wires — must be installed on or integrated into the chip. Due to these essential components, the large size of the chip complicates the design and performance of LED lighting products. Additionally, the process of assembling the complex LED lighting systems can be slow, manually intensive, and expensive.

In a study 'Monolithic integration of light-emitting diodes and power metal-oxide semiconductor channel high-electron-mobility transistors for light-emitting power integrated circuits in GaN on sapphire substrate' (Appl. Phys. Lett. 102, 192107 (2013)) led by T. Paul Chow, professor in the Department of Electrical, Computer, and Systems Engineering (ECSE) at RPI, the researchers hence sought to develop a chip with components all made from GaN. The monolithically integrated integration simplifies LED device manufacturing, requiring fewer assembly steps and less automation. Also, LED devices made with monolithically integrated chips will have fewer parts to malfunction, higher energy efficiency and cost effectiveness, and greater lighting design flexibility, it is reckoned.



**Cross-section of RPI's monolithically integrated LED & HEMT.**



**Integrated LED and HEMT, with LED off (left) and on (right).**

The research team grew a GaN LED structure directly on top of a GaN HEMT structure. Using basic techniques to interconnect the two regions, they created what is reckoned to be the first monolithic integration of a HEMT and an LED on the same GaN-based chip. The device, grown on a sapphire substrate, demonstrated light output and light density comparable to standard GaN LED devices. Chow reckons that the study is a key step toward creating a new class of optoelectronic device: the light-emitting integrated circuit (LEIC).

"Just as the integration of many silicon devices in a single chip — integrated circuits — has enabled powerful compact computers and a wide range of smart device technology, the LEIC will play a pivotal role in cost-effective monolithic integ-

ration of electronics and LED technology for new smart lighting applications and more efficient LED lighting systems," Chow says.

"LEICs will result in even higher energy efficiency of LED lighting systems," says Smart Lighting ERC director Robert Karlicek, co-author of the study and ECSE professor at RPI. "What will be even more exciting are the new devices, new applications, and new breakthroughs

enabled by LEICs."

Along with Chow and Karlicek, co-authors of the paper are: Christian Wetzel, the Wellfleet Constellation Professor of Future Chips at Rensselaer and a faculty member in the Department of Physics, Applied Physics, and Astronomy; Rensselaer graduate students Zhongda Li and John Waldron; and former Rensselaer research associate professor Theeradetch Detchprohm.

The research was funded by the US National Science Foundation (NSF) via the Smart Lighting ERC, with additional support from New York State via Empire State Development's Division of Science, Technology and Innovation (NYSTAR).

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## IN BRIEF

### Avago completes CyOptics acquisition

Avago Technologies Ltd has completed its acquisition of CyOptics Inc of Lehigh Valley, PA, USA, which makes indium phosphide-based optical chips and components, for about \$400m in cash.

Avago believes that the acquisition of CyOptics will strengthen its fiber-optics product portfolio for emerging 40G and 100G enterprise and data-center applications, with CyOptics' single-mode InP laser, receiver and photonics integration capability helping to extend its technology position.

Avago's optical transceiver products currently primarily leverage vertical-cavity surface-emitting laser (VCSEL)-based technology. Avago also expects the acquisition to facilitate its establishment of a complementary optical components business, not only to serve growing segments of the access, metro and long-haul markets but also for the enterprise and data-center segments.

CyOptics designs, fabricates and packages optical communications components for integration into transceivers, transponders and line-cards in enterprise, data-center, access, metro and long-haul networks. Leveraging its heritage from Bell Labs and Lucent, CyOptics has built a broad product portfolio and a customer base that includes the leading module and system OEMs, it is claimed. Revenue has more than tripled over the past three years, including rising by 21% from 2011 to about \$210m in 2012.

CyOptics' InP technology and optical manufacturing capability will accelerate Avago's ability to capture next-generation 40G and 100G enterprise and data-center sockets, believes Avago's president & CEO Hock Tan.

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

## OPEL achieves Milestone 6 in POET platform development roadmap ahead of schedule

### Complementary HFET-based inverter operation demonstrated

OPEL Technologies Inc of Toronto, Ontario, Canada — which develops III-V devices and processes via US affiliate OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT, USA — has achieved Milestone 6 in the development roadmap of its proprietary planar optoelectronic technology (POET) platform.

Developed by chief scientist Dr Geoff Taylor and his team over the past 18 years in cooperation with the University of Connecticut in Storrs, OPEL's POET platform enables monolithic fabrication of integrated circuit GaAs III-V semiconductor devices containing both electronic and optical elements on a single wafer, offering a next-generation alternative to silicon complementary metal-oxide semiconductor (CMOS) technology.

The new milestone is the integration of the complementary inverter (the basis for all on-chip logic). Specifically, OPEL has demonstrated complementary heterostructure field-effect transistor (HFET)-based inverter operation using POET.

Peter Copetti, executive director of OPEL and chair of its Special Strategic Committee (SSC) for commercialization of the POET platform, notes: "The SSC deemed Milestone 6 to be critical for our commercialization activities, and staff focused on this milestone. That we achieved Milestone 6 so quickly spotlights the caliber of the POET team, and our ability to execute and to pivot to industry needs."

Copetti added: "Due to ongoing needs of the SSC, other pre-determined milestones and dates may have to change without notice — but any changes will be consistent with our commercialization mandate."

OPEL says that the achievement of Milestone 6 obviates the need for Milestone 5 (3/4 terminal switching

laser, second-quarter 2013). Milestone 6 was originally scheduled for Q3/2013, and its achievement in Q2 puts OPEL ahead of its targeted development milestones.

"To serve the digital marketplace currently dominated by CMOS, complementary functions in GaAs/InGaAs are essential," says Taylor. "With this milestone, this functionality has been demonstrated on a POET device."

The OPEL lab demonstrated both nHFETs and pHFETs, with symmetrical positive thresholds, as an integrated circuit with thresholds of  $\pm 0.5V$  and  $V_D = 2V$  for  $1\mu m$  gates. Going forward, logic circuits will be integrated with in-plane lasers and detectors with the goal of reducing linewidths towards state-of-art CMOS circuits.

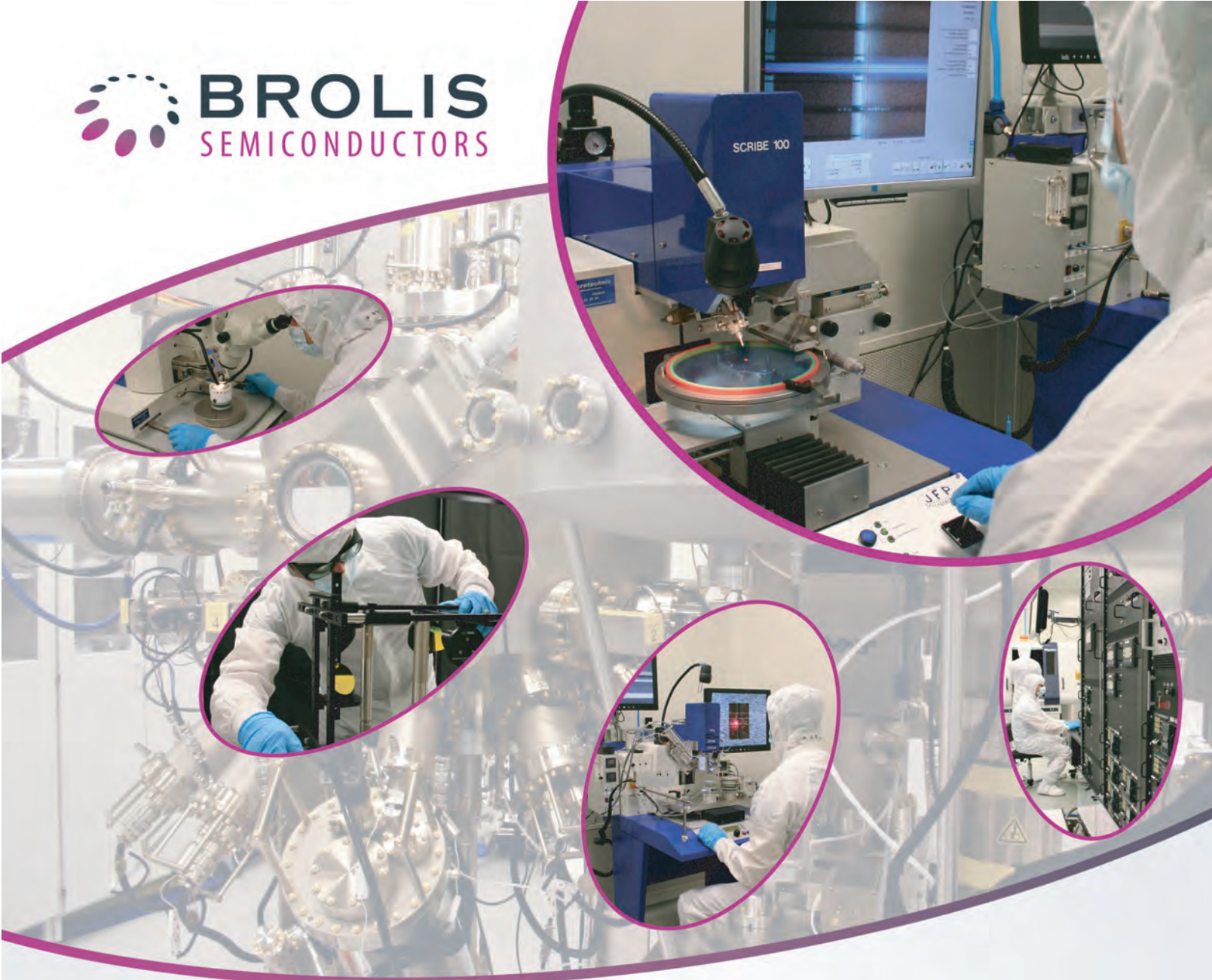
Coupled with the achievement of its previous milestones — including demonstration of the vertical-cavity laser — POET extends the capability of its unique monolithic platform, says the firm.

"This further underlines the capacity that POET has to be a disruptive technology, able to address current and future challenges facing the semiconductor industry, and provides the SSC with further momentum for its initiatives," says OPEL's president & CEO Leon Pierhal.

By offering components with increased speed, density, reliability, power efficiency and lower costs, POET offers the ability to push Moore's Law to the next level, claims the firm, overcoming existing silicon-based power and speed bottlenecks and potentially changing the roadmap for a broad range of applications, such as computer servers, storage arrays, imaging equipment, smartphones, tablet and wearable devices.

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





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# NeoPhotonics opens factory in China to support increased demand in cloud computing and 4G/LTE wireless networks

## Added capacity targets high-volume optical modules in cloud computing, broadband access, and 4G/LTE wireless networks

NeoPhotonics Corp of San Jose, CA, USA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems, has announced the first shipments of optical transceiver modules from its new, high-capacity factory in Dongguan, Guangdong Province, China.

"This milestone represents our commitment to our customers for production capacity to support their increasing need for high-speed optical modules in the accelerating

build out of broadband network infrastructure around the world," says chairman & CEO Tim Jenks. "Rapid growth in cloud computing, video and mobile applications is driving increased demand for optical modules in datacenter, 4G/LTE networks and FTTx deployments, both in established markets as well as emerging regions, such as the BRIC countries."

The new factory consists of about 80,000 square feet of production space, including about 50,000 square feet of cleanroom area. The production lines use manufacturing

equipment for optical sub-assembly (OSA) fabrication and final module assembly and test. Modular work cells are designed to support rapid reconfiguration of production lines, which allows quick reaction to the changing needs in the dynamic market of optical modules for high-speed communications worldwide, the firm says.

NeoPhotonics' existing manufacturing capabilities include facilities in Shenzhen, China, in Tokyo, Japan, and in Silicon Valley, California.

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

## Rusnano USA president & CEO Dmitry Akhanov named to board

NeoPhotonics Corp of San Jose, CA, USA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems, has announced the appointment of Dmitry Akhanov to its board of directors.

Akhanov was appointed as the designated nominee of Open Joint Stock Company 'RUSNANO', which has a contractual right to designate one nominee to NeoPhotonics' board of directors since the Russian sovereign fund investor RUSNANO completed a private placement investment in NeoPhotonics in May 2012.

Akhanov replaces previous nominee Sergery Polikarpov, who resigned from the Board in connection with Akhanov's appointment. Akhanov holds a Bachelor's Degree in economics and law and a Master's Degree in economics from the Peoples' Friendship University in Russia.

During his professional career, Akhanov has had significant experience in infrastructure utilities, government and in the energy sector in Russia, says NeoPhotonics. Since 2010, he has been president & CEO of Rusnano USA Inc. Previously, he was head of the Russian Federal Energy Agency, which was responsible for the implementation of national energy policy and management of state-owned energy assets (oil & gas, coal and electricity industries). Akhanov also served as head of the Strategy Department of RAO UES (a state-owned electric power holding company in Russia), where he was actively involved in developing and implementing strategy for the restructuring of Russia's electricity sector, and forming a new industry structure and electricity market model. In conjunction with this, Akhanov also implemented corporate projects for the separation, merger and acquisition of major energy companies in Russia. Akhanov has

extensive experience in strategic planning, corporate finance and investor relations.

"We look forward to the insight and other contributions Dmitry will provide as the board guides the company during this period of exciting opportunity in the optical networking sector," says NeoPhotonics' CEO & chairman Tim Jenks. "Furthermore, we expect his personal experiences in the Russia market will bring an important new dimension to the board, especially with regards to developing new markets," he adds.

"I am impressed with NeoPhotonics technology and market development to become one of the leading suppliers of optical components for a variety of broadband access and high-capacity backbone networks around the world," comments Akhanov. "The company has an important market position by virtue of its advanced PIC technology and commitment to customer service," he believes.

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

# Advanced Photonix's annual sales fall 20% but rebound of 35% expected after 100G supply-chain bottleneck solved

For its fiscal fourth-quarter 2013 (to end-March), Advanced Photonix Inc of Ann Arbor, MI, USA (which designs and makes APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) has reported net sales of \$6m, down 8% on \$6.5m a year ago but up 3% on \$5.8m last quarter. Sales for full-year fiscal 2013 were \$23.6m, down 20% on the prior year due to telecom, homeland security and medical market sales.

Gross margin for Q4 was 35.8%, down on 42% last quarter but up on 34.2% a year ago, aided by cost-reduction efforts and a favourable product mix. Full-year gross margin was 37.3%, down on 40.2% the prior year.

Operating expenses for Q4 were \$3.3m, similar to a year ago and \$3.5m last quarter, but equating to 54.5% of revenue, down from 59% last quarter but up from 49.9% a year ago. Full-year operating

expenses were \$13.2m (55.9% of revenue), down from \$14.5m (49.2% of revenue) last year.

Adjusted EBITDA (earnings before interest, taxes, depreciation, amortization and stock compensation) was -\$572,000 for Q4, increasing from -\$485,000 last quarter and -\$416,000 a year ago. For full-year 2013, adjusted EBITDA was -\$2.2m, compared to +\$257,000 a year ago. During the year, cash reserves hence fell from \$3.2m to \$619,000. Net working capital as of end-March 2013 was \$4.9m, and the firm had the ability to borrow up to \$1.5m on its line of credit.

"Last year was a difficult year, but we expect to return to growth this coming fiscal year," says chairman & CEO Richard Kurtz. "The Thailand flooding in late 2011 continued to impact 100G orders from our customers early in our fiscal year 2013 and we did not succeed getting our new low-cost source for a sub-component to ramp up in volume

as needed until after year end. Coupled with a slowdown in China and the fall off of the In-Q-Tel contract work, we saw our top line drop by 20%," he adds.

"As we announced in June, the supply-chain bottleneck has been solved and we have been able to respond to our customers increased demands for 100G product," notes Kurtz. "Combined with the recent purchase of the operating assets of Silonex, we expect a return to growth, with fiscal 2014 sales looking to be higher than this last year by over 35%."

Advanced Photonix acquired Silonex Inc of Montreal, Canada, a subsidiary of ARCAS Automotive Group (Luxco 1) S.a.r.l., in March for \$900,000. Silonex designs and makes optoelectronic devices and sensor solutions based on cadmium sulphide (CdS) for vertical markets including industrial controls, banking, vending, medical and telecoms.

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

## Infinera's Q2 revenue up 48% year-on-year

For second-quarter 2013, Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), has reported revenue of \$138.4m, up 11% on \$124.6m last quarter and 48% on \$93.5m a year ago.

On a non-GAAP basis, gross margin has risen, from 37% a year ago and 36% last quarter to 39%. Net loss has been cut from \$18.6m a year ago and \$7.3m last quarter to \$1.2m.

"We continued to increase momentum in the second quarter, delivering strong revenue growth, improved gross margin, and positive cash flow from operations," says CEO Tom Fallon. "Acceptance of the DTN-X platform also continues to grow. During the quarter, we

received seven new purchase commitments, including three from customers new to Infinera, bringing the total number of commitments to 34 since the platform was introduced a year ago," he adds.

"Our success reflects the strategic commitment of our customers to a new architecture as they face massive traffic growth, operational complexity and increasing demand for instant delivery of services," Fallon says. "Infinera's recently announced Intelligent Transport Network offers a clear path for service providers to address these challenges, while providing a compelling economic value proposition," he adds. "We remain focused on winning new network deployments and expanding our market presence to generate sustainable revenue growth and profitability."

● Following a similar award for its 100Gb/s PIC last year, Infinera's 500Gb/s PIC was named Best Optical Component Product Beyond 100G at the Next Generation Optical Networking Awards 2013 in Monaco.

Embedded in the DTN-X packet optical transport networking platform, PICs enable the only commercially available 500Gb/s long-haul super-channels. Super-channels reduce complexity in carrier networks by simplifying the process of provisioning transmission capacity.

"The InP technology-based PICs Infinera delivers is far and away the most innovative component available today," said the judges.

"500Gb/s PICs are a key ingredient of the Intelligent Transport Network," says Mark Showalter, senior director corporate communications.

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



# Finisar's quarterly revenue rises 2%, as datacoms growth counteracts drop in telecoms

## Continued rebound expected to kick-start first year over \$1bn in sales

For its fiscal fourth-quarter 2013 (ended 28 April), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of \$243.4m, up 2.1% on \$238.4m the prior quarter.

"Growth in revenues came primarily from sales of 10G and 100G Ethernet transceivers and transponders for datacom applications," said executive chairman Jerry Rawls. Sales of products for datacom applications grew by 11% from \$147.7m to \$163.9m.

However, continued strength in sales of datacom products was partially offset by sales of telecom products falling 12.3% from \$90.7m to \$79.5m. This was primarily due to "sluggish carrier capital expenditure levels and a full three-month impact of the annual price reductions for telecom products most of which, as in prior years, went into effect in January".

"We had one 10%-or-greater customer," noted chief financial officer Kurt Adzema, regarding the firm's dependency on certain key customers. "Our top 10 customers represented 59% of total revenues compared to 54.9% in preceding quarter," he added.

"Our favorable product mix in the quarter enabled us to achieve gross margin and share earnings that exceeded our guidance range," said Rawls. On a non-GAAP basis, gross margin rose from 30.7% the prior quarter to 32.2%. Due

mainly to the higher gross margin, operating income rose from \$17.4m (an operating margin of 7.3% of revenue) to \$20m (8.2% of revenue). Net income has risen from \$16.4m (\$0.17 per diluted share) to \$19.8m (\$0.20 per diluted share). During the quarter, cash and cash equivalents rose from \$265.5m to \$289.1m.

Capital expenditure totaled \$25.4m, which was lower than guidance of about \$32m. "This was a result of the slight delay in the timing of payments related to the new manufacturing facility we are building in Wuxi, China," said Adzema. "We still expect the building to be completed in the second half of calendar 2013." Capital expenditure is expected to be about \$32m in fiscal Q1/2014, driven primarily by the new building.

For full-year 2013, revenue was \$934.3m, down 1.9% on \$952.6m the prior year. Non-GAAP operating income fell from \$89.3m (9.4% of revenue) to \$65.2m (7% of revenue), due mainly to lower gross margin and an increase in operating expenses as a result of increases in employee-related expenses, costs of materials associated with new product development, and the consolidation of financial results of Red-C Optical Networks (acquired earlier in fiscal 2013).

"During the latest quarter, we continued to invest in technology and product development and made substantial progress on a

number of new products for our communications products lines, including our next-generation 100G CFP2 transceiver, 12x25G optical engine and new-generation dual-wavelength selective switch ranges," said CEO Eitan Gertel.

Finisar noted that, during fiscal Q4/2013 and during the first week of Q1/2014, it completed the divestment of two non-strategic subsidiaries of Ignis AS (acquired by Finisar in May 2012). These divested businesses accounted for about \$5m in revenue in fiscal Q4/2013.

### Outlook

"As we start the new fiscal year, we are expecting revenue and operating income to grow again in Q1/2014," said Rawls. Revenues should be \$245–260m. "This will be our fourth consecutive quarter with sequential revenue and earnings growth," he adds. Finisar expects continue improvements in gross margin (to about 33%), operating margin (to 9–10.5%) and earnings per diluted share (to \$0.22–0.26).

"For the full fiscal year 2014, we expect revenue to grow 10–15% over fiscal 2013, driven by continued strength for 10G, 40G and 100G Ethernet products for datacom and increased telecom carrier spending in the second half of the year," Rawls said. "Fiscal 2014 [could] be our first year with revenues over \$1bn."

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

Matthew Peach, Contributing Editor

## Mellanox completes acquisition of IPtronics

Mellanox Technologies of Sunnyvale, CA, USA and Yokneam, Israel, has completed its acquisition of IPtronics A/S (which designs optical interconnect components for digital communications, including high-speed analog transceiver technol-

ogy) for \$47.5m.

Mellanox says the transaction enhances its ability to deliver complete end-to-end optical interconnect solutions for servers and storage systems at 100Gb/s and beyond.

Operating as an indirect subsidiary, IPtronics' site in Roskilde, Denmark will serve as Mellanox's first R&D center in Europe. Mellanox expects to expand its customer support within Europe.

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

# Finisar and u2t partner to acquire exclusive access to 100G coherent modulator technology developed at Heinrich-Hertz-Institute

## u2t acquires former German subsidiary of COGO Optronics

Fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA and u2t Photonics AG of Berlin, Germany, which makes high-speed indium phosphide-based photo-detectors and receivers as well as gallium arsenide-based optical modulators, have entered into a memorandum of understanding with respect to exclusive access to and joint development of all indium phosphide-based Mach-Zehnder modulator (MZM) technology developed at Berlin-based Fraunhofer Heinrich-Hertz-Institute (HHI, a research center for communication systems, digital media and services). Finisar and u2t obtain immediate and exclusive access to HHI's high-speed InP modulators, including polarization multiplexed I-Q modulators for 100G coherent applications. Concurrently, u2t has acquired all of the assets of Berlin-based COGO Optronics GmbH, the former German operating subsidiary of high-speed optical network developer COGO Optronics Inc.

"With the completed acquisition of COGO Optronics GmbH and the memorandum of understanding with Finisar and HHI, u2t has taken a significant step to broaden its portfolio and further strengthen its long-standing collaboration with HHI on high-performance optoelectronic components for the optical communications industry," says u2t Photonics' CEO Andreas Umbach.

Finisar and u2t will gain exclusive access to not only HHI's current InP MZM technology but also future InP MZM technology that will be developed jointly by HHI, Finisar and u2t. "u2t's local presence and leading technical capabilities and

Finisar's global reach and volume manufacturing strength represent the ideal relationship for the continued development, commercialization, and broad market adoption of HHI's InP MZM technology," believes professor Martin Schell, head of HHI's Photonics Components Department.

**This new relationship with u2t and our joint exclusive access to HHI MZM technology will enable the rapid development of new InP MZMs**

"Since 2009, Finisar has worked with COGO and HHI to commercialize HHI's InP MZM technology in a number of leading 40G and 100G transceiver products," comments John Clark, Finisar's executive VP for Technology and Global R&D. "Building on that foundation, we believe this new relationship with u2t and our joint exclusive access to HHI MZM technology will enable the rapid development of new InP MZMs for next-generation 100G coherent long-haul line-cards and pluggable 100G coherent metro transceivers," he adds. "The u2t team has a solid track record of enabling successive generations of new high-speed fiber-optic equipment with unique receive-side components based on HHI technology. We're looking forward to a fruitful relationship with u2t to deliver unique transmit-side solutions for data rates of 100G and above."

[www.finisar.com](http://www.finisar.com)  
[www.u2t.de/en](http://www.u2t.de/en)  
[www.cogooptronics.com](http://www.cogooptronics.com)

### IN BRIEF

## Emcore wins \$22m Indian solar cell assembly contract

Emcore Corp of Albuquerque, NM, USA has entered into a supply contract with the Indian Space Research Organisation (ISRO) to manufacture, test and deliver high-efficiency multi-junction solar cell assemblies for ISRO's commercial geostationary telecoms and scientific earth-observation satellite missions.

Over the past four decades ISRO has launched more than 65 satellites for commercial and scientific applications. Emcore has been a key supplier of solar cell products to ISRO for the past 15 years, including supplying solar equipment to power several Indian National Satellite System (INSAT) telecoms missions.

Over the term of the new multi-year contract, Emcore expects to deliver Coverglass Interconnected Cells (CICs) incorporating its highest-efficiency ZTJ and ATJ solar cells for multiple satellite missions. With a conversion efficiency nearing 30%, the ZTJ cell is one of the highest-performance multi-junction solar cells on the market, the firm claims. The CICs use advanced interconnect welding techniques and offer high reliability under severe space radiation environments and thermal stress conditions, it adds.

"This contract is a very significant award for Emcore. It further reinforces our successful heritage in the Asia-Pacific satellite market, and expands our market share for both commercial and scientific missions," says Dr Brad Clevenger, general manager of Emcore's Photovoltaics Division. "We look forward to supporting ISRO on its next phase of telecommunications and earth observation satellites."

[www.emcore.com](http://www.emcore.com)  
<http://isro.org/index.aspx>



# NREL reports record 31.1% efficiency for two-junction solar cell under one-sun illumination

## Using reflective gold back contact in lower GaAs junction and coupling luminescence from upper GaInP junction boosts tandem cell

On 19 June at the 39th IEEE Photovoltaic Specialists Conference (PVSC 39) in Tampa, FL, scientist Myles Steiner at the US Department of Energy's National Renewable Energy Laboratory (NREL) reported record energy conversion efficiency of 31.1% for a two-junction solar cell under one-sun illumination. The previous record of 30.8% was held by Alta Devices of Sunnyvale, CA, USA.

Made of a gallium indium phosphide (GaInP) cell atop a gallium arsenide (GaAs) cell, the tandem cell has an area of 0.25 square centimeters and was measured under the AM1.5 global spectrum at 1000W/m<sup>2</sup>. It was grown inverted — similar to the NREL-developed inverted metamorphic multi-junction (IMM) solar cell — and flipped during processing. The cell was covered on the front with a bilayer anti-reflection coating and on the back with a highly reflective gold contact layer.

The work was done as part of the DOE's Foundation Program to Advance Cell Efficiency (F-PACE), a project of the DOE's SunShot Initiative that aims to lower the cost of solar energy to a point at which it is competitive with other sources including fossil fuels.

At the beginning of the F-PACE project, which aims to produce a 48%-efficient concentrator cell, NREL's best single-junction GaAs solar cell was 25.7% efficient. This has been improved upon by others over the years: Alta set a series of records, increasing the GaAs record from 26.4% in 2010 to 28.8% in 2012. Alta's then-record two-junction 30.8%-efficient cell was achieved just two months ago.

The new record may not last long either, but "it brings us one step closer to the 48% milestone," says NREL principal scientist Sarah Kurtz, who leads the F-PACE project in

NREL's National Center for Photovoltaics. "This joint project with the University of California, Berkeley and Spectrolab has provided us the opportunity to look at these near-perfect cells in different ways. Myles Steiner, John Geisz, Iván García and the III-V multi-junction PV group have implemented new approaches providing a substantial improvement over NREL's previous results," she adds.

"Historically, scientists have bumped up the performance of multi-junction cells by gradually improving the material quality and the internal electrical properties of the junctions — and by optimizing variables such as the bandgaps and the layer thicknesses," says NREL scientist

Myles Steiner.

But internal optics plays an under-appreciated role in high-quality cells that use materials from the third and fifth columns of the periodic tables, he adds. "The scientific goal of this project is to understand and harness the internal optics."

When an electron-hole pair recombines, a photon can be produced, and if that photon escapes the

cell, luminescence is observed (i.e. the mechanism by which light-emitting diodes work). In traditional single-junction GaAs cells, however, most of the photons are simply absorbed in the cell's substrate and are lost. With a more optimal cell design, the photons can be re-absorbed within the solar cell to create new electron-hole pairs, leading to an increase in voltage and conversion efficiency. In a multi-junction cell, the photons can also couple to a lower-bandgap junction (i.e. luminescent coupling), generating additional current.

The NREL researchers improved the cell's efficiency by enhancing the photon recycling in the lower GaAs junction by using a gold back contact to reflect photons back into the cell, and by allowing a significant fraction of the luminescence from the upper GaInP junction to couple into the GaAs junction. Both the open-circuit voltage and the short-circuit current were increased.

Silicon solar cells now dominate the PV market, but researchers see opportunities for new materials. High-efficiency concentrator cells bolstered by lenses that magnify the power of the sun are attracting interest from utilities, says NREL, because the modules have demonstrated efficiencies well over 30%. Also, there may be commercial opportunities for one-sun or low-concentration III-V cells if growth rates can be increased and costs reduced.

The same cell should work well when lenses are added to multiply the sun's power. "We expect to observe similar enhancements of the solar cell characteristics when measured under concentrated illumination," Steiner concludes.

[www.nrel.gov](http://www.nrel.gov)

**The NREL researchers improved the cell's efficiency by enhancing the photon recycling in the lower GaAs junction by using a gold back contact to reflect photons back into the cell, and by allowing a significant fraction of the luminescence from the upper GaInP junction to couple into the GaAs junction**

# NREL study shows Alta's solar material retains high efficiency at elevated temperatures

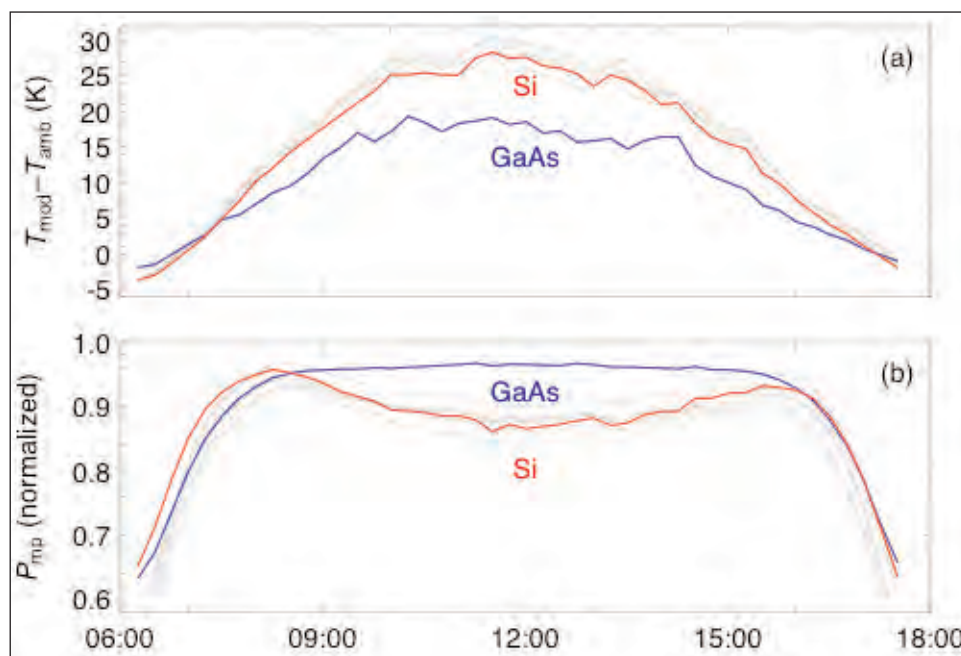
**Operation up to 10°C cooler than silicon in real-world conditions offers benefits for roof-integrated applications**

The US Department of Energy's National Renewable Energy Laboratory (NREL) and Alta Devices of Sunnyvale, CA, USA have jointly demonstrated that Alta's solar material retains its high efficiency in real-world conditions, particularly on hot days. Alta says that the primary reason is that its modules stay cooler and lose very little efficiency as the temperature rises. Combined with its energy density advantage, this has the potential for significant benefits, specifically in roof-integrated applications such as automobiles and buildings, the firm claims.

"To truly understand how much energy a particular solar technology will generate, it's critical to know how it performs in real-world conditions," notes Sarah Kurtz PhD, principal scientist, Reliability Group Manager, at NREL. "For years, the industry has desired a very efficient solar cell that could be built into the roof of a car or building without paying the performance penalty associated with a hot roof," she adds. "Alta's technology provides a fresh approach to these attractive applications by naturally rejecting heat and being less sensitive to high temperatures."

The NREL-supervised tests and results were presented at the 39th IEEE Photovoltaic Specialists Conference (PVSC 39) in Tampa, FL (16–21 June). The tests were conducted at NREL's outdoor testing facility in Golden, Colorado, measuring energy and operating temperatures over a nine-week period.

The result was that the Alta module operated cooler than conventional modules (up to 10°C cooler when the sun was brightest) and was about five times less sensitive to increased temperature. In fact, because of changes in the sun's spectrum associated with hot days,



(a) Module temperature rise above ambient and (b) normalized irradiance-corrected power ( $P_{mp}$ ) versus time for GaAs (blue) versus silicon (faint black lines show data from five additional Si modules from various manufacturers).

the module showed higher efficiencies on hot days than on cold days. In a simulation model using measured temperature coefficients (neglecting spectral effects), compared to a silicon module with the same power rating, the Alta module was predicted to generate  $8\% \pm 2\%$  more energy per year in Phoenix, Arizona. To the extent that these simulations were performed based on a rack-mounted configuration, it is expected that roof-integrated installations will show even greater benefit.

**The Alta module operated cooler than conventional modules.**

**Because of changes in the sun's spectrum associated with hot days, the module showed higher efficiencies on hot days than on cold days**

## Benefits for automotive industry

"Up until now, integrating PV material directly into a roof of any kind resulted in additional heat needing to be dissipated, and a reduction in power output in the hottest part of each day, usually when you need it most," says Alta's president & CEO Chris Norris. "Our technology addresses both of these problems."

The roof of a hybrid electric vehicle outfitted with an Alta-based solar array would run cooler and continue to perform well in higher temperatures versus a silicon-based roof, he adds. This provides more overall energy and allows the car's interior to stay cooler, further reducing the power demand for air conditioning. "Our technology delivers tangible economic benefits to automobile manufacturers by helping them meet the latest CAFE (Corporate Average Fuel Economy) standards while providing real-world benefits to the end-users," concludes Norris.

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



## NREL's Emery wins IEEE's Cherry Award

At the 39th IEEE's Photovoltaic Specialists Conference in Tampa, Keith Emery, a principal scientist at the US Department of Energy's National Renewable Energy Laboratory (NREL), received the William R. Cherry Award from the Institute of Electrical and Electronics Engineers.

"Accredited measurements from Emery's laboratories are considered the gold standard by the US and international PV communities," says NREL colleague Pete Sheldon, deputy director of the National Center for Photovoltaics on the NREL campus in Golden, CO. "His leadership in the development of cell and module performance measurement techniques, and the development of standards, has set the foundation for the PV community for the last 25 years."

The award is named in honor of William R. Cherry, a founder of the photovoltaic community. In the 1950s, he was instrumental in establishing solar cells as the ideal power source for space satellites and for recognizing, advocating and nurturing the use of photovoltaic



Keith Emery.

systems for terrestrial applications. The purpose of the award is to recognize an individual engineer or scientist who has devoted a part of their professional life to the advancement of photovoltaic energy conversion.

Emery is the third consecutive Cherry Award winner from NREL, following Jerry Olson (who developed the multi-junction solar cell) in 2011 and Sarah Kurtz (who helped Olson develop the multi-junction cell and is now a global leader in solar module reliability) in 2012. Three other NREL scientists have won the Cherry Award previously: Paul Rapaport (1980), Larry Kazmerski (1993), and Tim Coutts (2005).

Emery has spent his career building the capabilities of his testing and characterization lab, making it one of a handful of premier measurement labs in the world, and the

only place in the USA that calibrates primary terrestrial standards for solar-cell characterization.

"We've been able to offer the service to all terrestrial PV groups in the US, from national labs to universities to low-budget start-ups," says Emery. "They all get the same quality of service." The readily available service is so researchers and companies have equal access to the resources needed for independent efficiency measurement, he adds.

After bachelor's and master's degrees at Michigan State University, Emery went to Colorado State University to fabricate and test ITO on silicon solar cells. At NREL, in the 1980s, Emery developed the test equipment and put together the data-acquisition system for characterizing and measuring the efficiency of solar cells.

Sheldon comments that Emery's work "brings scientific credibility to the entire photovoltaic field, ensuring global uniformity in cell and module measurements".

[www.nrel.gov](http://www.nrel.gov)

## Fraunhofer ISE director receives SolarWorld Einstein Award for commitment to photovoltaics in Europe

The Einstein Award for 2013 from solar module maker SolarWorld AG of Bonn, Germany has been awarded to professor Eicke R. Weber, director of the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg (Europe's largest solar energy research institute) for his contribution to European solar energy research.

The Einstein Award has been presented since 2005 to people who have distinguished themselves in promoting the use of solar energy.

Under Weber's direction, Fraunhofer ISE develops expertise for the solar industry and carries it out to application maturity. "Weber is one of the European communicators and propagators for solar energy," says SolarWorld's CEO Dr Frank Asbeck. "He gave solar

energy a voice, which is heard beyond the scientific community and reaches into politics and society at large," he adds.

The solar industry in Germany and Europe is heading into difficulty regarding the competition from Asia, particularly China. Weber has been responding to this situation by campaigning to keep cutting-edge photovoltaic technology in Europe.

"It [the award] reinforces my efforts in the struggle to keep Europe as a leading location for photovoltaics," says Weber. "Germany and Europe still hold the lead in photovoltaic research and production technology, due not the least to our intensive research in this area," he adds.

"We can reach a global PV market of over 100GW/year by 2020 and

of 300GW/year in 2025," says Weber. "In order that Germany and Europe can continue to participate successfully in this global market, we need a European initiative similar to the Airbus model. In Europe, we need access to investment funds so that this key technology can develop in fair competition with our Asian competitors," he adds.

"One example could be the construction of multi-gigawatt scale manufacturing facilities for wafers, cells and modules," says Dr Winfried Hoffmann, president of the European Photovoltaic Industry Association. "Serving as a beacon for the European PV industry, this project can point the way into the future."

[www.solarworld.de/en](http://www.solarworld.de/en)

[www.ise.fraunhofer.de](http://www.ise.fraunhofer.de)

# Fraunhofer ISE teams with EVG to enable direct wafer bonding for next-gen solar cells

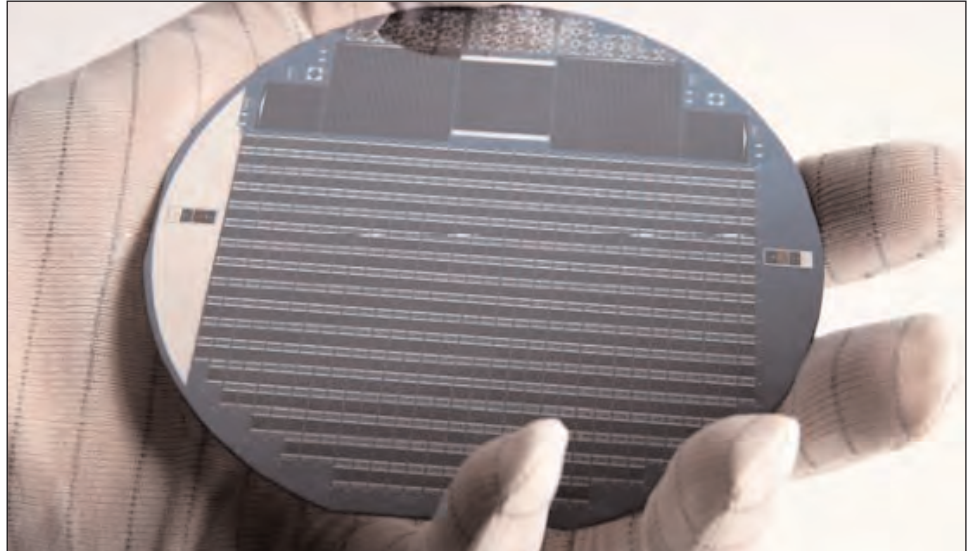
**ComBond technology targets highly mismatched combinations such as GaAs-on-Si, GaAs-on-InP, InP-on-Ge and GaAs-on-GaSb**

Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany (the largest solar energy research institute in Europe) has joined forces with 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, to develop equipment and process technology to enable electrically conductive and optically transparent direct wafer bonds at room temperature.

Developed in partnership with Fraunhofer ISE based on EVG's ComBond technology (unveiled in March), the new solutions aim to enable highly mismatched material combinations such as gallium arsenide (GaAs) on silicon, GaAs on indium phosphide (InP), InP on germanium (Ge) and GaAs on gallium antimonide (GaSb). Direct wafer bonding provides the ability to combine a variety of materials with optimal properties for integration into multi-junction solar cells, which can lead to new device architectures with unparalleled performance, it is reckoned.

"Using direct semiconductor bond technology developed in cooperation with EVG, we expect that the best material choices for multi-junction solar cell devices will become available and allow us to increase the conversion efficiency toward 50%," says Dr Frank Dimroth, head of department 'III-V – Epitaxy and Solar Cells' at Fraunhofer ISE. The aim of the partnership is to develop industrial tools and processes for the application.

Fraunhofer ISE has developed III-V multi-junction solar cells for more than 20 years and has reached record energy conversion efficiencies of up to 41% with its



**III-V multi-junction concentrator solar cells on 4-inch diameter wafer.**

metamorphic triple-junction solar cell technology on Ge substrates. Higher efficiencies require the development of four- and five-junction solar cells with new material combinations to span the full absorption range of the sun's spectrum over 300–2000nm. The integration of III-V solar cells on silicon opens another opportunity to reduce manufacturing cost, especially when combined with modern substrate lift-off technologies. Direct wafer-bonding is expected to play an important role in the development of next-generation III-V solar cell devices with applications in space as well as in terrestrial concentrator photovoltaics (CPV).

"Fraunhofer ISE's broad expertise in the area of PV, specifically in concentrated PV cell manufacturing and photonics, will allow us to characterize bonding interfaces with respect to PV applications on our new ComBond equipment platform," says Markus Wimplinger, corporate technology development & IP director at EVG.

EVG's ComBond technology was developed in response to market

needs for more sophisticated integration processes for combining materials with different lattice constants and coefficients of thermal expansion (CTE). The process and equipment technology enables the formation of bond interfaces between heterogeneous materials — such as silicon to compound semiconductors, compound semiconductors to compound semiconductors, Ge to silicon, and Ge to compound semiconductors — at room temperature, while achieving what is claimed to be excellent bonding strength. ComBond technology will be commercially available later this year on the new EVG580 ComBond 200mm modular platform currently in development, which will include process modules designed to perform surface preparation processes on both semiconductor materials and metals.

In addition to PV, other potential application areas for processes developed in cooperation between EVG and Fraunhofer ISE include LEDs and silicon photonics.

[www.ise.fraunhofer.de](http://www.ise.fraunhofer.de)

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

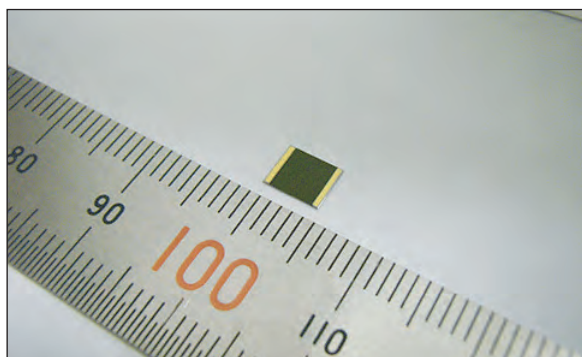


# Sharp sets CPV cell efficiency record of 44.4%

**Widening effective cell surface and matching width of interface to electrodes raises record from 43.5%**

Japan's Sharp Corp has used a concentrator triple-junction III-V compound semiconductor photovoltaic cell to achieve a solar energy conversion efficiency of 44.4%, exceeding the record of 43.5% for concentrating conversion efficiency set in March 2011 by Solar Junction Corp of San Jose, CA, USA, a manufacturer of III-V multi-junction solar cells for concentrated photovoltaics (CPV), and equalled by Sharp in June 2012.

Measurement of the 44.4% conversion efficiency was confirmed in April by the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany cell surface of about 0.165cm<sup>2</sup> under a light-concentrating magnification of 302 times. One of several organizations around the world that officially certifies efficiency measurements in solar cells, ISE is one of the participating members from the European Union in the collaboration 'NGCPV: A new generation of concentrator photovoltaic cells, modules and systems', which began in June 2011 as part of the project



**Photo of Sharp's record triple-junction concentrator photovoltaic solar cell.**

'R&D in Innovative Solar Cells'.

The latest record arose through work as part of the 'R&D on Innovative Solar Cells' project, promoted by Japan's New Energy and Industrial Technology Development Organization (NEDO), which is one of the country's largest public management organizations for promoting R&D as well as for disseminating industrial, energy, and environmental technologies.

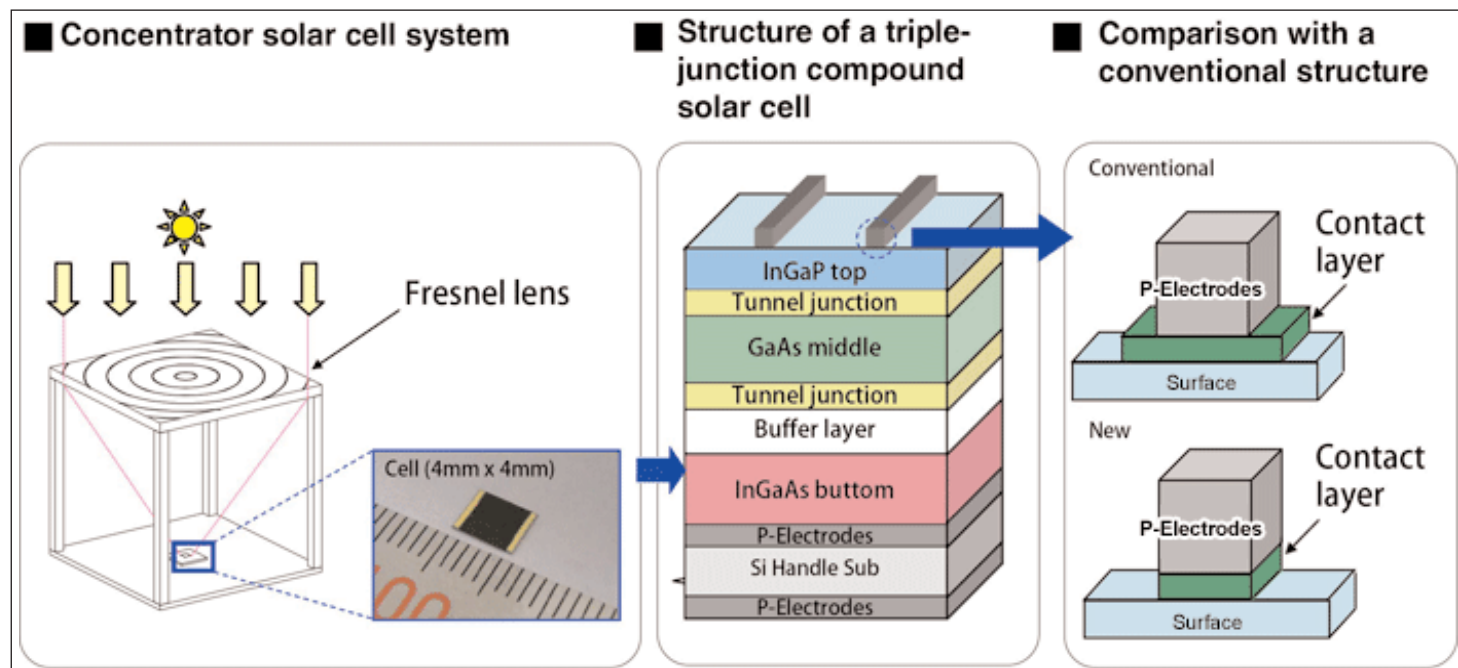
By using photo-absorption layers made from compounds of multiple elements such as indium and gallium, compound semiconductor

solar cells typically offer high conversion efficiency. Sharp's concentrator triple-junction compound solar cells use a proprietary technology that enables the efficient conversion of sunlight into electricity by means of a stack of three photo-absorption layers, the bottom-most of which is made from indium gallium arsenide (InGaAs).

Sharp says that, to achieve a concentrating conversion efficiency of 44.4%, it worked to widen the effective concentrator cell surface and ensure uniform width of the interface between the cell and the electrodes.

Because of their high conversion efficiency, compound solar cells have so far been used primarily on space satellites. However, Sharp's aim for the future is to apply this latest development in CPV power systems and make the use of compound solar cells more feasible in terrestrial applications.

[www.sharp-world.com](http://www.sharp-world.com)



**Schematic of the record triple-junction concentrator photovoltaic solar cell.**

## Soitec completes first solar power plant in California with modules from its San Diego factory

At the Intersolar North America 2013 conference in San Francisco (9–11 July), concentrating photovoltaic (CPV) solar system maker Soitec of Bernin, France announced that its subsidiary Soitec Solar Development LLC of Peabody, MA, USA has completed construction of the 1.5MWAC Newberry Solar 1 project in San Bernardino County, CA. Power generated by Newberry Solar 1 will be sold to Southern California Edison under a 20-year power purchase agreement (PPA). It is the largest CPV power plant in California, featuring Soitec's latest and most efficient technology with modules manufactured in nearby San Diego.

"This announcement represents a major milestone for Soitec in establishing its newest generation of CPV technology and a critical step in our ambitious deployment plans in the region," says Gaetan Borgers, executive VP of Soitec's Solar Energy Division. "Newberry Solar 1 is the first solar power plant constructed in the US with our most advanced CPV modules shipped directly from our new San Diego manufacturing facility," he adds.

"With a current production capacity of 280MWp and a worldwide pipeline of solar power plant projects totaling hundreds of megawatts, we're very happy to show that our new product is now shipping and can be installed and operational in a very short timeframe."

The Newberry Solar 1 power plant connects directly to Southern California Edison's distribution network and will provide about 500 Southern California homes with energy while offsetting the emission of almost 2300 tons of CO<sub>2</sub> each year.

The power plant uses Soitec's fifth-generation Concentrix CX-S530 CPV systems, designed as Soitec's next step towards achieving a levelized cost of electricity (LCOE) for utility-scale solar power plants in the sunniest regions of the world. With a module area of over 100m<sup>2</sup> (1130ft<sup>2</sup>), one CX-S530 generates a capacity of 28kWp. The size of the system is optimized to deliver high performance while drastically reducing costs for manufacturing, installation and maintenance. The system uses 12 of the large Soitec CX-M500 modules and delivers an efficiency of 30% (about twice the

efficiency of conventional photovoltaic panels).

The 720 CX-M500 modules used at Newberry Solar 1 were manufactured in Soitec's new North American manufacturing headquarters in San Diego on fully automated assembly lines. Commissioned in December 2012, the factory is currently targeted to reach its full capacity of 280MWp by October, making Soitec the third largest solar module maker in the USA.

With installations in 18 countries around the world, Soitec says that its CPV technology is proving its competitiveness to generate solar power, largely due to its higher production yields throughout the sunlight hours. In addition, CPV technology's ability to operate without cooling water, withstand hot ambient temperatures and have minimal environmental impact make it suitable for use in desert areas. Soitec hence reckons that it is well positioned to expand quickly in the sunniest regions of the world, which are also the fastest-growing market segments of the solar industry.

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

## Soitec installs 25kW CPV demonstration plant in rural Namibia

Soitec has installed a CPV demonstration plant in the isolated village of Usib near Rehoboth in central Namibia. The 25kW installation is connected to the grid of national power utility NamPower and supplies users including a rural school.

Under a cooperative agreement, Soitec has constructed and operates the plant and will transfer the knowledge gained as well as operations and maintenance duties to NamPower.

"Building a project such as this one allows us to demonstrate the real-world application of our CPV technology in hot and arid locations," says Gaetan Borgers,

executive VP of Soitec Solar Division. "Through our direct involvement, we also can express Soitec's commitment to improving educational opportunities and community life," he adds. "Our environmentally friendly and cost-effective alternative-energy solution provides not only a reliable source of electricity, but also local jobs. We are actively deploying our CPV systems in high-solar-irradiation regions around the world."

Funds from the sale of the solar-generated electricity to the grid will be credited to the school's electricity bill. The plant will operate for at least 20 years.

Soitec's CPV modules use a durable glass-glass design and Fresnel lenses to concentrate sunlight 500 times onto small multi-junction solar cells. The firm says that, by using dual-axis tracking, its systems provide high, constant power output throughout daylight hours. In addition, the systems are resistant to energy losses in high temperatures and achieve passive cooling without water consumption, offering competitive advantages in countries with high direct normal irradiance (DNI) such as Namibia, it is reckoned.

Soitec has installed its CPV technology in 18 countries to date.



# First wafer-scale heteroepitaxial growth of III-V nanowires on silicon

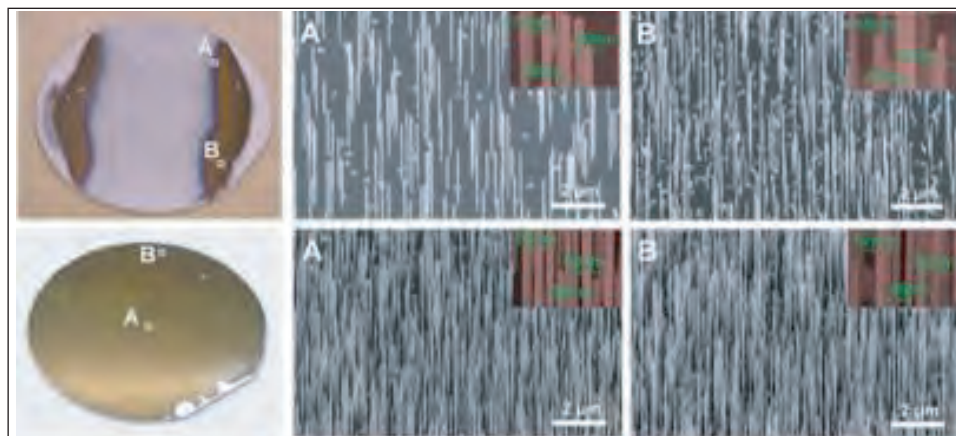
**Management of nanowire density and bandgap energy could yield large-scale, low-cost high-efficiency solar cells**

A team of researchers led by Kyoung Jin Choi, associate professor at South Korea's Ulsan National Institute of Science and Technology (UNIST), and Xiuling Li, professor at University of Illinois in the USA, have developed what is claimed to be the first wafer-scale hetero-epitaxial growth of III-V semiconductor nanowires on a silicon wafer ('Wafer-Scale Production of Uniform  $\text{InAs}_y\text{P}_{1-y}$  Nanowire Array on Silicon for Heterogeneous Integration', published online on 7 May in ACS Nano; DOI: 10.1021/nn4014774).

Supported by the Future-based Technology Development Program (Nano Fields) through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology, the team demonstrated a method to epitaxially synthesize structurally and compositionally homogeneous and spatially uniform ternary  $\text{InAs}_y\text{P}_{1-y}$  nanowire on silicon on the wafer-scale using MOCVD. The high quality of the nanowires is reflected in the narrow photoluminescence (PL) and x-ray peak width and low ideality factor in the  $\text{InAs}_y\text{P}_{1-y}$  nanowire/Si diode.

High-aspect-ratio semiconductors have led to significant breakthroughs in conventional electrical, optical and energy-harvesting devices, say the researchers. Among such structures, III-V nanowires offer unique properties arising from their high electron mobility and absorption coefficients, as well as their direct bandgaps.

The common technique for creating a nanowire — i.e. vapor-liquid-solid (VLS) synthesis — can produce crystalline nanowires of some semiconductor materials, but metal catalysts (usually expensive noble metals) need to be used to initiate the VLS mechanism. Also, these metal catalysts are known to



Optical and SEM images of the  $\text{InAs}_y\text{P}_{1-y}$  nanowire array.

significantly degrade the quality of semiconductor nanowires by creating deep levels, limiting practical applications of nanowires in optoelectronic devices.

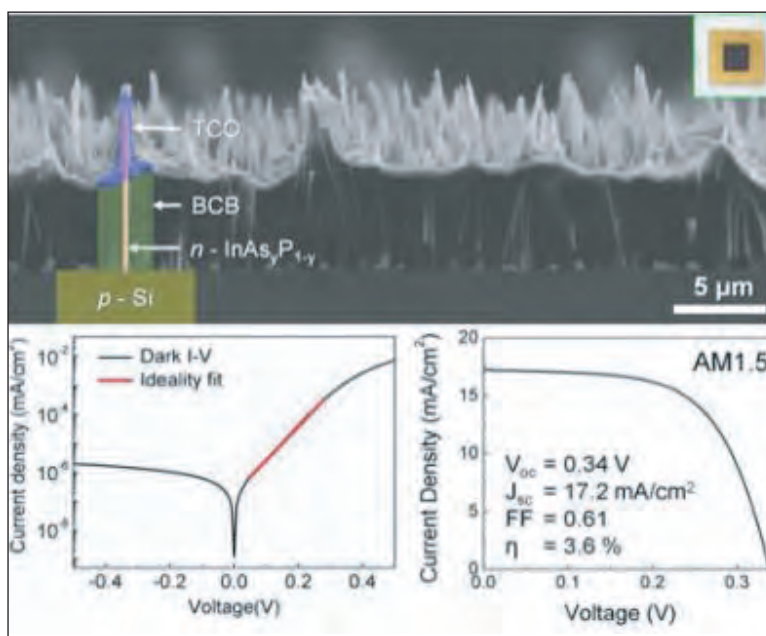
However, Choi's group has developed a technique of growing III-V semiconductor nanowires without metal catalysts or nano-patterning. An Aixtron AIX 200 MOCVD system was used for growing the  $\text{InAs}_y\text{P}_{1-y}$ . A 2-inch Si (111) wafer was cleaned with buffer oxide etch for

1 minute and deionized (DI) water for 2 seconds. Then, the wafer was immediately dipped in poly-L-lysine solution (from Sigma-Aldrich Inc) for 3 minutes then rinsed in DI water for 10 seconds. The silicon substrate was then immediately loaded into the MOCVD system. The reactor pressure was lowered to 50mbar with 15liter/min of hydrogen gas flow. The reactor was then heated to growth temperature (570–630°C), and stabilized for

10 minutes.

"If we develop new technology which manages the density of nanowire and bandgap energy with further study, it is also possible to produce high-efficiency and low-cost large-scale solar cells," concludes Choi.

[www.unist.ac.kr](http://www.unist.ac.kr)



Electrical characterization of solar cells composed of  $n\text{-InAs}_{0.7}\text{P}_{0.3}$  nanowire array on p-Si (111) substrate.

# Sol Voltaics gains \$6m loan from Swedish Energy Agency; former REC chief technology officer Erik Sauar invests

## Loan to be used to develop larger Aerotaxy machine, refine liquid carriers in Solink, and scale deposition and bonding techniques for industrial use

Sol Voltaics AB of Ideon Science Park, Lund, Sweden says that the Swedish Energy Agency (SEA), the national authority for energy policy issues, has provided a \$6m conditional loan (one of the largest it has ever issued to a company) to further the commercial development of Solink, a nanomaterial that promises to boost the efficiency of solar modules by up to 25%.

Also, Erik Sauar — chief technology officer & senior VP at Norway-based solar manufacturer REC (Renewable Energy Corporation) for more than ten years — has become an investor.

Founded in 2008, Sol Voltaics has previously raised \$11m from private investors including Stockholm-based venture capital firm Industrifonden, Foundation Asset Management AB of Sweden, Teknoinvest AS, Provider Venture of Sweden, Nano Future Invest and Scatec Energy of Norway. The firm has also received public funding from the European Union, Vinnova, Nordic Innovation Center, and others.

"Solar will play an increasingly important role in global energy markets, but the industry right now is struggling," says Viveca Johansson, program manager at the SEA. "The technology developed by Sol Voltaics holds the potential to simultaneously make solar competitive with fossil fuels at market prices while increasing the business case for developers and manufacturers."

Solink is a gallium arsenide additive for crystalline silicon or thin-film solar modules that enables modules to convert more of the sun's light into electricity. GaAs is the most efficient solar material currently available but, due to high costs, it has been confined to niche markets, says Sol Voltaics. The firm minimizes the amount of GaAs needed: less than

a gram of nanowires is required to produce Solink-enhanced modules. Each GaAs nanowire in Solink is effectively an independent solar cell, making a Solink-enhanced module a vertically stacked device that generates energy from a wider light spectrum than a standard solar panel, says the firm.

With Solink, a solar power plant or residential rooftop solar array can generate up to 25% more power than a standard system of the same size or generate an equal amount of power with smaller arrays, says Sol Voltaics. By maximizing the physical assets, labor and real-estate needed for photovoltaic systems, the price of solar electricity can be reduced, the firm adds.

Solink is applied to conventional solar panels toward the end of the existing module production process with relatively inexpensive standard equipment.

Sol Voltaics' founder Lars Samuelson (a professor at Lund University) headed the research teams that invented both Solink and Aerotaxy, an economical process for mass producing nanomaterials. A paper published in *Nature* late

last year details how professor Samuelson and his team used Aerotaxy to manufacture GaAs nanowires ('Continuous gas-phase synthesis of nanowires with tunable

properties' by Magnus Heurlin et al, *Nature*, 492, 90–94 (6 December 2012); doi: 10.1038/nature11652). "Aerotaxy transforms the production of active nanomaterials from a scientific endeavor into a high-throughput manufacturing process," comments Sauar.

Sol Voltaics is currently producing GaAs nanowires in its laboratories in Lund, Sweden. The firm has already demonstrated performance with 13.8% indium phosphide (InP) nanowires and it anticipates producing functional solar cells made from GaAs nanowires for demonstration by the end of 2013.

Rather than produce modules or sell capital equipment, Sol Voltaics will produce Solink and provide it to module makers to incorporate into their own products. Hence a single, relatively small facility can deliver hundreds of megawatts worth of materials to module makers worldwide, it is reckoned. The conditional loan from the SEA will be used to develop a larger Aerotaxy machine, further refine the liquid carriers in Solink and scale deposition and bonding techniques for industrial use. Commercial production of Solink-enhanced modules should begin in 2015 and move into volume production in 2016.

"We have two goals: to make solar more profitable for solar manufacturers and developers and to lower the price of solar energy for consumers, utilities and businesses," says Sol Voltaics' CEO David Epstein. "We look forward to demonstrating our technology later this year."

The firm reckons that other potential applications for Aerotaxy include producing nanomaterials for power electronics, LEDs, batteries and energy storage.

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

**The firm has already demonstrated performance with 13.8% InP nanowires and it anticipates producing functional solar cells made from GaAs nanowires for demonstration by the end of 2013**



# RSI announces record-size CdTe solar modules

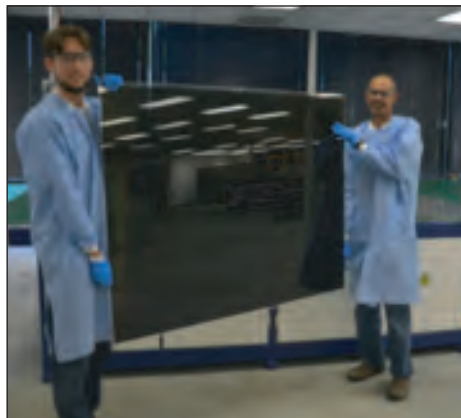
## Proprietary tool and low-temperature process speeds plating step and yields 1.5 square meter panel area

REEL Solar Inc (RSI) of San Jose, CA, USA has announced a new record for cadmium telluride (CdTe) photovoltaic module size, achieving a 1.5 square meter module.

Conventional cadmium telluride (CdTe) modules measure 0.72 square meters, a limitation that stems from the use of high-temperature CdTe deposition processes. RSI has developed a proprietary tool and low-temperature process, called Rapid Efficient Electroplating on Large-areas (REEL) that both speeds the plating step and eliminates constraints on panel area. RSI has been developing low-cost electroplating processes since 2009. The firm is now offering a 'virtual turnkey' manufacturing capability to a single licensee in each major region of the world. The firm projects a manufacturing cost of less than 40 cents per peak watt in 2014.

The availability of low-cost, large-area CdTe panels — coupled with a business model that leverages exclusive regional manufacturing partners — promises the widespread acceleration of grid parity for utility-scale solar, says the firm.

"At each step in the manufacturing process we are moving more Watts



RSI's record CdTe solar modules.

for a given capex, materials and labor cost," says RSI's co-founder & president Kurt Weiner. "At the end, our panels produce significantly more power so they're cheaper to install. When we founded the company we recognized that in thin-film, you needed larger panel sizes with higher power outputs, in addition to efficiency, to truly differentiate against silicon. We've achieved both at RSI," he adds.

"The solar industry is growing massively, but the only manufacturers who have made consistent profits are those with access to proprietary technology," says chief executive Ed Grady. "Incremental improvements to undifferentiated

technology like crystalline silicon are not enough to prosper in this commoditized market. Manufacturers end up giving away their margin to survive," he adds.

"First Solar has shown how to make profits through technology and cost differentiation. RSI is delivering a step change improvement in the cost structure, while retaining all the characteristics that have made CdTe so successful," Grady continues.

"The combination of low capital need and a focus on solving the key manufacturing scale and capital cost issues made RSI stand out as an investment opportunity," comments investor Matt Jones of Nth Power. "RSI had the highest profit and investor return potential of any solar module company we have seen," he adds.

"The solar industry is just beginning to hit its stride," believes Pedram Mokrian of Mayfield Fund. "RSI's large-area manufacturing technology, based on the proven CdTe material system, represents a step change in PV manufacturing costs. Most importantly, our investment focused on the strength of the RSI team, and their ability to execute against this vision."

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

# First Solar to build three projects totaling 23MW for New Mexico's largest electricity provider PNM

First Solar Inc of Tempe, AZ, USA has signed an agreement with Public Service Company of New Mexico (PNM) to construct three solar power plants totaling 23MW<sub>AC</sub> of generating capacity. First Solar will provide cadmium telluride thin-film photovoltaic modules as well as engineering, procurement & construction (EPC) services. PNM is the largest electrical provider in New Mexico, serving more than 500,000 customers.

Contingent on approval from the New Mexico Public Regulation Commission (which PNM filed for earlier in July), the agreement establishes terms for the plants' EPC work. The projects are part of PNM's 2014 portfolio of renewable energy resources. They are extra to five plants completed in 2011 and another 21.5MW to be completed this year, all totaling 67MW<sub>AC</sub> that First Solar has contracted or is expected to construct with PNM by the end of 2014.

The three new projects should begin construction and be completed in 2014, creating up to 300 local construction jobs at peak.

The solar plants in total will generate enough energy to power up to 8960 average New Mexico homes, displacing about 25,300 metric tons of CO<sub>2</sub> annually (equivalent to taking 5270 cars off the road, and displacing up to 14.5m gallons of water consumption annually).

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

## Sivananthan made White House 'Champion of Change'

On 29 May, Dr Sivalingam (Siva) Sivananthan, CEO & founder (in 1998) of EPIR Technologies Inc in Bolingbrook (a suburb of Chicago), IL, USA (which develops infrared sensor, biosensor and photovoltaic products), was honored at a White House ceremony in Washington DC as one of 11 'Champions of Change' among immigrant entrepreneurs — an award recognizing "the best and brightest from around the world who are helping create American jobs, grow the economy and make our nation competitive in the world".

The sixth of nine children born to schoolteachers in Chavakacheri, Sri Lanka, after earning a bachelor's degree in physics at the University of Peradeniya, in 1982 he became a graduate student at University of Illinois at Chicago (UIC), obtaining Master's and Ph.D. in physics. In 1994, he was made director of the Microphysics Laboratory (MPL) in UIC's Department of Physics. In 2011, Sivananthan was named the College of Liberal Arts and Sciences Distinguished Professor of Physics at UIC. Sivananthan is also a fellow of the American Physical Society (APS). This May at the SPIE Defense, Security and Sensing symposium in Baltimore, MD, USA, he was honored by SPIE (the International Society for Optics and Photonics)

for his contributions to the development of II-VI photovoltaic materials, receiving the SPIE fellowship.

"I started EPIR in 1998 to provide R&D for mercury cadmium telluride [MCT, or HgCdTe] technology, and to eventually become a manufacturer for infrared materials and devices," Sivananthan says. "I saw the need and opportunities for a horizontally integrated merchant supplier in the infrared imaging and sensor market," he adds.

"Military requirements necessitate research and development work done at industrial as well as university laboratories," Sivananthan continues. His work with MCT is at the heart of night-vision technology used by the US military. Working with US defense agencies and industry, Sivananthan promoted the need for on-shore capabilities and horizontal integration for infrared materials and devices. In 2005 Dr Fenner Milton, director of the US Army Night Vision Laboratory, awarded Sivananthan the 'Friend of the Night' award and the 'Conquest of Darkness' medallion.

Sivananthan is currently leading strategies at EPIR to strengthen its infrared material foundry and focal plane array (FPA) fabrication facilities, in collaboration with DRS Technologies, FLIR Systems and

BAE Systems. DRS is qualifying the material from EPIR. "The ultimate goal is to qualify EPIR as a merchant supplier of HgCdTe material for DRS NIS' future cooled products," says Dr James Robinson, VP of technology at DRS Network and Imaging Systems (NIS). BAE Systems has licensed to EPIR the fabrication of its liquid-phase epitaxy (LPE) MCT detector array technology.

Also, because, at its most fundamental, MCT technology is about transforming light into electricity, Sivananthan has helped to found InSPIRE (Institute for Solar Photovoltaic Innovation, Research and Edu-training), a nonprofit organization with the mission of training workers and encouraging high-school and college students to pursue careers in renewable energy, and hence nurturing a solar ecosystem in Illinois.

Sivananthan is also the founder of the Bell-Labs-styled incubator Sivananthan Laboratories Inc in Bolingbrook, which aims to nurture small businesses by fostering fundamental R&D that bridges the gap between academia and industry, focusing on IR technology, radiation detection, materials research and biosensors.

[www.whitehouse.gov/champions](http://www.whitehouse.gov/champions)  
[www.uic.edu](http://www.uic.edu)

## First Solar breaks ground on New Mexico's largest plant

Regional electric utility firm El Paso Electric Power, The New Mexico State Land Office and cadmium telluride module maker First Solar Inc of Tempe, AZ, USA have announced that construction has started on the Macho Springs Solar Project (which will be the state's largest solar power plant), located on State Trust Land near Deming in Luna County.

"Benefits to the local and regional economy include millions of dollars in direct and indirect economic benefits, and about 300 temporary construction jobs," says New Mexico State Land Commissioner Ray Powell.

Construction is due to complete by May 2014, and the active power plant will include three operational and maintenance jobs.

Under a 20-year power purchase agreement (PPA) between El Paso Electric and First Solar, the 50MW<sub>ac</sub> project will generate enough energy to power more than 18,000 average homes in the El Paso Electric service territory. The project will displace more than 40,000 metric tons of CO<sub>2</sub> (equivalent to taking 7500 cars off the road) and will displace more than 340,000 metric tons of water consumption annually.

The project represents a system resource for El Paso Electric Company as the firm will purchase the entire output power from the Macho Springs project to serve its New Mexico and Texas territory. The project was secured by El Paso Electric via an all-source competitive Request for Proposal process conducted in 2011. It will operate on a commercial lease from the New Mexico State Land Office on about 500 acres of land at Macho Springs. First Solar also has an interconnection agreement with El Paso Electric.

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



## SoloPower to restructure while seeking financing Amid lay-offs, head office to move from San Jose to Oregon to cut costs

SoloPower Inc of San Jose, CA, USA, which makes thin-film copper indium gallium diselenide (CIGS) photovoltaic (PV) cells and light-weight flexible solar modules using a proprietary roll-to-roll electro-deposition process, says that an agreement in principle has been reached with its major secured creditors on a comprehensive restructuring plan as it continues to seek new strategic financing for future expansion.

The firm has previously announced job lay-offs and the sale of some "surplus or redundant assets" at its San Jose site in an effort to keep the company afloat. SoloPower laid off 29 staff at the site on June 17, according to a

notice from Oregon's Department of Community Colleges and Workforce Development.

"This agreement will enable SoloPower to seek new strategic partners to enable continued production at the Portland, Oregon facility and advance our innovative lightweight PV technology," says CEO Rob Campbell. According to The Korea Herald, SoloPower is in talks with Korean convergence technology firm CTI Korea, and the aim is to open a solar panel manufacturing unit in Guangju and start phase one production as early as next year, according to Campbell. However, he says that, although South Korea is part of SoloPower's long-term plans, the development

would not threaten domestic US jobs: the Oregon factory is "an essential part of our going forward strategy," he adds. "We are confident that we are on the right path and appreciate the support of our secured creditors."

SoloPower has also confirmed reports that it is planning to move its head office location to Portland, Oregon, in order to further optimize operations.

The firm says that its proprietary lightweight, flexible solar modules serve a unique and underserved market — commercial and industrial rooftops on which traditional solar panels cannot be installed due to their weight and rigidity.

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

## China's Hanergy acquires US-based Global Solar Energy Operations to continue in USA as subsidiary of Hanergy, following acquisitions of MiaSolé and Solibro

Beijing-based Hanergy Holding Group Ltd – which is claimed to be the world's biggest thin-film photovoltaic (PV) firm – has completed the equity acquisition of Global Solar Energy Inc (GSE) of Tucson, AZ, USA, which makes flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic cells and modules.

Last December, GSE implemented cost-cutting measures while it pursued a sale process and evaluated strategic options (as announced in June 2012, when German subsidiary Global Solar Energy Deutschland GmbH also applied for insolvency proceedings).

The acquisition follows approval from the Committee on Foreign Investment in the USA and the National Development and Reform Commission (the regulators governing cross-border acquisitions in the USA and China, respectively). GSE is one of just a few producers able to manufacture flexible CIGS solar cells on a commercial scale.

Its products are applied in areas including building-integrated photovoltaic (BIPV), rooftop solar systems, electronic vehicles and other portable solar products.

In the past year, Hanergy has acquired CIGS PV manufacturers MiaSolé of Santa Clara, CA, USA and Solibro GmbH (the latter from Q.CELLS SE of Bitterfeld-Wolfen, Germany). Hanergy says that the acquisition of GSE closes the loop of its strategic consolidation of technologies combining the competitive advantages of flexible thin-film PV modules with large scale production.

"Flexible and thin-film photovoltaic technology is the future and the trend of the industry," comments Hanergy's chairman Li Hejun. "The acquisition of GSE marks another landmark deal for us after MiaSolé and Solibro. Together these complete the circle of Hanergy's global technology integration strategy, meaning we now have the ability to accelerate

the development and large-scale application of our high-efficiency flexible CIGS modules," he adds.

"We are pleased to join with Hanergy, which we believe will best leverage our unique products and technologies to complement Hanergy's existing ones," comments Global Solar's CEO Jeff Britt. "Together, we are well positioned to implement Hanergy's strategy of accelerating the growth of the flexible solar market and exploit new market potentials."

Following the acquisition, GSE will become a subsidiary of Hanergy, but will continue its operation in the USA.

According to the report 'Global Renewable Energy Report 2013' (published by Hanergy), China's investment in renewable energy is ranked first in the world. By 2013, China is expected to surpass Germany and become the world's largest PV application market.

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

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

# Solar Frontier reaches 14.6% efficiency with 1257mm x 977mm CIS module

## Efficiency on a par with 15% of mass-market polysilicon modules

Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — says that its latest champion module from its flagship gigawatt-scale Kunitomi Plant in Miyazaki, Japan, has achieved 14.6% conversion efficiency. The rated capacity of the 1257mm x 977mm module has been certified by Underwriters Laboratories Inc (UL) at 179.8W.

The efficiency is at the same level as mass-marketed polycrystalline silicon modules, the firm says (as of April, the efficiency of polycrystalline silicon modules is about 15%, according to GTM Research senior solar analyst Shyam Mehta in 'The module market landscape',

GTM Solar Summit 2013). Manufacturing the new CIS module on a production line at the Kunitomi Plant suggests an accelerated outlook for transferring the technology to full mass production, the firm says.

This year marks the 20th anniversary of R&D on CIS technology at parent company Showa Shell Sekiyu. Solar Frontier's other recent milestones include the world's highest aperture area efficiency of 17.8% for a 30cm x 30cm CIS solar module, and record conversion efficiency of 19.7% for a cadmium-free CIS solar cell (about 0.5cm<sup>2</sup> in area).

CIS technology has the potential to achieve even higher energy

conversion efficiency, says Solar Frontier, and there is also room for further production cost reductions. The firm says that its manufacturing process requires a lower quantity of raw materials and energy, so its CIS solar modules have a lower environmental impact.

"Champion modules are a key validation of technology transfer from Solar Frontier's laboratories," says chief technology officer Satoru Kuriyagawa. "This is the kind of result we look for in the production factory once we have confirmed experimental results and simulation in our pilot plant at Atsugi Research Center."

[www.solar-frontier.com](http://www.solar-frontier.com)

## Production re-started at 60MW Miyazaki No.2 Plant Conventional CIS PV modules for residential use to give way to new type of module in second-half 2013

Solar Frontier has re-started production at its Miyazaki No.2 Plant. The plant at Kiyotakecho in Miyazaki, Japan (which has an annual capacity of 60MW) had been temporarily suspended since the end of 2012, and the firm has since been evaluating the feasibility of manufacturing new products.

In July, the plant will re-start manufacturing conventional thin-film CIS modules for residential use while final arrangements are being made to begin commercial production of a new type of module, which has been developed at Solar Frontier's Atsugi Research Center. Based on a feasibility evaluation, production of the new module will start in second-half 2013.

Miyazaki No.2 Plant (which opened in 2009) provided the experience that enabled Solar Frontier to open the 900MW-



Solar Frontier's Miyazaki No.2 Plant.

capacity Kunitomi Plant, Japan's largest solar module production plant. At the end of 2012, Solar Frontier temporarily halted operations at Miyazaki No.2 Plant, as it

was able to streamline all production at the Kunitomi Plant. It is now re-starting Miyazaki No.2 Plant to meet growing demand for CIS thin-film modules.



# Ascent to build CIGS PV module manufacturing plant in China's Jiangsu Province in JV with Suqian Government

## Six year project targets consumer electronics contract manufacturers

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight copper indium gallium diselenide (CIGS) thin-film photovoltaic modules integrated into its EnerPlex series of consumer products, has signed a framework agreement for the establishment of a joint venture with the Government of the Municipal City of Suqian in Jiangsu Province, China, covering a multi-faceted, three-phase project over the next six years.

Suqian is a prefecture-level city in northern Jiangsu Province with an area of 3303 square miles and a population over 5 million. Strategically located between the Yellow River and the Yangtze River, the city is connected to both Beijing and Shanghai in less than 3 hours by high-speed train. Suqian is one of the fastest-growing prefecture-level cities in China, with a gross domestic product (GDP) of \$25bn in 2012 and growing nearly 13% annually.

In the first phase, Ascent and Suqian will form a joint venture in which Ascent will have majority interest of up to 80%. The JV will build a factory to manufacture Ascent's proprietary CIGS PV modules on flexible thin films. Ascent will contribute proprietary technology and intellectual property, about \$1.6m in cash and certain equipment from its Colorado facility. Suqian will provide cash of about \$32.5m as well as rent-free use of a

270,000 square foot factory that is currently being built in the Suqian Economic and Industrial Development Science Park. This factory is expandable to 1,000,000 square feet for phases two and three of the agreement. The total project size of Phase 1 of the alliance is expected to be about \$160m. Ascent will have the right to purchase the factory anytime within the first 5 years at the initial construction cost, as well as the right to purchase Suqian's ownership interest in the JV for a modest nominal cost above Suqian's cash investment.

Suqian will also provide a package of additional incentives including a multi-year corporate tax holiday, coverage of substantial operational costs for scientists, engineers and management personnel, and housing subsidies and tax incentives for key JV staff. As Phases 2 and 3 of the program are implemented, Ascent will have the option to purchase about 1.3 million square feet of land zoned for commercial usage at a favorable cost, as well as the right to arrange the sale or lease of land and factory rights to suppliers and support industries brought in by Ascent, which may generate additional cash flow for the JV.

"This partnership enables us to accelerate our paradigm shift into consumer electronics and specialty market applications, given China's very large and growing consumer

base and readily available contract manufacturers for our EnerPlex range of consumer products," says Ascent's president & CEO Victor Lee.

"We are convinced that CIGS, and more specifically Ascent's proprietary CIGS technology utilizing a flexible plastic substrate, is the next breakthrough in photovoltaics," comments Lan Shao Min, Top Leader & Governor of the Municipal City of Suqian.

"The aim of our alliance with Ascent is to build a state-of-the-art industrial park in Suqian for solar and solar-related products, anchored by the Ascent factory, but including equipment suppliers, contract manufacturers and other supporting industries," he adds.

"The funding and other subsidies will enable Ascent to develop the scale of manufacturing needed to bring the cost of CIGS down substantially," says Ascent's chairman Amit Kumar. "The combination of cost reduction and our higher-margin EnerPlex products and other specialty market applications will allow Ascent to carry on to its next stage as a high-growth company. The alliance with Suqian, as it develops over the next six years, will provide a means for Ascent to build positive cash flow from numerous sources, including control of the real-estate rights in the Suqian Economic and Industrial Development Science Park."

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

## Ascent to receive \$6m funding boost from Asian investor

Ascent Solar has signed an agreement with a private investor in Asia to raise \$6m through a private placement. Ascent will use the proceeds to fund the expansion of retail channels for its EnerPlex products in the USA, Europe and Asia; brand building; and the launch of additional EnerPlex products.

In the private placement, the company will issue (i) shares of Series A Preferred Stock convertible, at a conversion price of \$0.80 per share, into 7,500,000 shares of common stock and (ii) warrants with a three-year term to acquire 2,625,000 shares of common stock at a cash exercise price of \$0.90 per share. The private

placement will be funded in three tranches, with the initial \$1m tranche closed this week. The remaining two tranches are expected to fund after a registration statement (to be filed by the company relating to the private placement securities) is declared effective by the US Securities and Exchange Commission (SEC).

## PVMC releases first US CIGS roadmap

The US Photovoltaic Manufacturing Consortium (PVMC) — an industry-led collaboration headquartered at the College of Nanoscale Science and Engineering (CNSE) of the State University of New York (SUNY) in Albany, NY — has released the first US CIGS (copper indium gallium diselenide) PV Roadmap reports.

"Photovoltaics and especially thin-film PV are again at a tipping point," says Larry Kazmerski, co-chair of the US CIGS PV Roadmap. "We want PV to be a substantial part of the world's energy portfolio and our efforts with this roadmap are aimed to help make CIGS thin films a significant part of that solar success," he adds.

"In building on the innovation strategy of Governor Andrew Cuomo that is establishing New York as a hub for solar energy technologies and companies, we engaged over 75 partner firms and 100 industry experts to develop a 10-year projection in the first-ever US CIGS PV roadmap," says Dr Pradeep Haldar, PVMC's chief operating & technology officer and CNSE's VP for Clean Energy Programs. "This blueprint identifies the critical challenges for CIGS PV manufacturing, applications for sustainable innovation, and technical developments that will serve our members and stakeholders, and enable a competitive US solar industry amid the global marketplace."

Spearheaded by CNSE and SEMATECH (the global research consortium of device, equipment, and materials manufacturers) as part of the US Department of Energy's (DOE) SunShot Initiative, PVMC is an industry-led consortium for cooperative R&D among industry, university and government partners to accelerate the development, commercialization and manufacturing of next-generation solar PV systems. Through its programs and advanced manufacturing development facilities, PVMC is a proving ground for innovative solar technologies and manufacturing processes. Specifically, PVMC is targeting a reduction

in the total installed cost of solar energy systems by 75% over the next decade. The CIGS PV Roadmap aims to provide a congruent plan for the national CIGS industry, including module and systems manufacturers, suppliers and end-users, that will identify common challenges and define the areas of technical developments needed to sustain and advance a competitive US photovoltaic industry.

The annual roadmap '2013 US CIGS PV Roadmap Reports' identifies the technology challenges to attain projected module cost and performance targets over the next 10 years. Various reports, based on the latest industry analysis, advance the effort for achieving the SunShot target.

The roadmap addresses six focus areas relevant to the entire industry, including roll-to-roll, rigid glass, metrology, modules and packaging, substrates and materials, and reliability/certification/test. Each section outlines the current status and critical challenges for each technology, discusses the role of industry standards for CIGS, and potential areas of innovation for the pre-competitive domain.

As the primary sponsor of the effort, PVMC provides resources to manage and coordinate roadmap activities. Members of the CIGS PV Roadmap represent all areas of the PV industry, including module producers and integrators, equipment suppliers, materials and metrology tools, end-users, as well as researchers.

On 11 July, during the Third Annual US CIGS PV Roadmap Public Forum at Intersolar North America 2013 in San Francisco, roadmap working group leaders presented summaries of these reports and announced plans for a revised 2014 roadmap. The Forum, sponsored by PVMC and hosted by industry association Semiconductor Equipment and Materials International (SEMI), invited new members to join the various teams to develop the next assortment of reports.

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

### IN BRIEF

## Ascent Solar appoints West Coast as EnerPlex distributor for UK and Ireland

Ascent Solar Technologies Inc of Thornton, CO, USA — which makes lightweight, flexible, copper indium gallium diselenide (CIGS) thin-film photovoltaic modules, integrated into its EnerPlex series of consumer products — has announced a new distribution partnership with West Coast Ltd, an electronics distributors in the UK and Ireland (represented by PowerIT-2-Channel Ltd).

Founded in 1984, West Coast's annual revenue exceeds €1bn. Over the past decade, the firm has become the largest UK distributor for companies such as Hewlett Packard, Samsung and Toshiba.

"This agreement enables Ascent to leverage West Coast's considerable distribution capabilities to reach nearly every consumer in the UK and Ireland via both e-commerce, retail and direct channels, bringing Ascent's EnerPlex products to market in force in an incredibly short period of time," says John Maslanik, Ascent's manager of business development. "Consumers in the UK and Ireland have shown great interest in renewable energy products, a trend which the EnerPlex series of products is perfectly situated to immediately benefit from. Furthermore, this agreement represents a blueprint for Ascent's expansion into new international markets, taking advantage of entrenched distribution channels and relationships which enable rapid deployment of EnerPlex products to an attractive target market."

[www.westcoast.co.uk](http://www.westcoast.co.uk)  
[www.ascentsolar.com](http://www.ascentsolar.com)

# First polariton laser with electrical pumping

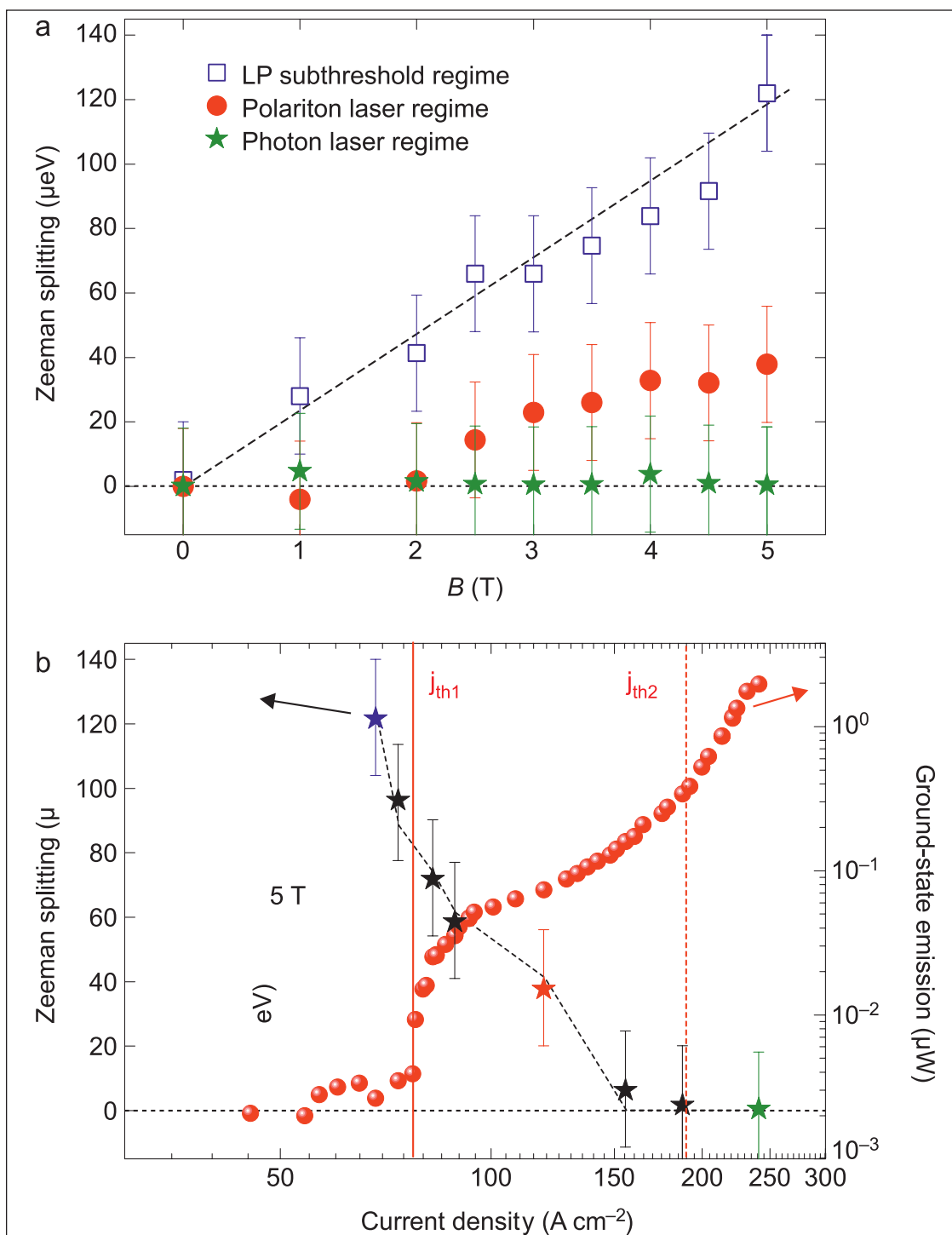
**Researchers claim an important step towards practical implementation of polaritonic light sources and electrically injected condensates.**

**A** transnational team of researchers has reported the first electrically pumped exciton-polariton laser device using an arsenide semiconductor microcavity [Christian Schneider et al, *Nature*, vol. 497, p348, 2013]. The team was variously based at Universität Würzburg (Germany), University of Stanford (USA), University of Tokyo (Japan), University of Iceland, Nanyang Technological University (Singapore), Russian Academy of Science Institute of Solid State Physics, Technische Universität Berlin (Germany), and National Institute of Informatics (Japan).

Researchers hope that polariton lasing principles will lead to more energy-efficient semiconductor lasers with lower thresholds.

Normal 'weak-coupling' laser diodes use transitions of electrons from the conduction band across the gap to holes in the valence band (electron-hole recombination).

Exciton-polaritons represent mixed quasi-particle states that arise due to strong coupling between photons and



**Figure 1. Zeeman splitting of polaritonic emission: (a) mode splitting as function of magnetic field for different current densities in three characteristic regimes; (b) current-density-dependent mode splitting at 5 T; light output power is also plotted.**



bound pairs of electrons and holes ('excitons'). The dispersion relation for these particles has upper- and lower-energy branches. The pumping of energy into the system accumulates polaritons in a single-particle ground state of the lower-energy branch by a nonlinear stimulated scattering mechanism. A polariton laser generates coherent light by leakage of photons from the system.

For arsenide semiconductors, very low temperatures of around 10K are needed for stable polaritons. However, optically pumped polariton lasing in nitride semiconductors at room temperature was demonstrated in 2007. Also, a one-dimensional polariton condensate in zinc oxide nanowires at room temperature was reported in 2010. Nitride semiconductors and zinc oxide are wide-bandgap semiconductor materials.

The researchers comment: "Our results represent an important step towards the practical implementation of polaritonic light sources and electrically injected condensates, and can be extended to room-temperature operation using wide-bandgap materials."

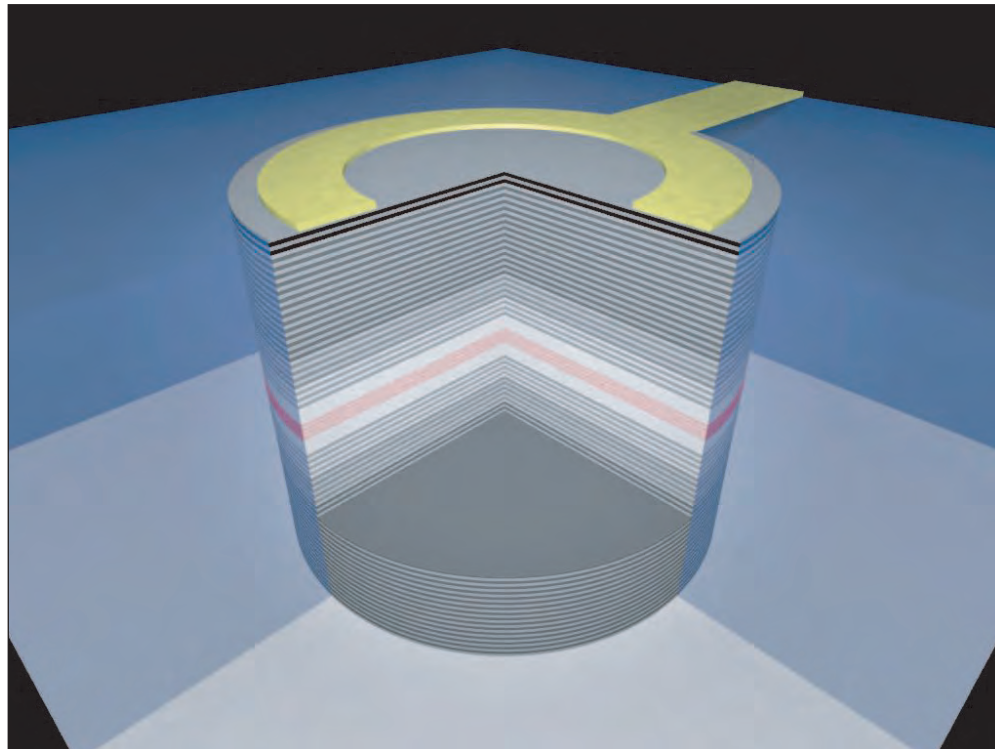
The researchers carried out an extensive series of experiments on their device to confirm that the laser light produced was from exciton-polaritons and not through the normal weak-coupling interaction that traps photons in a cavity.

Magnetic fields were useful in the discrimination of polariton effects as opposed to cavity-mediated lasing. In particular, the Zeeman splitting effect of the magnetic field allows determination of exciton densities.

The researchers found two current thresholds in operation, which they associated with a transition from incoherent to coherent (i.e. laser) polariton emission and with a transition from polariton to cavity-mediated laser operation. It was found that the Zeeman splitting of the mode decreased as the injected current increased towards the second threshold (Figure 1).

The polariton laser threshold current density was around  $82\text{A}/\text{cm}^2$  in zero magnetic field and  $77\text{A}/\text{cm}^2$  in a 5 Tesla (5T) field. The second threshold occurs around  $190\text{A}/\text{cm}^2$  for both zero and 5T magnetic fields. The researchers believe that the second threshold represents a transition to weak-coupling due to screening effects from the high density of excitons.

The researchers write: "The fact that the [Zeeman] mode splitting at 5T remains detectable up to the current at which the photon lasing threshold is crossed is



**Figure 2. Schematic of quantum well microcavity polariton diode.**

unambiguous evidence of an excitonic component of our system, due to which the strong coupling is preserved across the first threshold attributed to polariton lasing."

The electrically pumped laser structure was similar to a vertical-cavity surface-emitting laser (VCSEL) with distributed Bragg reflectors (DBRs) above and below the multiple quantum well (MQW) active light-emitting region (Figure 2). The arsenide semiconductor layers were built up using molecular beam epitaxy (MBE) on n-type (silicon-doped) (100)-oriented gallium arsenide (GaAs) substrate.

The bottom n-DBR consisted of 27 pairs of gallium arsenide/aluminium arsenide (GaAs/AlAs) and the top p-DBR consisted of 23 pairs with the same material combination. The doping concentration was graded, reducing towards the MQW region. Delta-doping was applied at every second interface to improve the conductivity of the structure.

The MQW consisted of four indium gallium arsenide (InGaAs) wells with GaAs barriers. The MQW cavity was designed to be one wavelength thick (281nm).

The laser  $20\mu\text{m}$ -diameter pillar structure was fabricated by electron cyclotron resonance reactive ion etching (ECR-RIE), followed by evaporation of a titanium/gold ring p-contact, a thin titanium/gold semi-transparent film on the p-type side, and then a back-side gold-germanium/nickel/gold alloy n-contact.

■

[www.nature.com/nature/journal/v497/n7449/full/nature12036.html](http://www.nature.com/nature/journal/v497/n7449/full/nature12036.html)

Author: Mike Cooke

# Longer-wavelength-lasing metamorphic InAs quantum wells on InP diodes

**Researchers in Shanghai have extended the dominant mode of InP-based antimony-free interband laser diodes to 2.7μm at 77K.**

**T**he Chinese Academy of Sciences'

Shanghai Institute of Microsystem and Information Technology has extended the longest wavelength of indium phosphide-based antimony-free interband laser diodes to 2.7μm [Y. Y. Cao et al, Appl. Phys. Lett., vol102, p201111, 2013].

Laser light of such wavelengths has applications in molecular spectroscopy, gas analysis and medical inspection. The attractions of InP-based antimony-free structures include lower substrate costs, more mature processing technology, and better thermal conductivity, compared with the alternative of growing laser material on gallium antimonide (GaSb) substrates.

The epitaxial material (Table 1) was grown on (100) indium phosphide (InP) using a VG Semicon V80H gas-source molecular beam epitaxy (GSMBE) system. The  $\text{In}_x\text{Al}_{1-x}\text{As}$  graded buffer was achieved by increasing the indium and lowering the aluminium temperatures to give x of 0.52 at the buffer layer and 0.84 at the beginning of the

Layer	Material	Thickness (nm)	Concentration (/cm <sup>3</sup> )
Contact	$\text{In}_{0.8}\text{Ga}_{0.2}\text{As:Be}$	300	$p = 1 \times 10^{19}$
Cladding	$\text{In}_{0.8}\text{Ga}_{0.2}\text{As:Be}$	1700	$p = 8 \times 10^{17}$
Waveguide	$\text{In}_{0.8}\text{Ga}_{0.2}\text{As}$	150	Undoped
Barrier	$\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$	7.5	Undoped
Well	InAs	15	Undoped
Barrier	$\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$	15	Undoped
Well	InAs	15	Undoped
Barrier	$\text{In}_{0.6}\text{Ga}_{0.4}\text{As}$	7.5	Undoped
Waveguide	$\text{In}_{0.8}\text{Ga}_{0.2}\text{As}$	150	Undoped
Cladding	$\text{In}_{0.8}\text{Ga}_{0.2}\text{As:Si}$	800	$n = 8 \times 10^{17}$
Graded buffer	$\text{In}_x\text{Al}_{1-x}\text{As:Si}$	1800	$n = 2 \times 10^{18}$
Buffer	InP:Si	200	$n = 2 \times 10^{18}$
Substrate	InP:S	350μm	$n = 2 \times 10^{18}$

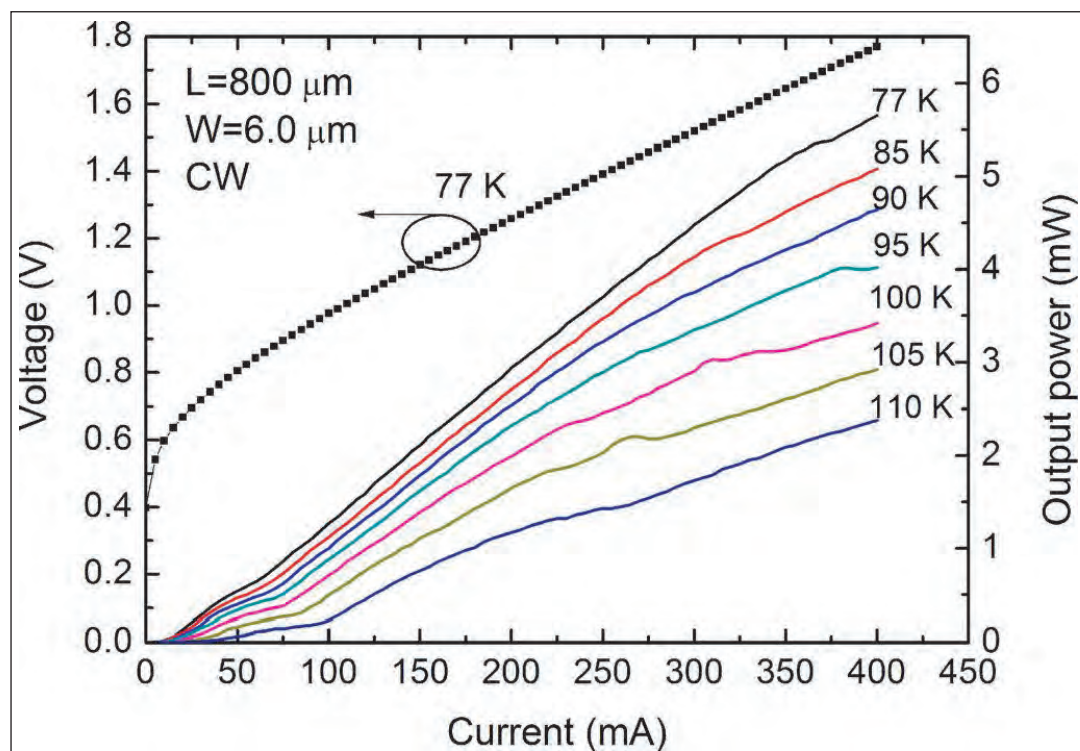
**Table 1. Layer parameters of laser structure.**

separate confinement heterostructure (SCH) laser material. The purpose of the grading is to provide 'metamorphic' strain compensation of the mismatch of the laser heterostructure and underlying InP substrate.

Ridge waveguide lasers were produced with a ridge width of  $6\mu\text{m}$ . Isolation was achieved through plasma-enhanced chemical vapor deposition (PECVD) of  $300\text{nm}$  of silicon nitride. A  $4\mu\text{m}$ -wide hole opened in the silicon nitride on top of the ridge was filled with titanium/platinum/gold as a top metal contact. The devices were then thinned to  $100\text{--}120\mu\text{m}$  and a back metal contact of germanium/gold/nickel/gold was applied. The devices were cleaved into  $0.8\mu\text{m}$ -long bars, soldered on copper heat sinks and wire bonded. The facets were not coated.

Running in continuous wave (CW) operation at  $1.2\times$  the threshold current, the dominant lasing peak wavelength was  $2.697\mu\text{m}$  at  $77\text{K}$  and  $2.71\mu\text{m}$  at  $110\text{K}$ . The red-shift of  $0.61\text{nm/K}$  on average was attributed to narrowing of the bandgap as the temperature increased.

The threshold current was  $7\text{mA}$  ( $145\text{A/cm}^2$  density) at  $77\text{K}$ , and at  $400\text{mA}$  injection current the output power was  $5.7\text{mW}$  (Figure 1). The output power at  $400\text{mA}$  decreased to  $2.4\text{mW}$  at  $110\text{K}$ . The relatively low characteristic temperature ( $T_0$ ) of  $20.1\text{K}$  was possibly due to the narrower bandgap in the waveguide layers compared with the quantum well barriers,



**Figure 1.** Current versus output power and voltage characteristics of laser under CW operation.

leading to unfavorable electron/hole confinement. The researchers believe that an optimized waveguide material could improve the electron/hole confinement, leading to better laser performance.

The threshold current density at  $77\text{K}$  is lower than other values in the literature such as  $290\text{A/cm}^2$  for a  $2.45\mu\text{m}$  InP-based device at the same temperature, produced by a consortium of US-based researchers. ■

<http://link.aip.org/link/doi/10.1063/1.4807671>

Author: Mike Cooke

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# Overgrowth and surface plasmons for ultraviolet LEDs made on silicon wafers

**Northwestern University has achieved peak output power of 1.2mW at wavelengths around 346nm.**

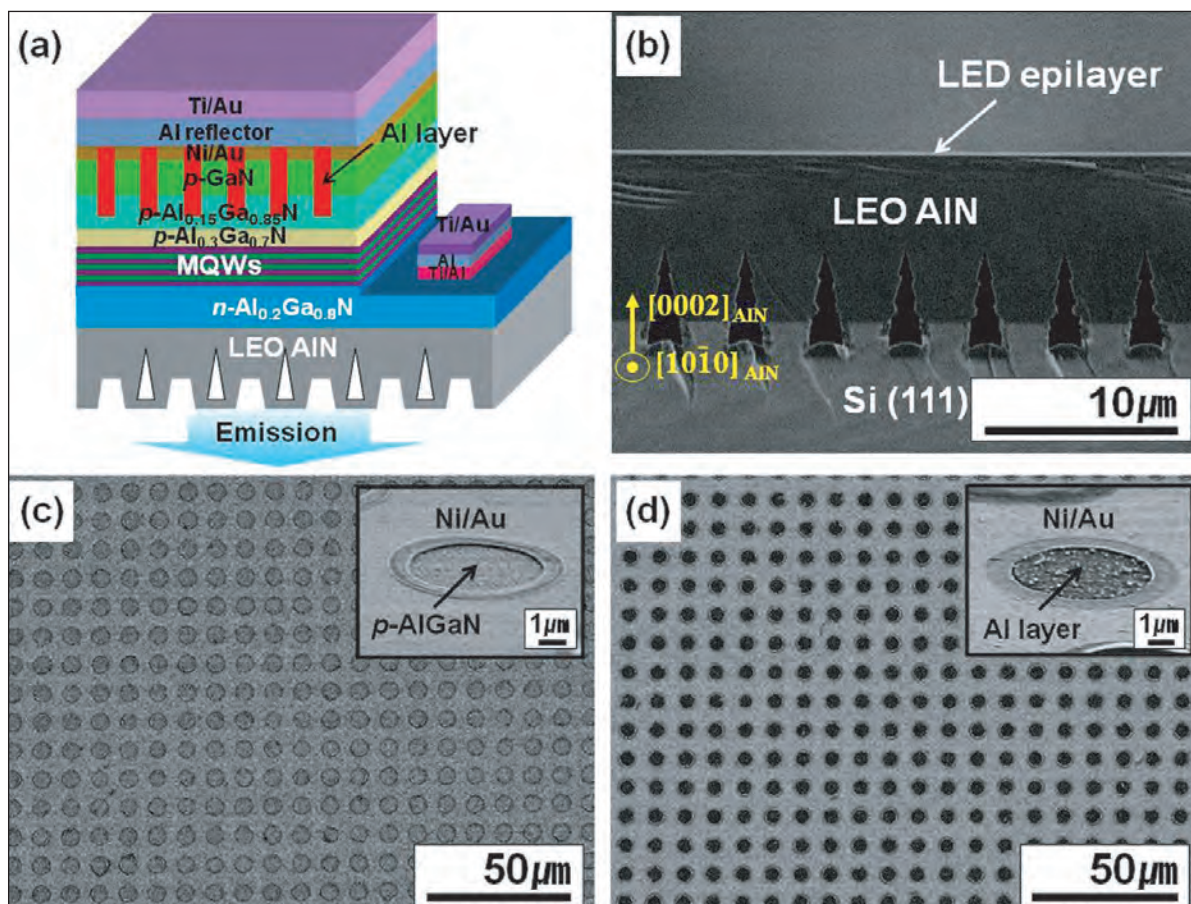
**N**orthwestern University's Center for Quantum Devices has developed a surface-plasmon (SP) enhancement technique for ultraviolet (UV) light-emitting diodes (LEDs) produced on silicon substrates [Chu-Young Cho et al, Appl. Phys. Lett., vol102, p211110, 2013]. The resulting devices achieved a peak output power of 1.2mW at wavelengths around 346nm.

The use of silicon as a substrate for nitride semiconductor structures has been of much interest in the past few years for high-power and high-frequency transistors. Silicon offers the prospect of lower costs, economies of scale from the availability of larger-diameter wafers, and so on. More recently, researchers have turned to the more difficult challenge of producing light-emitting devices using nitride semiconductor grown on silicon.

Northwestern has developed techniques to improve the crystal quality of the nitride semiconductor growth on silicon and in addition used aluminium (Al) metal structures to boost quantum efficiency with coupling to surface plasmons (collective oscillations of free electrons at metal-dielectric interfaces).

The epitaxial material was grown on (111) silicon using low-pressure metal-organic chemical vapor deposition (MOCVD). Lateral epitaxial overgrowth (LEO) was used to improve the quality of the initial aluminium nitride (AlN) layer. It is particularly difficult to grow AlN on silicon due to the large ~19% lattice mismatch between their crystal structures.

The LEO method consisted of first growing a thin 100nm layer of AlN, etching a 2µm-wide stripe pattern with a period of 4µm to expose regions of silicon, and the re-growth of a thick 8µm layer of AlN with reduced dislocations and cracks. The growth steps used a high



**Figure 1. (a) Schematic diagram of the SP-enhanced AlGaIn-based UV LED structure with embedded Al layer. (b) Cross-sectional SEM image of LED structure grown on Si (111) substrate. Plan-view SEM images of circular-shaped holes in p-contact layer (c) before and (d) after deposition of the Al layer.**

temperature (1300°C) and atomic layer epitaxy, achieved using pulses of the different precursors.

After the AlN growth the material was found to have air-voids (Figure 1b) where the material had grown laterally and then coalesced to form the AlN template for the subsequent layers. "These voids decouple the top AlGaIn layers from the silicon substrate and help avoid the formation of cracks," the researchers write.

Further epitaxial layers consisted of 600nm of n-type aluminium gallium nitride ( $n\text{-Al}_{0.2}\text{Ga}_{0.8}\text{N}$ ), a multiple quantum well (MQW) active region, 10nm of p- $\text{Al}_{0.3}\text{Ga}_{0.7}\text{N}$  for electron blocking, 50nm p- $\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$  cladding, and a 50nm p-GaN contact. The MQW consisted of three 3nm  $\text{Al}_{0.1}\text{Ga}_{0.9}\text{N}$  wells separated by 7nm  $\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$  barriers. The MQW was grown at a reduced temperature of 1150°C.

LED fabrication consisted of electron cyclotron resonance reactive ion etch (ECR-RIE) of 300µm x 300µm square mesas, the application of a titanium/aluminium ohmic n-contact, and the deposition of a nickel/gold ohmic p-contact. Surface-plasmon enhancement was achieved by drilling 5µm holes 90nm deep into the p-type GaN/AlGaIn layers with ECR-RIE. These holes (with 10µm period) were filled with Al metal.

The researchers used Al surface plasmons since their energy is in resonance with the ~340nm UV light of the AlGaIn LED structure. To couple surface plasmons with the radiation in the MQW, the Al metal needs to be close by, of the order of tens of nanometers. The penetration depth of the SP fringing field was estimated at ~50nm. In the Northwestern LEDs, the pillars were 20nm away from the MQW.

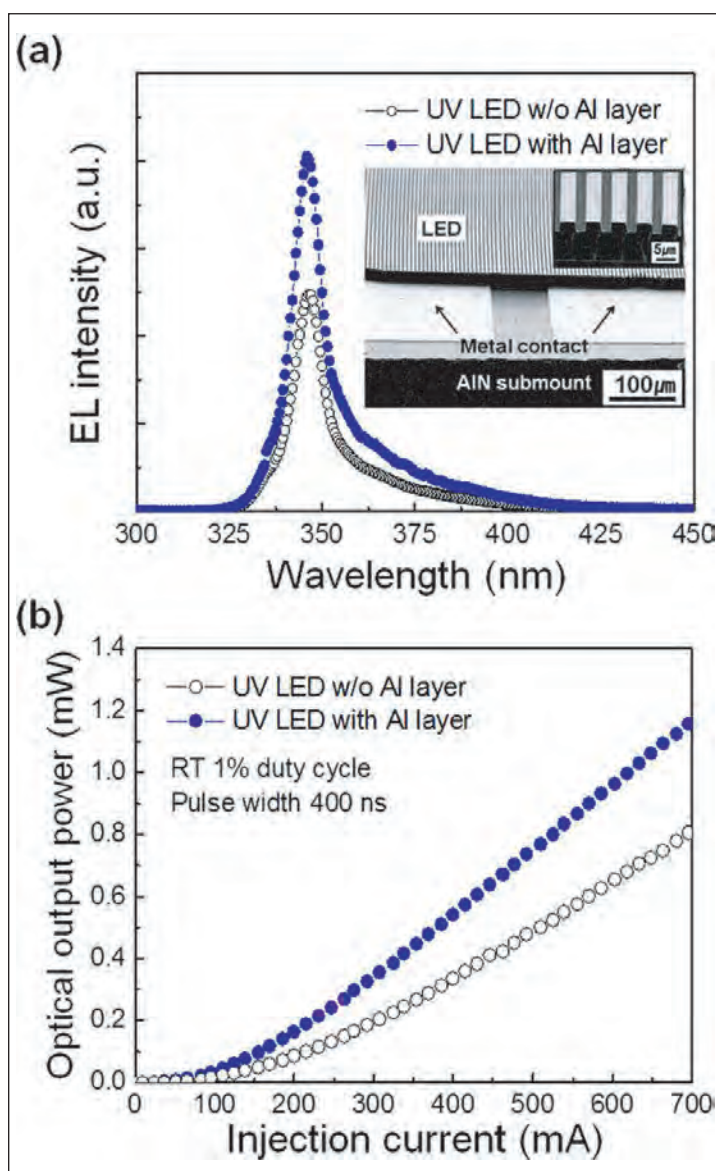
The devices were completed with an Al reflector, and titanium/gold layers were added to both n- and p-contacts. The chips were flipped onto AlN submounts and the silicon substrate was chemically removed.

As is usual, the structures were first tested for photoluminescence (PL), with the SP-MQW devices showing an enhancement of 2.4x integrated intensity at room temperature. This is more than would be expected from just having an Al mirror (<2x).

The researchers comment: "This improvement of the PL intensity is believed to be due to an increase in the spontaneous emission rate and improved internal quantum efficiency of MQWs by SP-coupling."

Normalizing with respect to PL measurements at 10K, where the internal quantum efficiency (IQE) is estimated to be 100%, the IQE without Al structures was 3.7%, increasing to 10.1% with SP-MQW structures. It is thought that the coupling of SPs with the excitons (electron-hole pairs) in the MQW region increases the spontaneous recombination rate and improves IQE.

Tests with structures where the distance between the MQW and Al SPs is increased by inserting a silicon dioxide spacer supports the concept of SP-MQW coupling.



**Figure 2. (a) Room-temperature EL spectra of UV LEDs with and without Al layer. Inset: inclined plan-view SEM images of SP-enhanced UV LED bonded to AlN submount after removal of Si substrate. (b) Optical output power of UV LEDs with and without Al layer versus injection current.**

Devices with and without Al SP structures had very similar current-voltage behavior. This is encouraging, since etch processes can degrade electrical performance.

The improved performance of Al SP structures carried over to the full LEDs (Figure 2). A maximum output power of 1.2mW was achieved with an injection current of 700mA, a 45% improvement over the device without Al SP structures. Pulsed operation was used to avoid performance degradation from self-heating effects.

The researchers explain the smaller improvement for electroluminescence (EL), as compared with PL, as being due to the PL including enhancements of both energy absorption and emission. ■

<http://link.aip.org/link/doi/10.1063/1.4809521>

Author: Mike Cooke



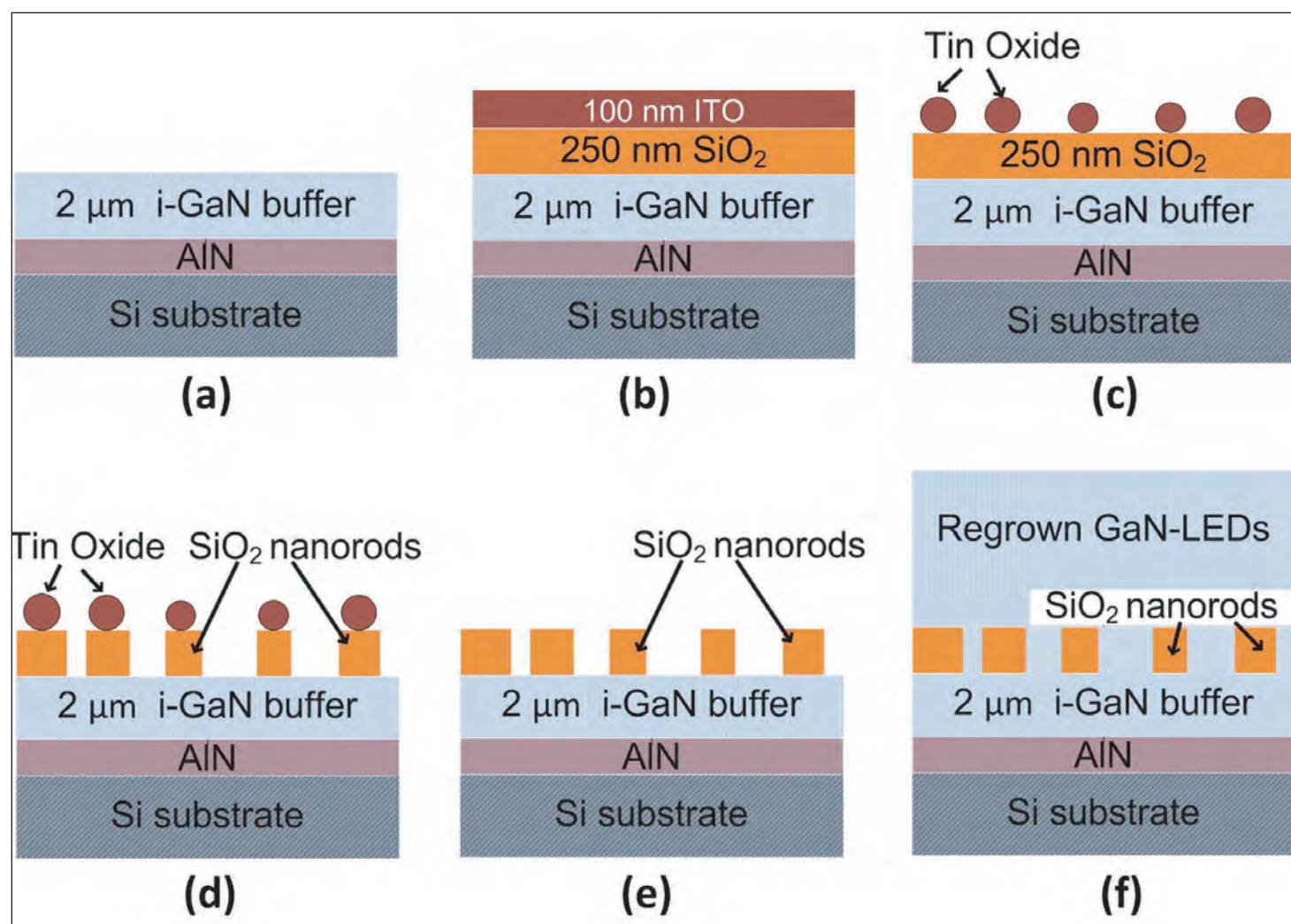
# First yellow LEDs from nitride semiconductor MQWs on silicon substrate

**Silicon dioxide nanorods have been used to improve material quality from lateral overgrowth.**

**H**ong Kong University of Science and Technology (HKUST) has developed silicon substrate growth of high-performance nitride semiconductor light-emitting diodes (LEDs) in the green and yellow bands [Xinbo Zou et al, IEEE TRANSACTIONS ON ELECTRON DEVICES, published online 29 May 2013]. The researchers claim the 565nm yellow LEDs as the first multi-quantum well (MQW) devices produced on silicon.

Producing longer-wavelength nitride semiconductor LEDs is challenging due to the difficulty of producing good-quality indium gallium nitride (InGaN) with higher indium concentration. Although growth on silicon is well established in nitride semiconductor transistor development, it is only fairly recently that similar growth methods have been applied to LED device material.

The attractions of silicon as a substrate include lower



**Figure 1.** Schematic process for GaN-based LEDs with embedded SiO<sub>2</sub> nanorods: (a) 2 μm GaN deposition on Si; (b) SiO<sub>2</sub> and ITO deposition; (c) ITO patterning in HCl; (d) SiO<sub>2</sub> dry etching; (e) dry etching mask removal; and (f) re-growth of GaN-based LEDs.



material cost and economies of scale in mass production from the larger wafer diameters available. However, the quality of nitride semiconductors on silicon suffer from the larger lattice mismatch compared with conventional, more expensive substrates of free-standing GaN, sapphire or silicon carbide (SiC).

The initial template, grown on 2-inch (111) silicon using metal-organic chemical vapor deposition (MOCVD), consisted of aluminium nitride (AlN) nucleation, 8 pairs of aluminium nitride/gallium nitride (AlN/GaN) layers to create a superlattice (SL) as stress-balancing interlayer, and a 2µm GaN buffer.

Silicon dioxide (SiO<sub>2</sub>) nanorods were then formed by depositing layers of SiO<sub>2</sub> and indium tin oxide (ITO), etching the ITO with hydrochloric (HCL) acid solution to form a mask, and finally plasma etching out the nanorods. The density of nanorods was 2x10<sup>9</sup>/cm<sup>2</sup>, giving a surface coverage of 35%. The purpose of the nanorods was to act as a mask in GaN re-growth with reduced dislocation density and improved crystalline quality.

The LED structure was then grown by MOCVD with re-growth of 800nm of GaN around the nanorods, an AlN/GaN SL interlayer, 2µm of n-type GaN, a 5-period multiple quantum well (MQW), and 200nm of p-GaN. The re-grown GaN had a dislocation density of 8x10<sup>8</sup>/cm<sup>2</sup>, described by the researchers as "one of the lowest values reported for GaN-on-Si substrates, as determined by TEM".

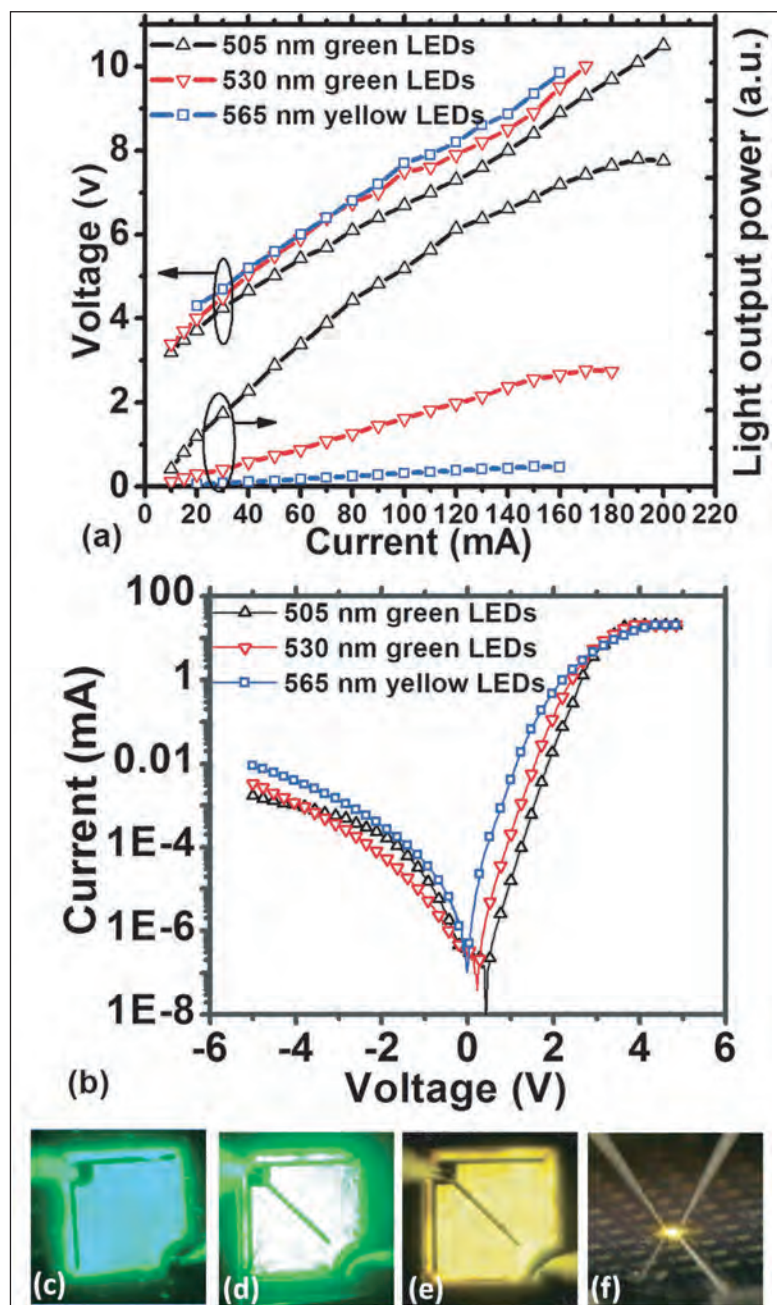
Materials suitable for emitting yellow (565nm) and green (505 and 530nm) light were prepared and formed into 300µm x 300µm LED chips.

As was to be expected, the light output power (LOP) decreased as the wavelength increased (Figure 2). At 20mA, the output at 505nm was 1.18mW. The respective values for 530nm and 565nm were 0.30mW and 74µW, respectively. Saturation of the light output power was achieved at 7.60mW (200mA), 2.72mW (180mA) and 0.52mW (160mA), for the 505nm, 530nm and 565nm devices, respectively.

The researchers comment: "This is the first report of fabricated 565nm yellow InGaN/GaN MQW LEDs on a silicon substrate, and the LOP of the 505nm LEDs was much higher than that for the LEDs on Si reported in the past."

Apart from the improved material quality, the researchers believe the nanorods also provide a scattering enhancement of light extraction from the devices.

The longer wavelength also increased the forward voltage at 20mA from 3.8V at 505nm to 4.3V at 565nm. Higher forward voltages indicate larger power losses. The researchers attribute the two primary reasons for the lower performance of the longer-wavelength



**Figure 2. (a) Light output power and voltage versus current characteristics of green and yellow LEDs encapsulated with silicone domes. (b) Current versus voltage characteristics. Light-emitting images of (c) 505nm, (d) 530nm and (e, f) 565nm LEDs.**

devices as "inferior p-GaN quality induced by the lower growth temperature and the lattice mismatch introduced by the high-indium-content quantum wells".

Temperature-dependent photoluminescence and electroluminescence spectra indicated the presence of In-rich clusters that induced localized states in the MQWs. Effective carrier injection into these localized states played a key role in the highly efficient 'green gap' spectrum emission, the researchers believe. ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6521369>

Author: Mike Cooke

# Silicon nitride gate insulation and passivation reduces current collapse

**The maximum drain current and breakdown voltages have also been increased in nitride high-electron-mobility transistors.**

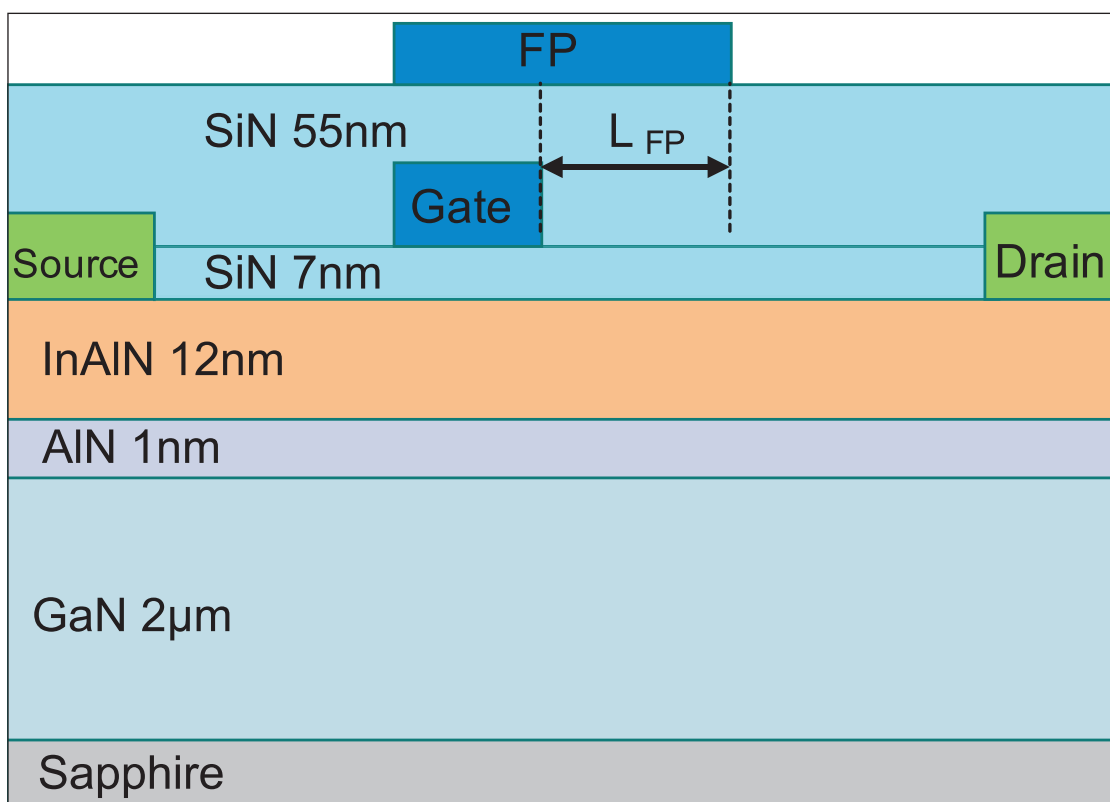
**X**idian University has developed a nitride field-plated metal-insulator-semiconductor high-electron-mobility transistor (FP MIS-HEMT) with 'negligible' current collapse, along with high maximum current and enhanced breakdown voltage performance [Mao Wei et al, Chin. Phys. Lett., vol30, p058502, 2013]. The device uses silicon nitride (SiN) as gate insulation and passivation to achieve these results.

Current collapse is a serious problem in nitride HEMTs, observed in pulsed operation in comparison with direct current (DC) performance.

Since transistors tend to be operated with varying bias conditions, such performance degradation must be minimized.

The nitride layers of the FP MIS-HEMT (Figure 1) were grown using metal-organic chemical vapor deposition (MOCVD) on c-plane sapphire. The barrier layer consisted of indium aluminium nitride ( $\text{In}_{0.15}\text{Al}_{0.85}\text{N}$ ), which is nearly lattice matched to the underlying gallium nitride (GaN).

The GaN and AlN layers were grown at 940°C/40Torr. The InAlN was constructed using a pulse approach at the lower temperature of 760°C/200Torr as a series of short-period AlN/InN superlattices to improve indium incorporation. The nitride semiconductor structure had a two-dimensional electron gas (2DEG) with  $1.49 \times 10^{13}/\text{cm}^2$  carrier density and  $1503 \text{ cm}^2/\text{V-s}$  mobility.



**Figure 1. Schematic of FP MIS-HEMT.**

Device fabrication began with mesa isolation reactive ion etching and deposition of ohmic titanium/aluminium/nickel/gold source-drain electrodes separated by  $3.5 \mu\text{m}$ .

The first layer of 7nm silicon nitride (SiN) was then deposited using plasma-enhanced chemical vapor deposition (PECVD). The gate was then created with a nickel/gold/nickel structure at a distance of  $0.7 \mu\text{m}$  from the source terminal. The gate was  $0.6 \mu\text{m}$  long and  $100 \mu\text{m}$  wide. Another 55nm of SiN was deposited, followed by a titanium/gold gate field plate (FP) with an effective length of  $0.3 \mu\text{m}$ .

A comparison HEMT was also produced without a field plate or SiN insulation/passivation.

One effect of the structure is to reduce gate leakage currents. Under a reverse bias of  $-15\text{V}$ , the leakage is suppressed by almost one order of magnitude. At



forward biases of 2V, the leakage is suppressed by more than five orders of magnitude. At 5V forward bias, the leakage was 0.02mA/mm. Breakdown occurred above 5V gate bias, giving an estimated critical field in the SiN of 7.1MV/cm. The field was in line with that achieved with other PECVD SiN films (3–12MV/cm).

The maximum drain current with 10V drain bias was 1211mA/mm (5V gate), compared with 836mA/mm (1V gate) for the comparison HEMT. However, the peak transconductance was reduced to 184mS/mm

(318mS/mm in the comparison HEMT) due to the lower electrostatic control of the gate through the SiN layers of the FP MIS-HEMT.

The off-state breakdown characteristics (–8V gate, 1mA/mm gate leakage) were 120V drain bias for the FP MIS-HEMT and 82V for the comparison HEMT.

“This improvement is attributed not only to the adoption of the SiN gate dielectric layer to reduce the leakage current but also to the adoption of the FP, which effectively modulates the magnitude of the peak electric field near the drain side of the gate edge and the distribution of the electric field between the gate and the drain,” the researchers write.

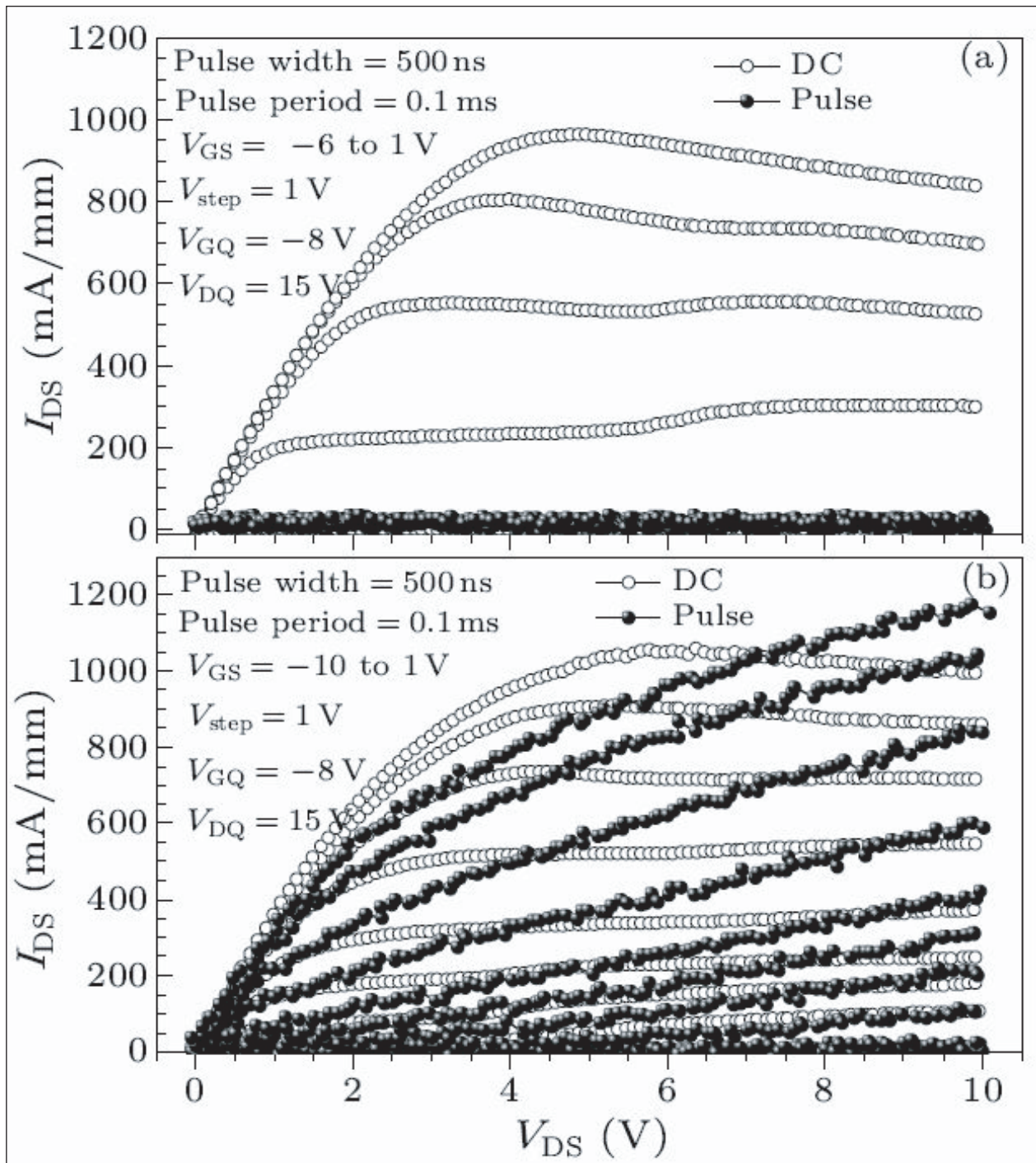


Figure 2. DC and pulsed current–voltage (I–V) performances of HEMT (a) and FP-MIS HEMT (b).

Pulsed operation was tested to reveal current collapse effects. The baseline bias was -8V gate and 15V drain. The pulse width was 500nsec with a period of 0.1msec. The current collapse of the comparison HEMT was ‘pronounced’, while the researchers described that of the FP MIS-HEMT as being ‘negligible’ (Figure 2).

“These considerable improvements in the current collapse for the FP MIS-HEMT are attributed not only to the passivation effect of the SiN layer on the surface state traps, but also to the modulation of the ionization probability of the traps in terms of the FP,” they write. ■

<http://cpl.iphy.ac.cn/EN/Y2013/V30/I5/058502>

Author: Mike Cooke



# Improving the dynamic performance of nitride HEMTs

Researchers in China have improved the falling delay time by 55% and dynamic on-resistance by 17% by applying a 30V bias to the top-gate.

Chinese Academy of Sciences' Suzhou Institute of Nano-Tech and Nano-Bionics (SINANO) has extended its work on double-gated nitride semiconductor high-electron-mobility transistors (DG-HEMTs) [Guohao Yu et al, IEEE Electron Device Letters, vol. 34, p747, 2013]. In particular, the researchers applied large positive potentials to the top-gate of their structure, rather than merely trying to imitate the effects of source or gate field-plates.

The aim of the work was to find ways to avoid 'current collapse', where the device has reduced performance when switched compared with static characteristics. This has been a particular problem for nitride-based devices and needs to be tackled before such transistors can be used in power switching applications.

Various techniques for reducing current collapse have been suggested, such as surface passivation or field-plates connected to the source or gate to manipulate the electric field configuration. The effect of these is thought to be an alteration in the way charges are trapped on the surface or in the barrier layer of the nitride semiconductor heterostructure.

The double-gate HEMT (Figure 1) was fabricated as in SINANO's previous work [reported at [www.semiconductor-today.com/news\\_items/2013/FEB/SINANO\\_050213.html](http://www.semiconductor-today.com/news_items/2013/FEB/SINANO_050213.html)]. The test set-up consisted of a 20kΩ load resistor chosen to give a drain current at about a third of the maximum output. A 200V power supply was used. The off-state consisted of a -5V gate bias with 0V applied to the top gate. The on-state gate potential was +1V, with varying biases applied to the

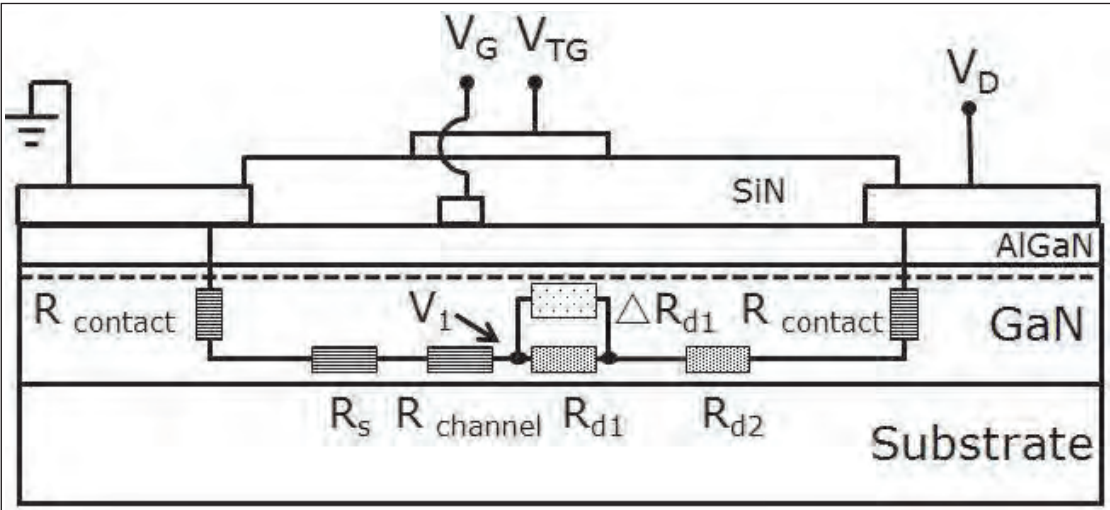


Figure 1. Schematic diagram showing the components of the dynamic on-resistance ( $R_{ON,D}$ ) in a DG-HEMT with gallium nitride (GaN) buffer and aluminium gallium nitride (AlGaN) barrier. The gate-source distance was 5μm; gate-drain 12μm; gate width 100μm; (bottom) gate length 2μm; top-gate extension 4μm over drain side.

top gate. This differs from the group's previous work in that the top-gate bias is positive rather than negative. The researchers believe that the new setup is more feasible for high-voltage high-power switching applications with normally-off devices (although the tested device was normally-on).

The devices were tested over a 25μsec cycle with the device on and off 50% of the time (Figure 2). With +30V top-gate bias in the on-state, the falling delay time ( $t_{fd}$ ) was improved by 55% and the dynamic on-resistance ( $R_{ON,D}$ ) by 17% compared with 0V top-gate

Table 1. Falling delay time ( $\tau_{fd}$ ) and dynamic on-resistance ( $R_{ON,D}$ ) versus on-state top-gate voltage.		
$V_{TG\_ON\_state}$ (V)	$\tau_{fd}$ (μsec)	$R_{ON,D}$ (Ω)
0	1.60	500
10	0.94	460
20	0.78	430
30	0.72	415

bias (Table 1). With 0V top-gate, the setup mimics the effect of a source field-plate.

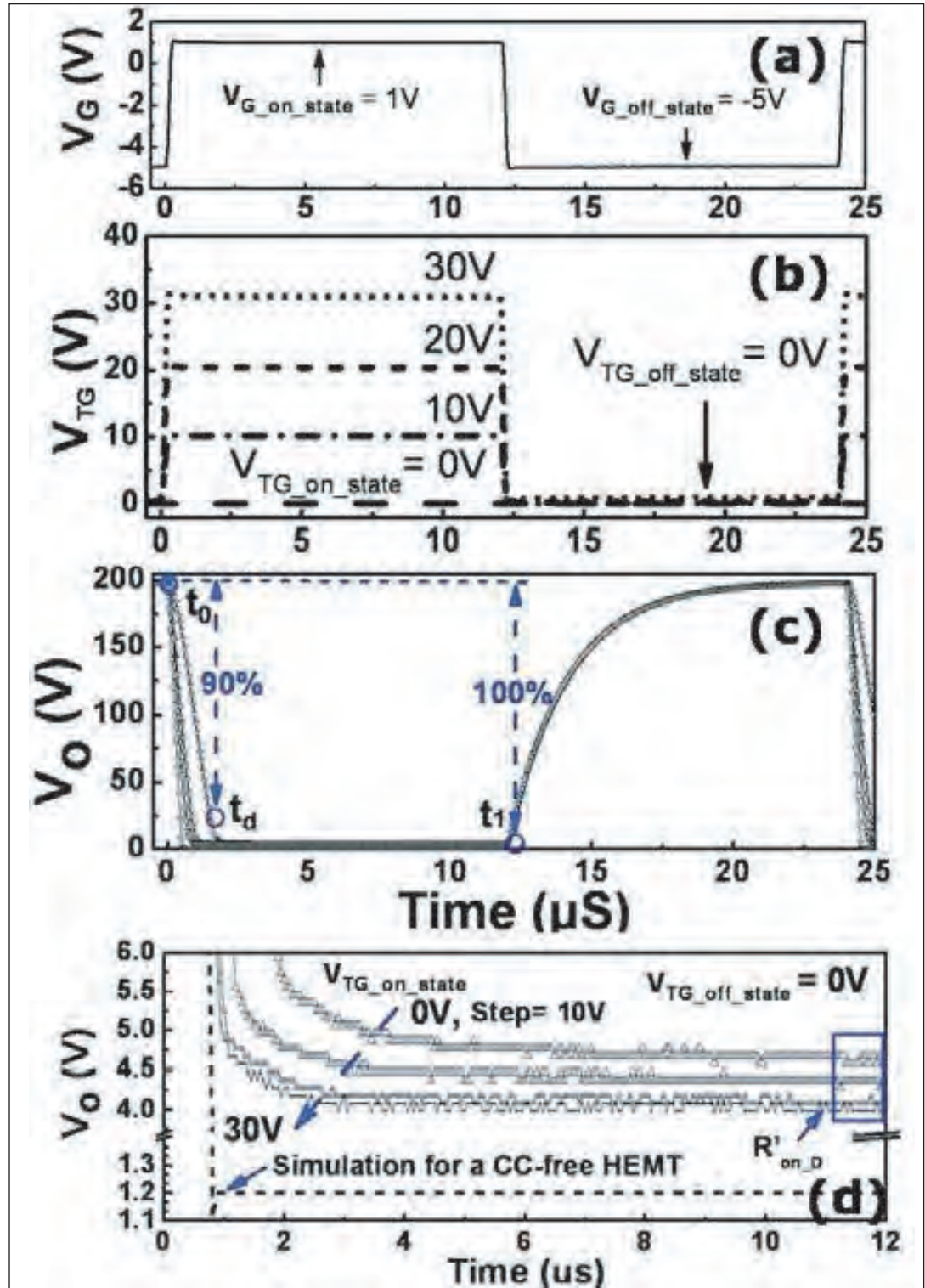
However, the researchers estimate that without current collapse  $\tau_{fd}$  could be as low as  $0.56\mu\text{sec}$ , based on parasitic characteristics derived from static DC measurements. The 30V top-gate result is 29% longer than this. In addition, the static on-resistance of  $115\Omega$  is around a factor of three smaller than the best dynamic value.

Given that the top-gate bias would be expected to increase the carrier density in the two-dimensional electron gas (2DEG) channel by about  $0.8 \times 10^{13}/\text{cm}^2$ , the researchers believe that part of the current collapse effect involves the region between the top-gate and drain.

By comparing the dynamic on-resistance just before the switch to the off-state with the top-gate potential, the researchers estimate the intrinsic dynamic resistances below the top-gate ( $R_{d1}$ ) and between the top-gate and drain contact ( $R_{d2}$ ) to be  $80\Omega$  and  $330\Omega$ , respectively. The corresponding sheet resistances are  $2000\Omega/\text{square}$  and  $4125\Omega/\text{square}$ .

The higher sheet resistance of the d2 region suggests that the 'current collapse' there is not impacted by lateral current injection. Possible reasons could be hot-electron injection from the channel, or charges being trapped in the buffer layer, but the researchers write that the situation is not clear.

The researchers conclude from their study that current collapse under the top-gate (d1) affects more strongly the falling delay time while the d2 current collapse tends to reduce the dynamic on-resistance. ■



**Figure 2.** (a)–(c) Input pulse signals and drain output voltage ( $V_o$ ) waveforms of DG-HEMT. (d) Drain output voltage ( $V_o$ ) waveforms of DG-HEMT in on-state pulse mode. The on-state top-gate voltage ( $V_{TG\_ON\_state}$ ) is biased from 0V to 30V. The off-state top-gate voltage ( $V_{TG\_OFF\_state}$ ) is constantly biased at 0V. Dynamic  $V_o$  waveform simulation of current-collapse-free AlGaIn/GaN HEMT based on DC characteristics.

<http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6515605>

<http://dx.doi.org/10.1109/LED.2013.2259213>

<http://english.sinano.cas.cn>

Author: Mike Cooke

# China's first diamond MESFET with gigahertz frequency performance

**Cut-off frequency and maximum oscillation frequency reach 1.7GHz and 2.5GHz, respectively; shorter gate lengths promise improvement.**

China-based researchers have reported that country's first diamond metal-semiconductor field-effect transistors (MESFETs) with RF characteristics [Feng ZhiHong et al, Science China Technological Sciences, vol56, p957, 2013]. The team was based at four sites: Hebei Semiconductor Research Institute, Hebei University of Technology, University of Science and Technology Beijing, and Hebei Institute of Laser.

Diamond is of interest for high-power, high-frequency and high-temperature electronics due to its high breakdown field ( $\sim 10\text{MV/cm}$ , which is 3.3x that of silicon carbide and 4x that of gallium nitride), its high thermal conductivity ( $\sim 22\text{W/cm-K}$ , 4x SiC, 13x GaN),

and its low dielectric constant ( $\sim 5.7$ ). Unfortunately, large-scale diamond manufacture is not available as yet.

The researchers used a 15mm x 15mm x 0.3mm free-standing polycrystalline film grown by arc melting. The polycrystalline grains were larger than  $100\mu\text{m}$  — of the order of the size of the fabricated transistors. A p-type surface channel was created using a hydrogen plasma treatment. The treated samples had a surface channel carrier density of  $10^{12}/\text{cm}^2$  and mobility  $20\text{cm}^2/\text{V-s}$ .

Devices were fabricated using gold masks that were patterned using lithography. Gold masking was needed to avoid damage to the hydrogen termination of the diamond surface from oxygen plasma used to remove

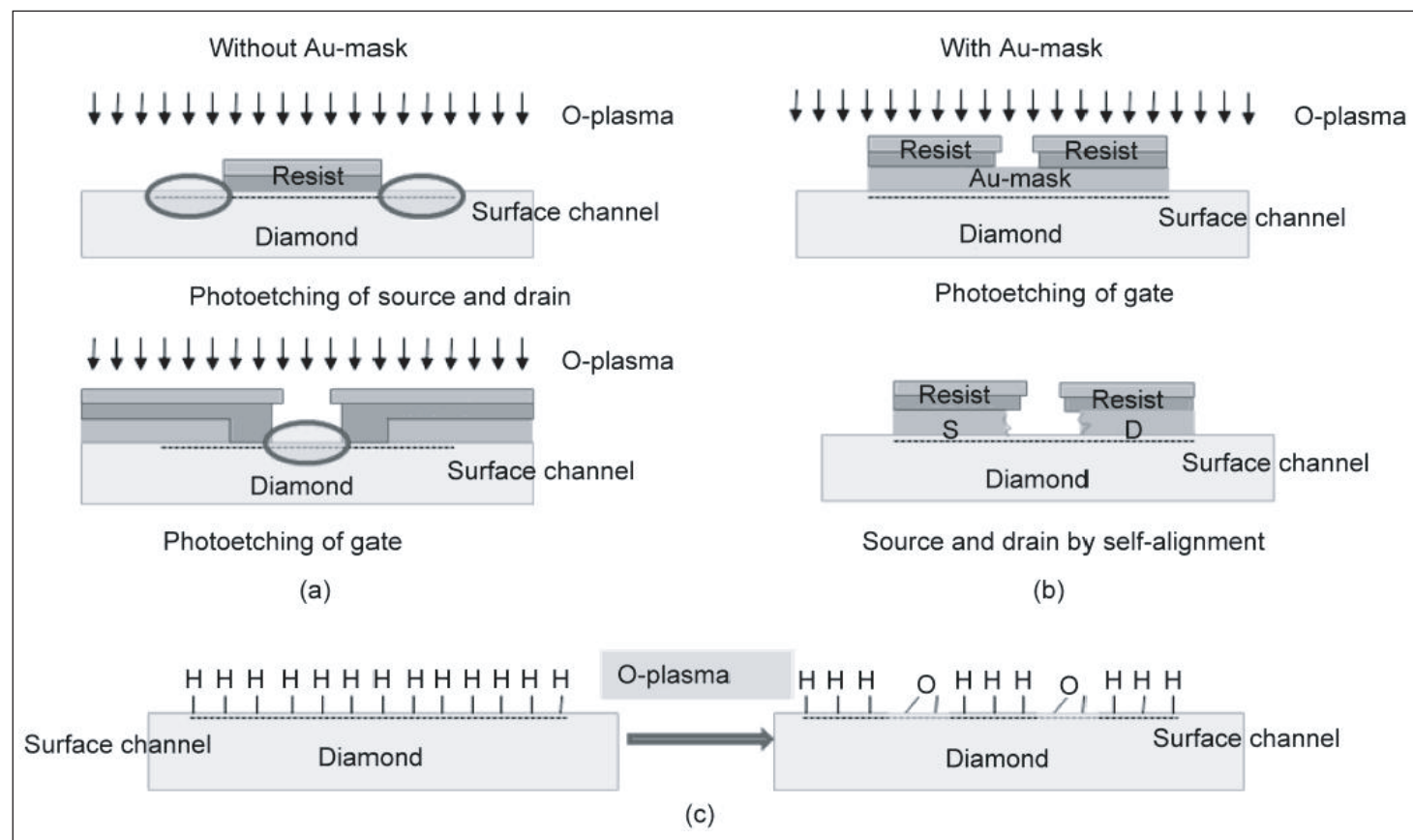


Figure 1. (a) The lithography process with (a) and without (b) Au-mask. Damaged areas are indicated by circles; (c) O-plasma on hydrogen-terminated diamond surfaces.



resist layers (Figure 1). Unannealed gold also makes a good ohmic contact with the hydrogenated diamond surface with a specific resistivity of  $10^{-5}\Omega\text{-cm}^2$ .

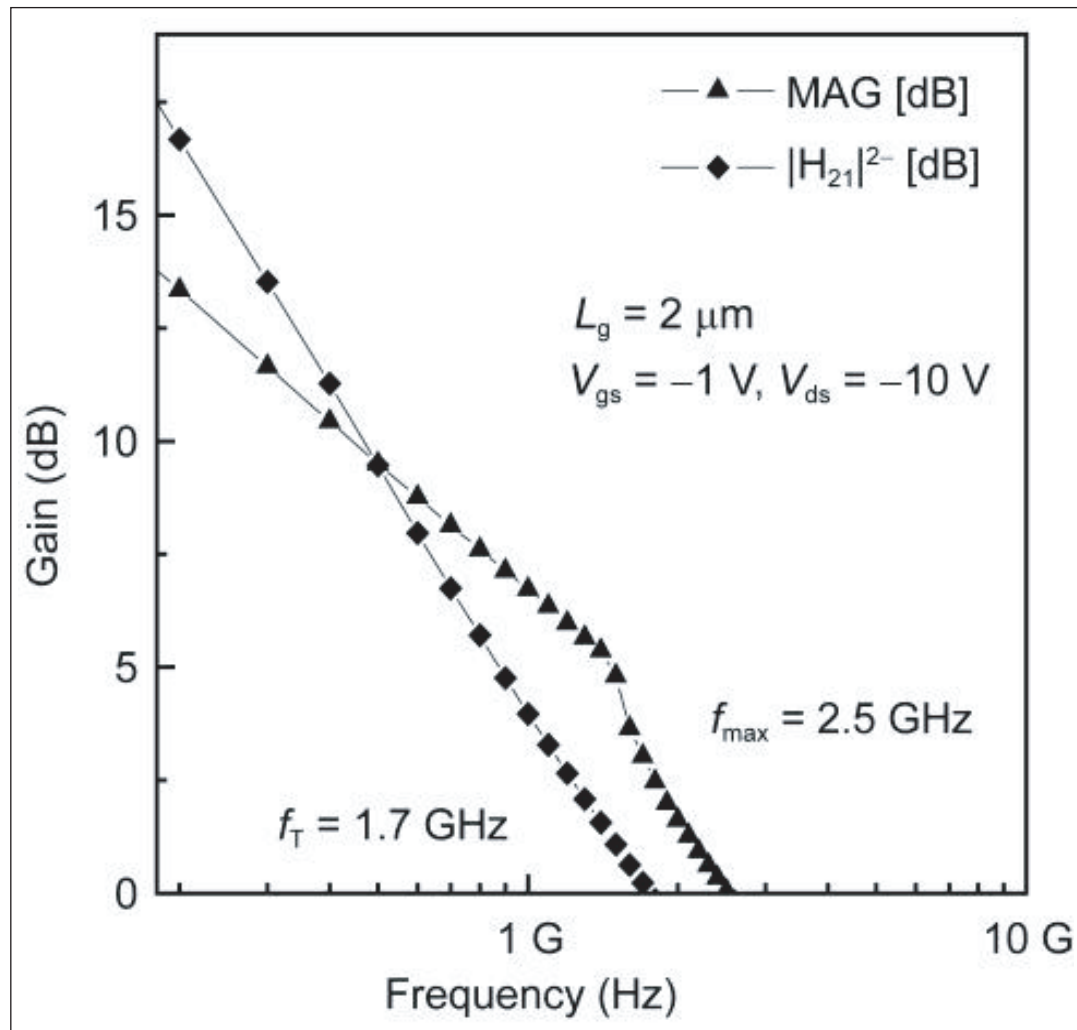
The devices were isolated using an oxygen plasma mesa etch. A selective etch of the gold with potassium iodide created the source and drain electrode regions. The  $2\mu\text{m}$  Schottky gate was made from aluminium. The gate width was  $2\times 100\mu\text{m}$ .

The maximum drain current density was increased to  $204\text{mA/mm}$  when using gold masking, compared with  $22\text{mA/mm}$  without gold masking. The maximum drain current density of  $204\text{mA/mm}$  was achieved with a negatively biased gate of  $-6\text{V}$ . The maximum transconductance was  $20\text{mS/mm}$  at  $-1.5\text{V}$  gate, and the off-state breakdown voltage was  $-47\text{V}$ .

The extrinsic cut-off and maximum oscillation frequencies were  $1.7\text{GHz}$  and  $2.5\text{GHz}$ , respectively

(Figure 2). The researchers believe that these values can be improved with shorter gate lengths. Outside of China, diamond MESFETs with frequency performance values of tens of gigahertz have been fabricated.

The frequency response was lower than expected.



**Figure 2.** DC and pulsed current–voltage ( $I$ – $V$ ) performances of HEMT (a) and FP-MIS HEMT (b).

This could be attributed to the effects of the grain boundaries and problems with crystal quality inside the grains. ■

<http://link.springer.com/article/10.1007/s11431-013-5163-z>

Author: Mike Cooke

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# SiC power device market grows at 38% year-on-year, despite 2012's overall power electronics downturn

## Market reshaping as silicon device makers enter sector

Starting in late 2011, the power electronics downturn in 2012 was quite severe, exhibiting a 20% drop. The market suffered from the global economic downturn, combined with external factors such as China controlling what happened in some selected markets (e.g. wind turbine or rail traction projects that have been cancelled or postponed). Nevertheless, the silicon carbide (SiC) device market has kept on growing with a +38% increase year-on-year, according to the report 'SiC Market 2013: Technology and Market for SiC Wafers, Devices and Power Modules' from market research firm Yole Développement, which spans the entire value-chain, covering all SiC applications in the low-, medium- and high-power ranges up to 2020.

The report also includes a bill-of-material analysis, to compare silicon versus SiC-based system costs, and a cost-reduction roadmap for SiC device manufacturing at different process steps.

SiC technology is now commonly accepted as a reliable and pertinent alternative to the silicon world, says Yole. Most power module and power inverter manufacturers have already included it in their roadmap as an option or as a firm project. However, time-to-market differs from application to application as a function of value proposals for cost, specifications, availability etc.

Despite a depressed market last year, photovoltaic (PV) inverters have proven their appetite for SiC devices in 2012, comprising the biggest consumer of SiC devices together with power factor correction (PFC).

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

The market for SiC devices (bare die or packaged discretes) reached about \$75m in 2012, with Infineon and Cree again dominant.

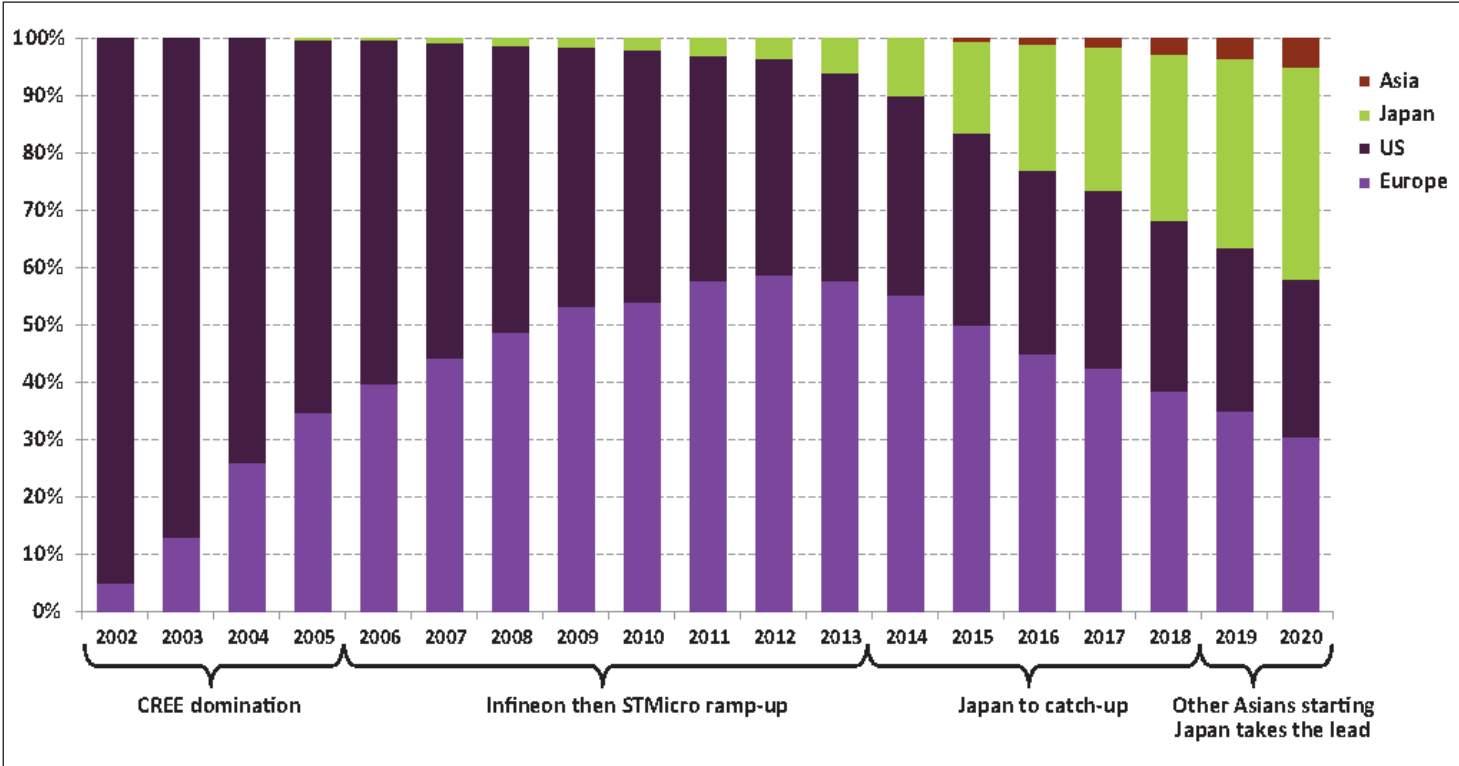
However, little by little the competition is grabbing market share, with STMicroelectronics and Rohm closing the gap.

### Over 30 players, several new entrants, and one closure

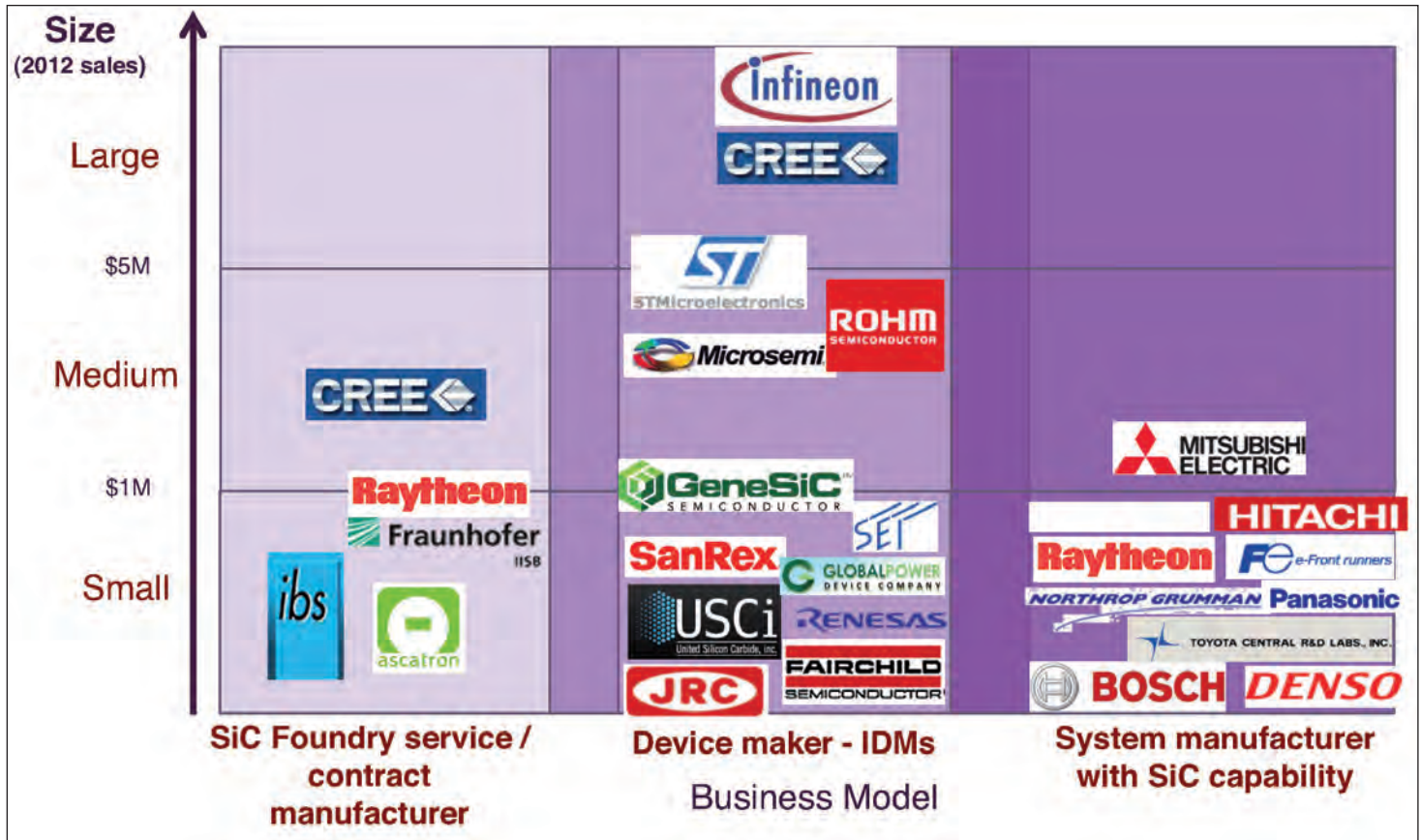
More than 30 companies worldwide have now established a dedicated SiC device manufacturing capability with related commercial and promotion activities, reckons Yole. Virtually all other existing silicon-based power device makers are also more or less active in the SiC market, but at different stages.

Last year saw the ramp-up of some firms, such as Rohm, MicroSemi, GeneSiC and STMicro, facing the two giants Cree and Infineon, pre-saging a new market shape in the coming years.

Four new companies — Raytheon, Ascatron, IBS (Ion Beam Services) and Fraunhofer IISB (Institute of Integrated Systems and Device Technology) — have decided, almost simultaneously, to launch SiC foundry services or contract



Percentage of SiC revenue by location of company headquarters.



Main players and related business models in the SiC device industry.

manufacturing services. The establishment of this business model addresses demand from future SiC fabless and design houses that may seek specific manufacturing partners. This will also probably act as a possible second source for integrated device manufacturers (IDMs) in cases of production overshoot.

In Asia, Panasonic and Toshiba are now clearly identified as credible contenders, along with Mitsubishi Electric, now developing SiC power modules. Also, Fuji Electric's new SiC line is now running within the Japanese national program. No Chinese device maker has emerged yet but, according to the huge investment plan in R&D, Yole suspects that new IDMs will soon enter the business.

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

Ultimately, the unexpected closing down of SemiSouth in October 2012 created chatter about the SiC business (which had been quite

stable until then). Several reasons have been disclosed that explain this decision (e.g. over-sized company, market lacking too long to take-off etc), however we cannot ignore that it discredits to some extent the normally-off (Noff) JFET technology, says Yole. Only the future will tell, it adds.

#### From discretes to modules

Yole now sees the SiC industry being reshaped, starting from a discrete device business and now mutating into a power module business. Originally, this was initiated by Powerex, MicroSemi, Vincotech and GeneSiC with hybrid Si/SiC products. Then, other players such as Mitsubishi, GPE and, more recently, Rohm have reached the market with full-SiC modules.

Yole forecasts that this trend will become dominant in the coming years as integrators require power modules in most of their mid- and high-power systems (generally starting at >3kW).

Yole does forecast that SiC-based power module demand could exceed \$100m by 2015 and \$800m

in 2020, depending on whether or not the auto industry will adopt SiC.

**Key challenges: cost reduction, packaging and multi-sourcing** SiC equates to high-frequency and high-temperature operation. That said, capturing these two added-values remains an issue, as no existing set of technologies can fully fulfill that request yet. The path to success for large-scale SiC implementation will necessarily be through new packaging solutions, says Yole. Numerous bottlenecks need to be unlocked, such as chip bonding, metallic contact techniques, gel filling, encapsulant, and electro-magnetic interference (EMI), the firm adds.

Power device integrators generally rely on two or even three sources to reduce supply-chain risks. In SiC, it is now easy operating multi-sourcing for diodes, though not yet for transistors, notes Yole. MOSFETs, JFETs and BJTs must be available from at least two companies with similar specifications, it concludes.

[www.yole.fr](http://www.yole.fr)



# Exploring CMOS power amplification for mobile phones

Qualcomm has announced a CMOS radio-frequency front-end solution for mobile phones, including a CMOS power amplifier. How close is silicon to compound semiconductors for this application? [Mike Cooke](#) reports.

**R**ecently the prospect has been raised that silicon could kick compound semiconductors out of the radio front-end of mobile phones in the near future. This has already been partially accomplished with the move to antenna switching and tuning technologies based on silicon-on-insulator (SOI) devices.

A further shot across the bow is Qualcomm's announcement of its RF360 'front-end solution', consisting of a dynamic antenna matching tuner (QFE15xx), envelope power tracker (QFE11xx), integrated power amplifier/antenna switch (QFE23xx), and RF 'POP' (QFE27xx).

The QFE23xx is claimed to be the industry's first chip that integrates a CMOS power amplifier (PA) and antenna switch with multiband support across 2G, 3G and 4G LTE cellular modes. This is a real concern for compound semiconductor manufacturers, since much of their financial prosperity has been based on the supply of power amplifiers for mobile phones.

Qualcomm expects OEM products featuring the complete solution in second-half 2013. The trade-marked 'POP' device is a '3D package' consisting of the QFE23xx PA/switch, along with filters and duplexers in a single component.

The use of CMOS, according to Qualcomm, has been enabled by its modem-assisted envelope tracking technology, which is designed to reduce the overall thermal footprint and RF power consumption by up to 30%. Qualcomm points to a smaller PCB area and simplified routing as attractions for its solution.

Although silicon is well established in the high-frequency PA market for nearer-range products such as Bluetooth and WiFi, the material faces a real challenge in supplying the signal boost needed for longer-range mobile phone transmissions of up to 30km. Such distances are the worst case of a 'Macrocell', typically in rural areas. Communications in urban areas and offices can take advantage of shorter-range Microcell (2km), Picocell (200m) or even Femtocell access (50m) to

reduce power drain in the phone.

Mobile networks hope to attract new business through advanced phones, but these devices set up an internal power struggle for real estate in the design, squeezing the radio footprint. Unfortunately, the problem has been worsened by new network standards such as Long-Term Evolution (LTE) with their proliferation of possible frequency bands ('fragmentation'). In addition, the newer radio technologies require the PAs to run in a more linear fashion, reducing power efficiency.

The old methodology of having a series of narrow-band PAs dedicated to each frequency range is no longer

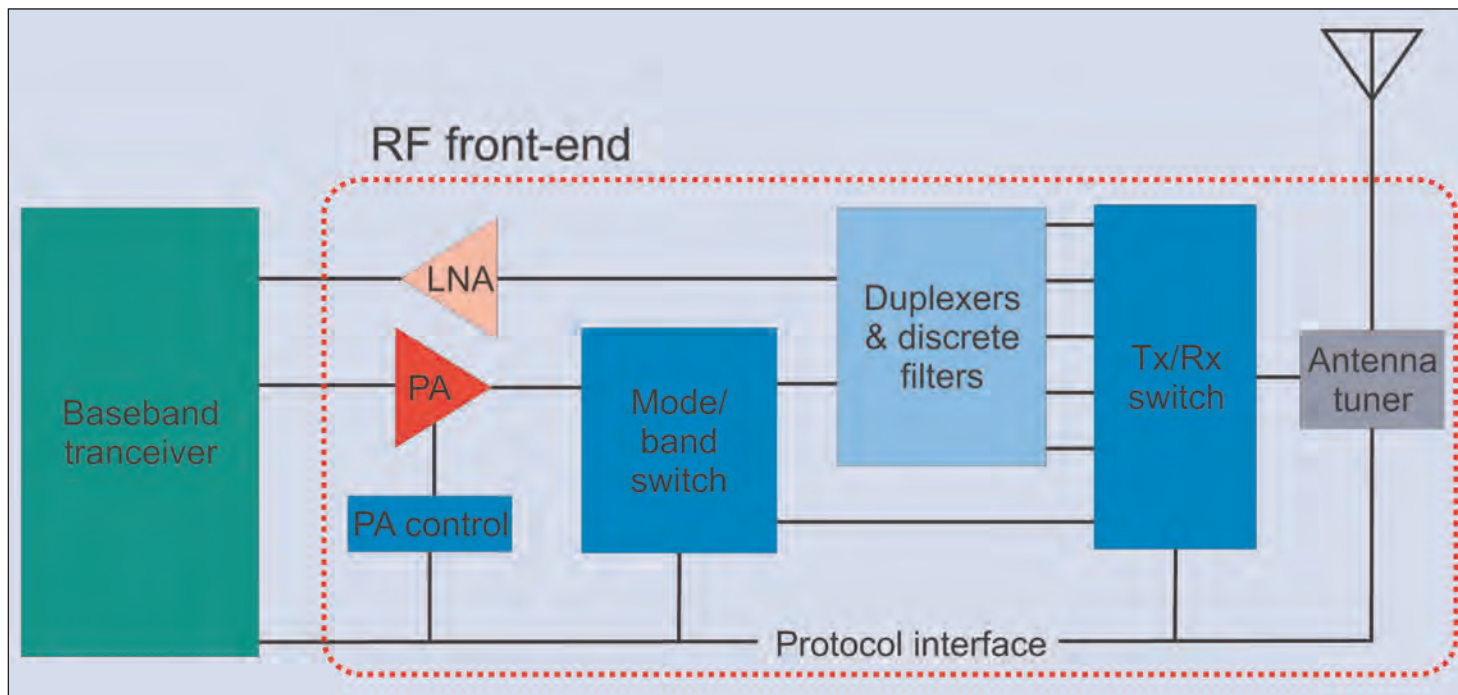
**Although the RF components have increasingly been packaged in modules, the industry would like even more integrated solutions. Separate compound semiconductor PAs are not easy to integrate within a silicon framework.**

adequate. In the past few years, PA manufacturers have been rolling out various multi-mode multi-band (MMMB) PA solutions designed to meet this challenge.

Although the RF components have increasingly been packaged in modules, the industry would like even more integrated solutions. Separate compound semiconductor PAs are

not easy to integrate within a silicon framework. This may change as a result of extensive work in integrating compound semiconductor high-mobility channels on silicon substrates to allow further CMOS scaling. However, such a solution will not be available for some time and, up to now, separate compound semiconductor PAs have been the only technology to deliver the required power densities for all but the lowest end of the mobile phone market.

Looking at the present typical RF front-end module (RFFE, Figure 1), there are two obvious directions to




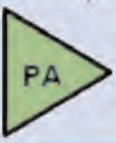


**Figure 1. Block diagram of RF front-end module, including power amplifier (PA) and low-noise amplifier (LNA) and other components necessary for transmit (Tx) and receive (Rx) functions on signal from baseband transceiver.**

integrate: PA+antenna switching/tuning or PA+power management. As was seen above, Qualcomm has adopted the first of these options. Since recent antenna switching/tuning components are generally based on silicon-on-insulator (SOI) technologies, it would not be surprising to learn that the Qualcomm chip is based on such an approach. Indeed, many commentators have speculated that this is the case, although Qualcomm has not confirmed this so far.

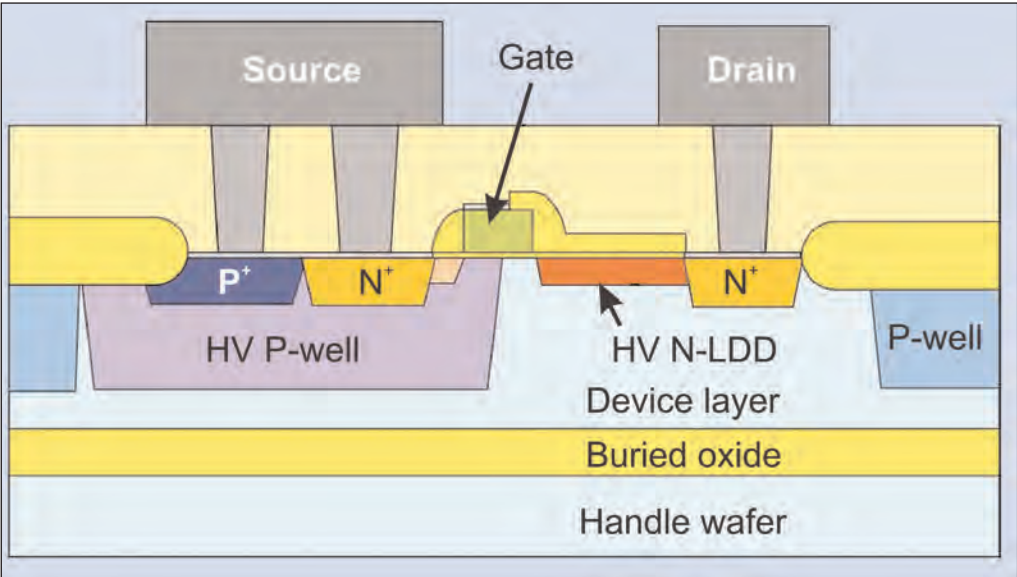
CMOS power management integrated circuits generally combine amplifier power level and mode control, bias management, dc-to-dc converter, power regulators, and electrostatic discharge (ESD) handling. These devices can also include more complex RF modulation features such as envelope tracking.

CMOS is the favored technology for this due to its combination of high performance with low cost.

SOI substrate manufacturers IQE and SOITEC are hoping that the application in RF PAs could lead to increased business on top of the already successful antenna switch/tuning market. Theoretically, SOI CMOS offers better frequency response, high-perform-

Block	Key device parameter	Key substrate parameter	2011 market technology of choice
Switch 	Breakdown voltage, $R_{on}$ , RF loss	Linearity, resistivity	GaAs pHEMT, SoS, HR-SOI
Power amplifier 	Gain, $f_T$ , current density, breakdown voltage	Carrier mobility, thermal dissipation, linearity, resistivity	GaAs HBT, LDMOS
Power mgt unit 	$R_{on}$ , current density, breakdown voltage, CMOS enable	Thermal dissipation	HV CMOS
Filter 	$Q(L)$ , temp stability, coupling coefficient	Resistivity, piezoelectricity	SAW, BAW, IPD, smd

**Figure 2. SOITEC's 2011 view of RFFE technologies.**



**Figure 3. RFMD’s IPMOS high-voltage (HV) power device on 1000Ω-cm resistivity SOI substrate. Device incorporates lightly doped drain (LDD) extension. The same structure was also produced on bulk silicon substrate of 3Ω-cm resistivity.**

ance passive components, and better isolation, compared with standard bulk CMOS.

Silicon-on-sapphire (SoS) is a particularly attractive SOI technology. According to a white paper by Soitec’s Eric Desbonnets and Stéphane Laurent [RF Substrate Technologies for Mobile Communications, May 2011, [www.soitec.com/pdf/RF\\_SubstratesTechnologies\\_2011-07-07.pdf](http://www.soitec.com/pdf/RF_SubstratesTechnologies_2011-07-07.pdf)]: “SoS substrates are well recognized for delivering the best-performance switches. As shown in Figure 2, this material has all the performance attributes needed for RFFE module integration, combining power amplifiers, switches and antenna tuning on a single chip.”

High-resistive silicon-on-insulator (HR-SOI) is a similar technology that could also be used for full RFFE module integration, including multiple functions on one chip. Desbonnets and Laurent add: “HR-SOI combines the extremely good performance of SOI for isolating signal from noise while ensuring signal power integrity. It also shows a good insertion loss and brings the same programmability level as a standard silicon bulk substrate.”

**Table 1. RFMD IPMOS device parameters on bulk silicon and SOI substrates.**

Parameter	Bulk-Si	SOI
Threshold voltage, $V_{TH}$ (V)	0.95	0.95
Saturation drain current, $I_{DSAT}$ (mA/mm)	500	460
Max. $g_m$ , (mS/mm)	145	140
Drain source breakdown voltage, $BV_{DSS}$ (V)	18	18
ON Resistance, $R_{ON}$ (Ω-mm)	2.8	2.8
Leakage Current, $I_{OFF}$ (nA/mm)	0.5	0.5
$fT/f_{max}$ (GHz)	21/40	21/42

One successful SoS antenna switch/tuning supplier, Peregrine Semiconductor, has also been exploring the integration of PAs into its process. The latest Peregrine SoS ‘UltraCMOS’ process is its Semiconductor Technology Platform 8 (STeP8), which uses a 250nm process that gives a 40% die shrink compared with its STeP5. Among the improvements claimed is a 36% reduction in the on-resistance/off-capacitance product.

The firm has recently transitioned from being a manufacturer with a foundry service to becoming a fabless supplier. In 2010, Peregrine entered an exclusive agreement to develop UltraCMOS with IBM using 180nm technology. This year, Peregrine also made a sourcing arrangement with Murata Manufacturing Company of Japan. This allows the Japanese company to buy or manufacture RF switches based on Peregrine’s technology for RFFE modules.

Another company that produces products based on Peregrine’s technology is MagnaChip of Korea, which expanded its arrangement to STeP5 late last year. Other SOI RF switch producers include Honeywell, Skyworks and TowerJazz.

Another CMOS-SoS PA development was reported last year by University of California San Diego (UCSD) with a device boasting 50% overall power-added efficiency (PAE) and 29.3dBm output power [M. Hassan et al, IEEE Compound Semiconductor Integrated Circuit Symposium (CSICS), 2012]. The process technology for the PA was 0.35μm, while an associated envelope-tracking amplifier was produced using 0.18μm bulk CMOS.

RF Micro Devices Inc (RFMD) has also been researching silicon PAs for the cellular market [Ali Tombak et al, IEEE Transactions On Microwave Theory and Techniques, vol. 60, p1862 2012], although presently most of its products are compound semiconductor based. The RFMD work includes attempted integration with power management circuitry.

The RFMD researchers used a 0.5μm high-voltage CMOS process on bulk and SOI substrates (Figure 3). The fabrication process is already a standard one for producing PA power controllers. The n-MOSFETs and p-MOSFETs are rated 5V and feature a gate with 130Å oxide insulation and silicided polysilicon electrode. The structure for the ‘integrated power MOS’ (IPMOS) transistors is a variant of laterally diffused MOS (LDMOS) transistors, as used for



base-station PA applications.

An important difference from standard LDMOS is that the heat dissipation is through copper pillar flip-chip packaging rather than through the handle wafer. The packaging also includes optimal ground inductances for the PA. Using the packaging rather than the substrate for grounding also allows the use of SOI. The resistivity of the SOI was 1000 $\Omega$ -cm, compared with 3 $\Omega$ -cm for the bulk silicon. The epitaxial silicon layer on the insulation was thicker than 1 $\mu$ m.

DC and RF measurements (Table 1) show little difference in performance. The lower saturation current and transconductance for the SOI device are attributed to self-heating effects arising in the wafer-level measurements. The actual differences in saturation drain current and transconductance for packaged SOI products using a copper pillar flip-chip are expected to be negligible, the researchers say. The small increase in the maximum oscillation frequency is attributed to reduced parasitic capacitance from the use of SOI technology.

The process also allows the integration of metal-insulator-metal (MIM) capacitors with 2000pF/mm<sup>2</sup> density and a standard third metal layer of 3 $\mu$ m-thick aluminium for RF designs.

The researchers designed a three-stage PA for low- and high-band operations in the ranges 850–900MHz and 1710–1980MHz, respectively. The SOI-based PAs gave 0.2dBm better output power than bulk silicon in the low band and 0.6dBm in the high band. The power-added efficiencies for bulk-Si PAs were hit, respectively, by 4 and 6 percentage points. Compared with other technologies (Table 2), the output power for the SOI-based PA was marginally better, while the PAE was significantly higher in the low band. The advantages were degraded in the higher band.

The team comments: “The measured results are similar to commercially available GaAs-based PAs for GSM saturated PA applications, which shows that the engineered IPMOS devices can withstand typical operating conditions of saturated PAs.”

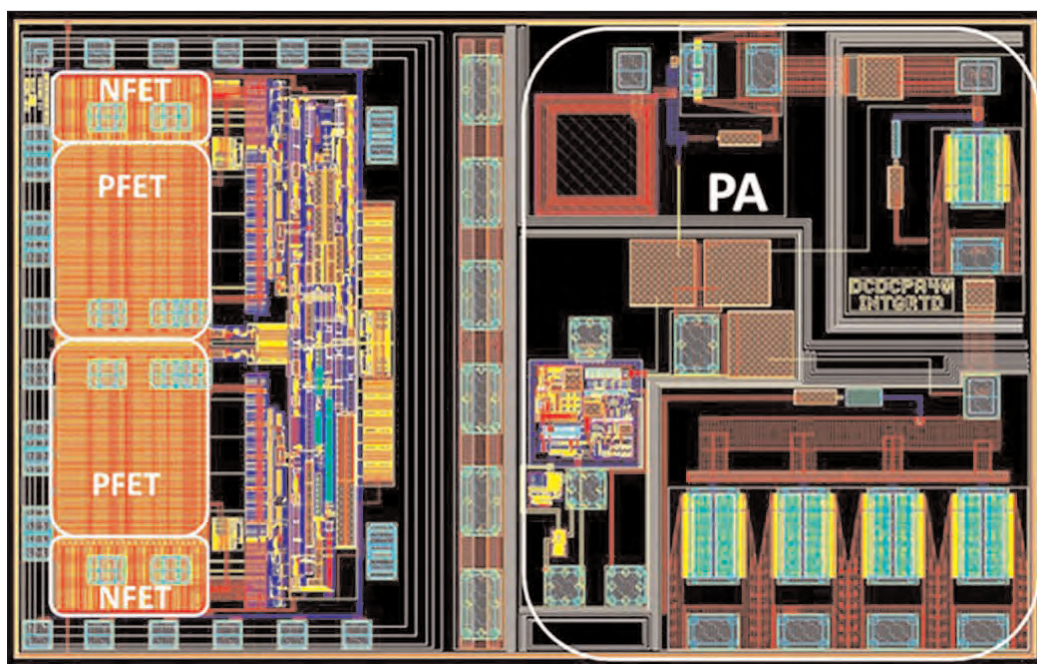
**Table 2. Comparison of RFMD IPMOS PA with other technologies. Last column is RFMD's RF3158, quad-band GSM/EDGE/GSM850/EGSM900/DCS/PCS power amplifier module.**

Technology	RFMD IPMOS				RFMD
	SOI LDMOS	Si CMOS	Si LDMOS	SiGe HBT	GaAs HBT
PCS P <sub>out</sub> /PAE (dBm/%)	3.5	3.5	3.5	3.4	3.6
V <sub>DD</sub> /V <sub>CC</sub> (V)	35.6/62	35/51	34/50	34.5/55	35/50
GSM 900 P <sub>out</sub> /PAE (dBm/%)	33.4/47	33/45	32/47	32.5/45	33/49

The three-stage PA was also produced in a chip with integrated DC–DC buck converter (Figure 4) measuring 3.2mm x 1.9mm (converter section 1.15mm x 1.9mm). The researchers estimated the converter efficiency at 90% for output power levels greater than 25dBm. Below this output power the performance of the converter began to degrade, as is typical for such devices. By having an on-chip converter the PAE is improved by about 23 percentage points, compared with a fixed supply voltage and an output power of 25dBm at 915MHz. However, having the convertor on-chip did cause some noise problems.

Another PA manufacturer, Skyworks Solutions, actually markets a CMOS GSM/GPRS quad-band PA that is produced using a 0.13 $\mu$ m process. The patented technology came with the acquisition of Axiom Microdevices in 2009. The product brief talks of “improved power-added efficiency”, but gives no figures. This suggests that the product as yet does not match compound semiconductor performance. ■

*Author: Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.*



**Figure 4. Layout of RFMD 3.2mm x 1.9mm integrated chip with dc/dc converter and PA.**

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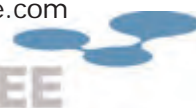
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CA 94551,  
USA  
Tel: +1 925 245 5817  
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## **7 Wafer processing materials**

#### **Air Products and Chemicals Inc**

7201 Hamilton Blvd.,  
Allentown, PA 18195,  
USA

Tel: +1 610 481 4911

[www.airproducts.com/compound](http://www.airproducts.com/compound)

#### **MicroChem Corp**

1254 Chestnut St. Newton,  
MA 02464,  
USA

Tel: +1 617 965 5511

Fax: +1 617 965 5818

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

#### **Power + Energy Inc**

(see section 10 for full contact details)

#### **Praxair Electronics**

(see section 5 for full contact details)

## **8 Wafer processing equipment**

#### **EV Group**

DI Erich Thallner Strasse 1,  
St. Florian/Inn, 4782,  
Austria

Tel: +43 7712 5311 0

Fax: +43 7712 5311 4600

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#### **Oxford Instruments Plasma Technology**

(see section 6 for full contact details)

#### **Plasma-Therm LLC**

(see section 6 for full contact details)

#### **Power + Energy Inc**

(see section 10 for full contact details)

#### **SAMCO International Inc**

532 Weddell Drive,  
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Tel: +1 408 734 0459

Fax: +1 408 734 0961

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#### **SPTS Technology Ltd**

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Newport NP18 2TA, UK

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Fax: +44 (0)1633 414141

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

#### **Veeco Instruments Inc**

(see section 6 for full contact details)

## **9 Materials & metals**

#### **Goodfellow Cambridge Ltd**

Ermine Business Park, Huntingdon,  
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UK

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Fax: +44 (0) 1480 424900

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



Goodfellow supplies small quantities of metals and materials for research, development, prototyping and specialised manufacturing operations.

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Fax: +43 5672 600 500

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



## **10 Gas and liquid handling equipment**

#### **Air Products and Chemicals Inc**

(see section 7 for full contact details)

#### **Cambridge Fluid Systems**

12 Trafalgar Way, Bar Hill,  
Cambridge CB3 8SQ,  
UK

Tel: +44 (0)1954 786800

Fax: +44 (0)1954 786818

[www.cambridge-fluid.com](http://www.cambridge-fluid.com)

#### **CS CLEAN SYSTEMS AG**

Fraunhoferstrasse 4,  
Ismaning, 85737,  
Germany

Tel: +49 89 96 24 00 0

Fax: +49 89 96 24 00 122

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

Inc

#### **Power + Energy Inc**

106 Railroad Drive,  
Ivyland, PA 18974, USA

Tel: +1 215 942-4600

Fax: +1 215 942-9300

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

## SAES Pure Gas Inc

4175 Santa Fe Road,  
San Luis Obispo,  
CA 93401,  
USA  
Tel: +1 805 541 9299  
Fax: +1 805 541 9399  
[www.saesgetters.com](http://www.saesgetters.com)

## 11 Process monitoring and control

### k-Space Associates

2182 Bishop Circle  
East, Dexter,  
MI 48130, USA  
Tel: +1 734 426 7977  
Fax: +1 734 426 7955  
[www.k-space.com](http://www.k-space.com)



k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

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CA 95035,  
USA  
Tel: +1 408 875 3000  
Fax: +1 408 875 4144  
[www.kla-tencor.com](http://www.kla-tencor.com)

### LayTec AG

Seesener Str.  
10-13,  
10709 Berlin,  
Germany  
Tel: +49 30 89 00 55 0  
Fax: +49 30 89 00 180  
[www.laytec.de](http://www.laytec.de)



LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

## Optical Reference Systems Ltd

OpTIC Technium,  
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St Asaph, LL17 0JD,  
UK  
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Fax: +44 (0)1745 535 186  
[www.ors-ltd.com](http://www.ors-ltd.com)

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für Elektronik- und  
Programmentwicklungen)  
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Furtwangen im Schwarzwald,  
Germany  
Tel: +49 7723 9197 0  
Fax: +49 7723 9197 22  
[www.wepcontrol.com](http://www.wepcontrol.com)

## 12 Inspection equipment

### Bruker AXS GmbH

Oestliche Rheinbrueckenstrasse 49,  
Karlsruhe, 76187,  
Germany  
Tel: +49 (0)721 595 2888  
Fax: +49 (0)721 595 4587  
[www.bruker-axs.de](http://www.bruker-axs.de)

## 13 Characterization equipment

### J.A. Woollam Co. Inc.

645 M Street Suite 102,  
Lincoln, NE 68508, USA  
Tel: +1 402 477 7501  
Fax: +1 402 477 8214  
[www.jawoollam.com](http://www.jawoollam.com)

### Lake Shore Cryotronics Inc

575 McCorkle Boulevard,  
Westerville, OH 43082,  
USA  
Tel: +1 614 891 2244  
Fax: +1 614 818 1600  
[www.lakeshore.com](http://www.lakeshore.com)

## 14 Chip test equipment

### Keithley Instruments Inc

28775 Aurora Road,  
Cleveland, OH 44139, USA  
Tel: +1 440.248.0400  
Fax: +1 440.248.6168  
[www.keithley.com](http://www.keithley.com)

## SUSS MicroTec Test Systems

228 Suss Drive,  
Waterbury Center, VT 05677,  
USA  
Tel: +1 800 685 7877  
Fax: +1 802 244 7853  
[www.suss.com](http://www.suss.com)

## 15 Assembly/packaging materials

### ePAK International Inc

4926 Spicewood Springs Road,  
Austin, TX 78759, USA  
Tel: +1 512 231 8083  
Fax: +1 512 231 8183  
[www.epak.com](http://www.epak.com)

### Gel-Pak

31398 Huntwood Avenue,  
Hayward, CA 94544, USA  
Tel: +1 510 576 2220  
Fax: +1 510 576 2282  
[www.gelpak.com](http://www.gelpak.com)

### Wafer World Inc

(see section 3 for full contact details)

### Williams Advanced Materials

2978 Main Street,  
Buffalo, NY 14214, USA  
Tel: +1 716 837 1000  
Fax: +1 716 833 2926  
[www.williams-adv.com](http://www.williams-adv.com)

## 16 Assembly/packaging equipment

### Ismeca Europe Semiconductor SA

Helvetie 283, La Chaux-de-Fonds,  
2301, Switzerland  
Tel: +41 329257111  
Fax: +41 329257115  
[www.ismeca.com](http://www.ismeca.com)

### Kulicke & Soffa Industries

1005 Virginia Drive,  
Fort Washington, PA 19034, USA  
Tel: +1 215 784 6000  
Fax: +1 215 784 6001  
[www.kns.com](http://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](http://www.PalomarTechnologies.com)



**TECDIA Inc**

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Fax: +1 408 748 0111  
[www.tecdia.com](http://www.tecdia.com)

**17 Assembly/packaging foundry****Quik-Pak**

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USA  
Tel: +1 858 674 4676  
Fax: +1 858 674 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 1 69 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****PLANSEE High Performance Materials**

6600 Reutte, Austria  
Tel: +43 5672 600 0  
Fax: +43 5672 600 500  
E-mail [info@plansee.com](mailto:info@plansee.com)  
[www.plansee.com](http://www.plansee.com)

  
**PLANSEE**
**W.L. Gore & Associates**

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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**

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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)

**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**

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Stuttgart,  
Germany  
Tel: +49 711 8804 1141  
Fax: +49 711 8804 1950  
[www.mw-zander.com](http://www.mw-zander.com)

**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**

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Fax: +1 408 428 9600  
[www.semi.org](http://www.semi.org)

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**4–9 August 2013**

**PRICM-8 (8th Pacific Rim International Conference on Advanced Materials and Processing)**

Hilton Waikoloa Village, Waikoloa, Hawaii, USA

**E-mail:** [mtgserv@tms.org](mailto:mtgserv@tms.org)

[www.tms.org/meetings/specialty/pricm8](http://www.tms.org/meetings/specialty/pricm8)

**4–10 August 2013**

**15th Summer School on Crystal Growth (ISSCG-15)**

Gdansk, Poland

**E-mail:** [isscg15@mif.pg.gda.pl](mailto:isscg15@mif.pg.gda.pl)

<http://science24.com/event/isscg15>

**5–6 August 2013**

**SolarTech Expo Spain 2013**

Valencia, Spain

**E-mail:** [ds@greenworldconferences.com](mailto:ds@greenworldconferences.com)

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

**11–16 August 2013**

**17th International Conference on Crystal Growth and Epitaxy (ICCGE-17)**

Warsaw, Poland

**E-mail:** [iccge17sec@mail.unipress.waw.pl](mailto:iccge17sec@mail.unipress.waw.pl)

<http://science24.com/event/iccge17>

**12–16 August 2013**

**16th Canadian Semiconductor Science and Technology Conference (CSSTC 2013)**

Thunder Bay, Canada

**E-mail:** [siskhako@lakeheadu.ca](mailto:siskhako@lakeheadu.ca)

<http://csstc2013.ca>

**25–29 August 2013**

**SPIE Optics + Photonics 2013**

San Diego Convention Center, CA, USA

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)

<http://spie.org/optics-photonics.xml>

**25–30 August 2013**

**10th International Conference on Nitride Semiconductors (ICNS 2013)**

Gaylord National Hotel and Convention Center,

Washington DC Metropolitan Area, USA

**E-mail:** [info@mrs.org](mailto:info@mrs.org)

[www.icns10.org](http://www.icns10.org) [www.mrs.org/icns-10](http://www.mrs.org/icns-10)

**28–30 August 2013**

**IEEE Photonics Society's 10th International Conference on Group IV Photonics (GFP 2013)**

Grand Hilton Seoul, Korea

**E-mail:** [m.figueroa@ieee.org](mailto:m.figueroa@ieee.org)

[www.gfp-ieee.org](http://www.gfp-ieee.org)

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**4–6 September 2013**

**SEMICON Taiwan 2013 and  
LED Taiwan 2013**

TWTC Nangang Exhibition Hall, Taipei, Taiwan

**E-mail:** ali@semi.org

[www.semicontaiwan.org/en](http://www.semicontaiwan.org/en)

**8–12 September 2013**

**IEEE Photonics Society's annual Photonics  
Conference (IPC-2013, formerly the IEEE  
LEOS Annual Meeting)**

Hyatt Regency Bellevue Hotel, Seattle, WA, USA

**E-mail:** m.hendrickx@ieee.org

[www.ipc-ieee.org](http://www.ipc-ieee.org)

**18–20 September 2013**

**Intersolar South America 2013**

Expo Center Norte, São Paulo, Brazil

**E-mail:** boesl@solarpromotion.com

[www.intersolar.net.br](http://www.intersolar.net.br)

**22–26 September 2013**

**39th European Conference on Optical  
Communications (ECOC 2013)**

ExCeL London Exhibition Centre, London, UK

**E-mail:** carina.meakins@nexusmediaevents.com

[www.ecoc2013.org](http://www.ecoc2013.org)

**23–24 September 2013**

**CPV USA 2013 (5th Concentrated  
Photovoltaic Summit USA)**

San Jose, CA, USA

**E-mail:** matt@pv-insider.com

[www.pv-insider.com/cpv](http://www.pv-insider.com/cpv)

**23–26 September 2013**

**SPIE Remote Sensing 2013, co-located with  
SPIE Security+Defence 2013**

Internationales Congress Centre Dresden, Germany

**E-mail:** info@spieeurope.org

<http://spie.org/remote-sensing-europe.xml>

<http://spie.org/security-defence-europe.xml>

**23–26 September 2013**

**5th International Conference on One  
dimensional Nanomaterials (ICON 2013)**

Annecy, France

**E-mail:** icon2013@grenoble.cnrs.fr

[www.icon2013.fr](http://www.icon2013.fr)

**24–26 September 2013**

**3rd International LED professional  
Symposium + Expo (LpS 2013)**

Bregenz, Austria

**E-mail:** symposium@led-professional.com

[www.led-professional-symposium.com](http://www.led-professional-symposium.com)

**29 September– 4 October 2013**

**International Conference on Silicon Carbide  
and Related Materials (ICSCRM 2013)**

Phoenix Seagaia Resort, Miyazaki, Japan

**E-mail:** secretary@icscrm2013.org

<http://icscrm2013.org>

**30 September – 1 October 2013**

**Deutscher MBE Workshop 2013**

Dresden, Germany

**E-mail:** dmbe2013@namlab.com

[www.namlab.com/pages/  
en\\_aboutus\\_1\\_mbe-workshop.htm](http://www.namlab.com/pages/en_aboutus_1_mbe-workshop.htm)

**30 September – 4 October 2013**

**28th European Photovoltaic Solar Energy  
Conference and Exhibition  
(EU PVSEC 2013)**

Parc des Expositions Paris Nord Villepinte, Paris, France

**E-mail:** press@wip-munich.de

[www.photovoltaic-conference.com](http://www.photovoltaic-conference.com)

**1–3 October 2013**

**IEEE Photonics Society's Avionics, Fiber-Optics  
& Photonics Conference  
(AVFOP 2013)**

San Diego, CA, USA

**E-mail:** m.figueroa@ieee.org

[www.avfop-ieee.org](http://www.avfop-ieee.org)

**7–10 October 2013**

**SEMICON Europa 2013**

Dresden, Germany

**E-mail:** ktorres@semi.org

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

**13–16 October 2013**

**2013 IEEE Compound Semiconductor IC  
Symposium**

Portola Hotel and Spa, Monterey, CA, USA

**E-mail:** customer.service@ieee.org

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

**16–17 October 2013**

**SEMI Strategic Materials Conference  
(SMC 2013)**

Santa Clara Marriott, CA, USA

**E-mail:** acobar@semi.org

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

**27–29 October 2013**

**1st IEEE Workshop on Wide Bandgap Power  
Devices and Applications (WiPDA 2013)**

Columbus, OH, USA

**E-mail:** program@wipda2013.org

[www.wipda2013.org](http://www.wipda2013.org)



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