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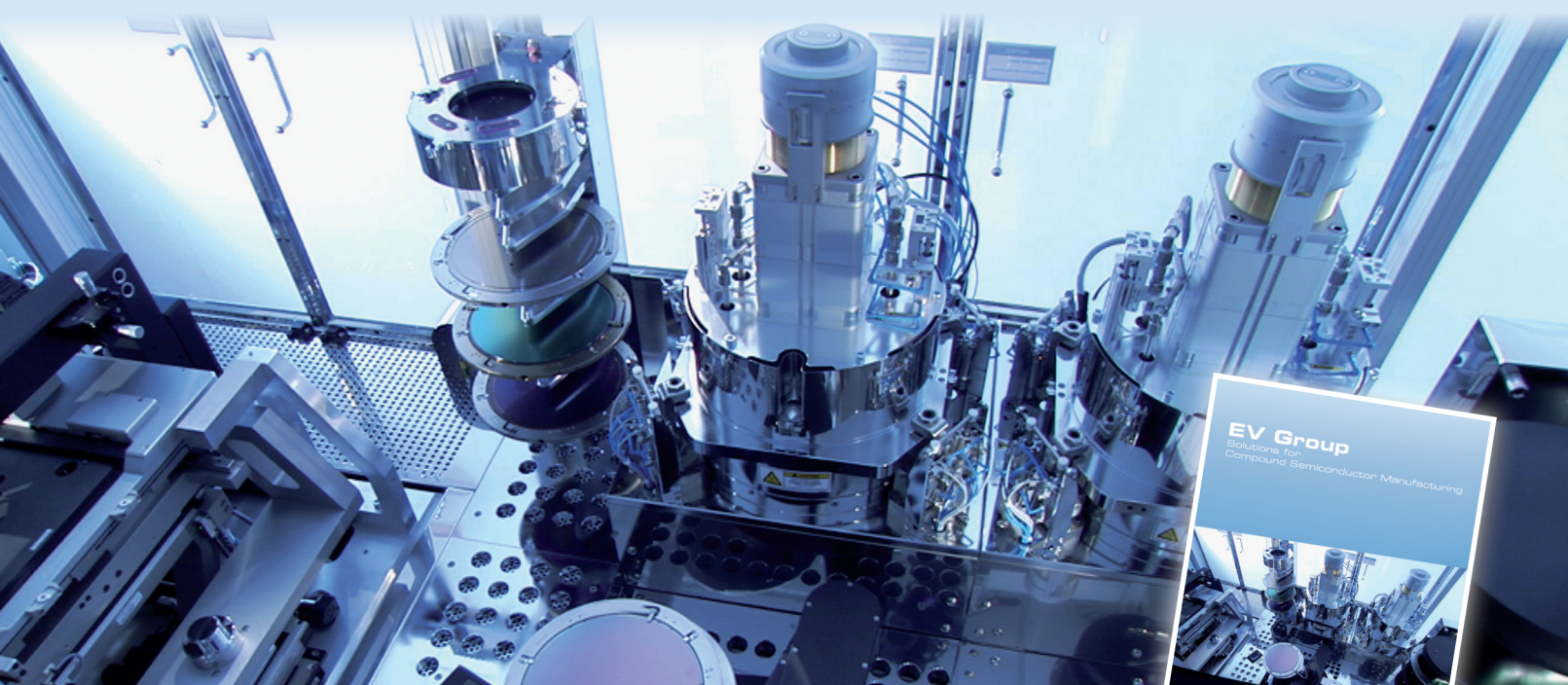
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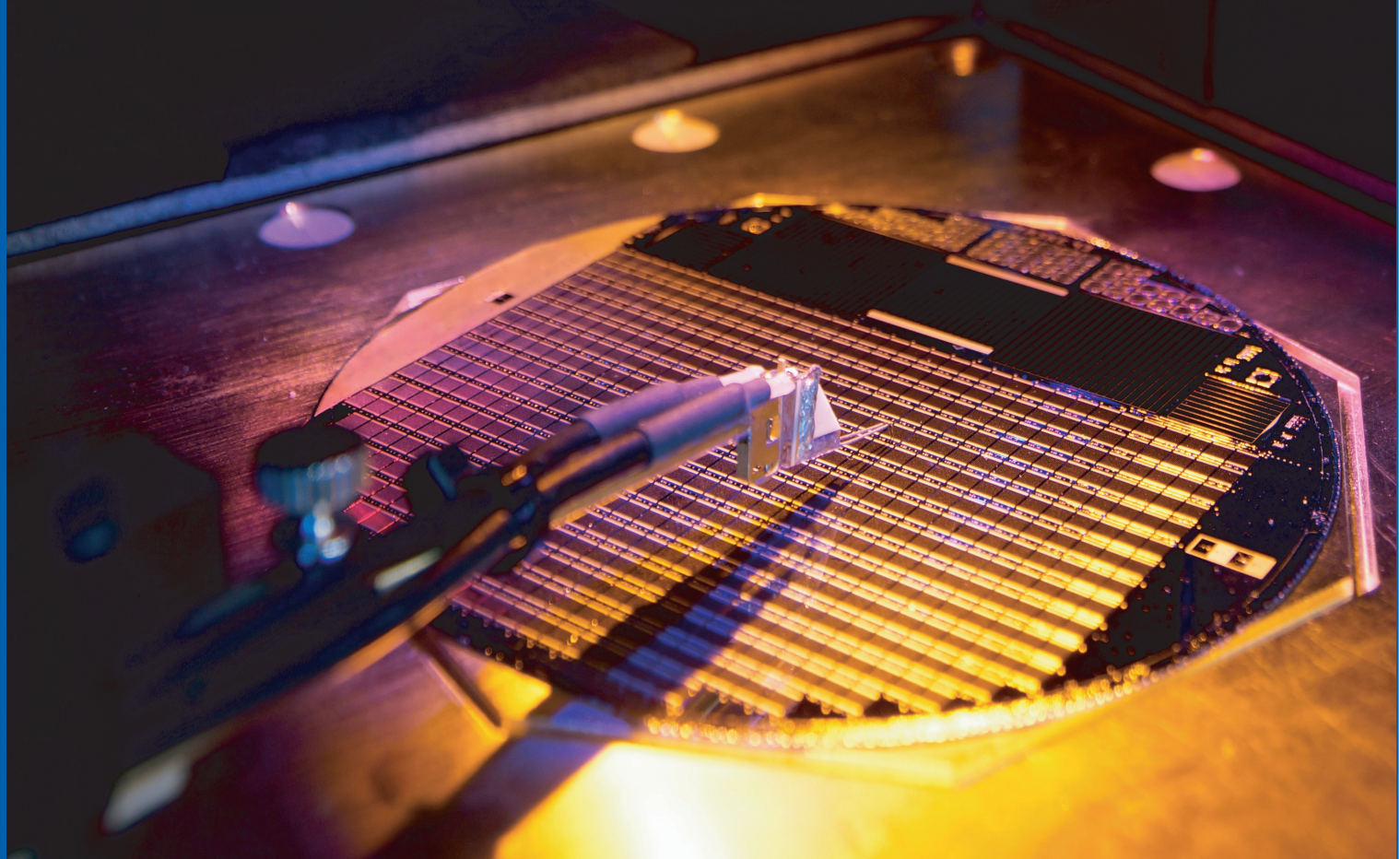


# semiconductor**TODAY**

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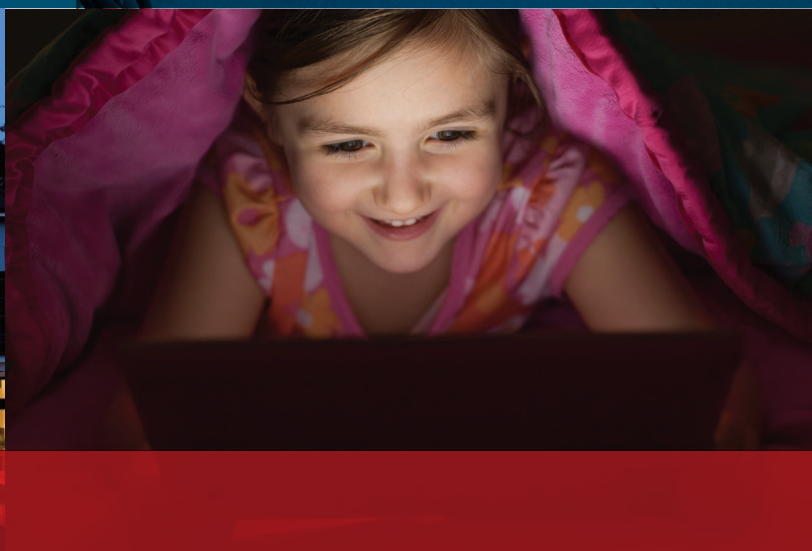
Vol. 9 • Issue 10 • December 2014/January 2015 [www.semiconductor-today.com](http://www.semiconductor-today.com)

## Solar cell efficiency record raised from 44.7% to 46%



RFMD/TriQuint merger completed • Veeco acquires SSEC  
Epistar buying TSMC's 94% stake in TSMC SSL





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*Veeco's New TurboDisc EPIK700 GaN MOCVD System*

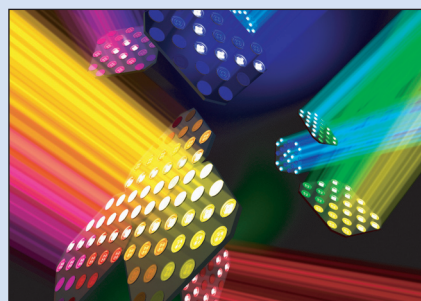


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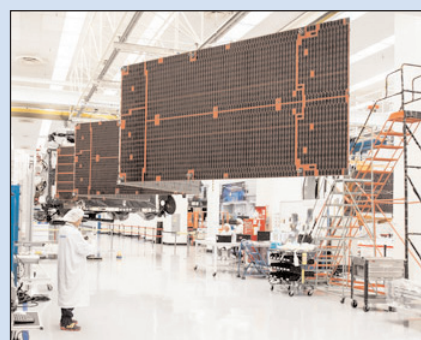
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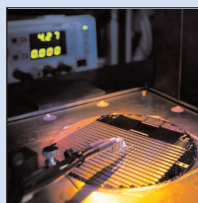
**p33** Epiluvac's EPI-1000X SiC reactor, which has been ordered by a leading European research center.



**p52** Osram's new Ostar Stage LED boosts brightness by up to 2.6x from component surface just 30% larger.



**p65** A satellite at Boeing powered by solar panels built by Spectrolab, which has just produced a record 4 millionth space solar cell.



Cover: France's Soitec and CEA-Leti, with Germany's Fraunhofer ISE, have developed a multi-junction solar cell that has raised the efficiency record from 44.7% to 46%. Pictured: record cell on 100mm wafer, yielding about 500 concentrator solar cell devices. ©Fraunhofer ISE/Photo Alexander Wekkeli. **p62**



## Consolidation & restructuring

The start of 2015 was heralded by the long-awaited finalization of the merger between RF Micro Devices and TriQuint Semiconductor (as Qorvo), almost a year after the deal was announced (see page 13). Despite falling initially from the launch price of \$69, Qorvo's stock has risen steadily over the last week or so to \$70.61 at the time of going to press,

Earlier, in mid-December, Japanese firm Murata completed its acquisition of San Diego-based Peregrine Semiconductor, a fabless provider of RFICs and RF front-ends based on silicon-on-insulator (SOI) technology (page 18). This follows earlier consolidation in the RF component sector when Analog Devices completed its acquisition of Hittite Microwave at the end of last July. Meanwhile, in power semiconductors, Infineon has just completed its purchase of International Rectifier in mid-January (gaining GaN-on-silicon technology — see page 25).

Consolidation in the optoelectronics sector includes Koch Industries (owner of electronics component maker Molex, which makes active optical cables) completing its purchase of Oplink Communications in December (page 57). Meanwhile, photonics firm Shearman Laser acquired diode laser maker Axcel Photonics on 1 January (page 54). In addition, in December and January respectively, Emcore closed the sales of its Space Photovoltaics business (to SolAero Technologies) and its tunable laser and transceiver product lines (to photonics integrated circuit firm NeoPhotonics), retaining its broadband fiber-optic product lines (see page 60).


In the LED sector, Taiwan's Epistar (the world's biggest LED epiwafer and chip maker) is buying the 94% stake in TSMC Solid State Lighting (TSMC SSL) held by Taiwan Semiconductor Manufacturing Co (the world's largest silicon wafer foundry) — see page 51. Although not adding much in capacity, Epistar says that TSMC SSL's "diverse personnel and management systems inherited from the foundry business will accelerate Epistar's innovation".

Such developments in the LED industry could provide much needed stimulus to the manufacturers of metal-organic chemical vapor deposition (MOCVD) systems, which have suffered in the last few years from the pause in LED industry growth and have only recently seen signs of an upturn in orders. In the meantime, as part of its ongoing reorganization launched in May 2013 (targeting a return to sustainable profitability), in early January MOCVD system maker Aixtron has announced plans to cut about 60 of its total staff of around 800 (see page 32). "Customer needs are evolving. The focus is increasingly on process and user-oriented solutions while we are executing our productivity programs in all areas of the company," says the firm. It adds that, alongside cost-cutting, it is pursuing new market opportunities, e.g. in promising future business fields such as power and logic semiconductors as well as OLEDs, "areas that are strengthened through the reorganization". Meanwhile, rival MOCVD system maker Veeco is diversifying by buying Solid State Equipment Holdings LLC (SSEC), which makes single-wafer wet etch, clean and surface preparation equipment (see page 30). "SSEC extends our compound semiconductor and MEMS footprint, and represents a stepping stone to the high-growth advanced packaging market," says Veeco's chairman & CEO John R. Peeler.

Such acquisitions and divestments indicate how trends in economics and technology continue to drive consolidation and restructuring.

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COMPOUNDS & ADVANCED SILICON



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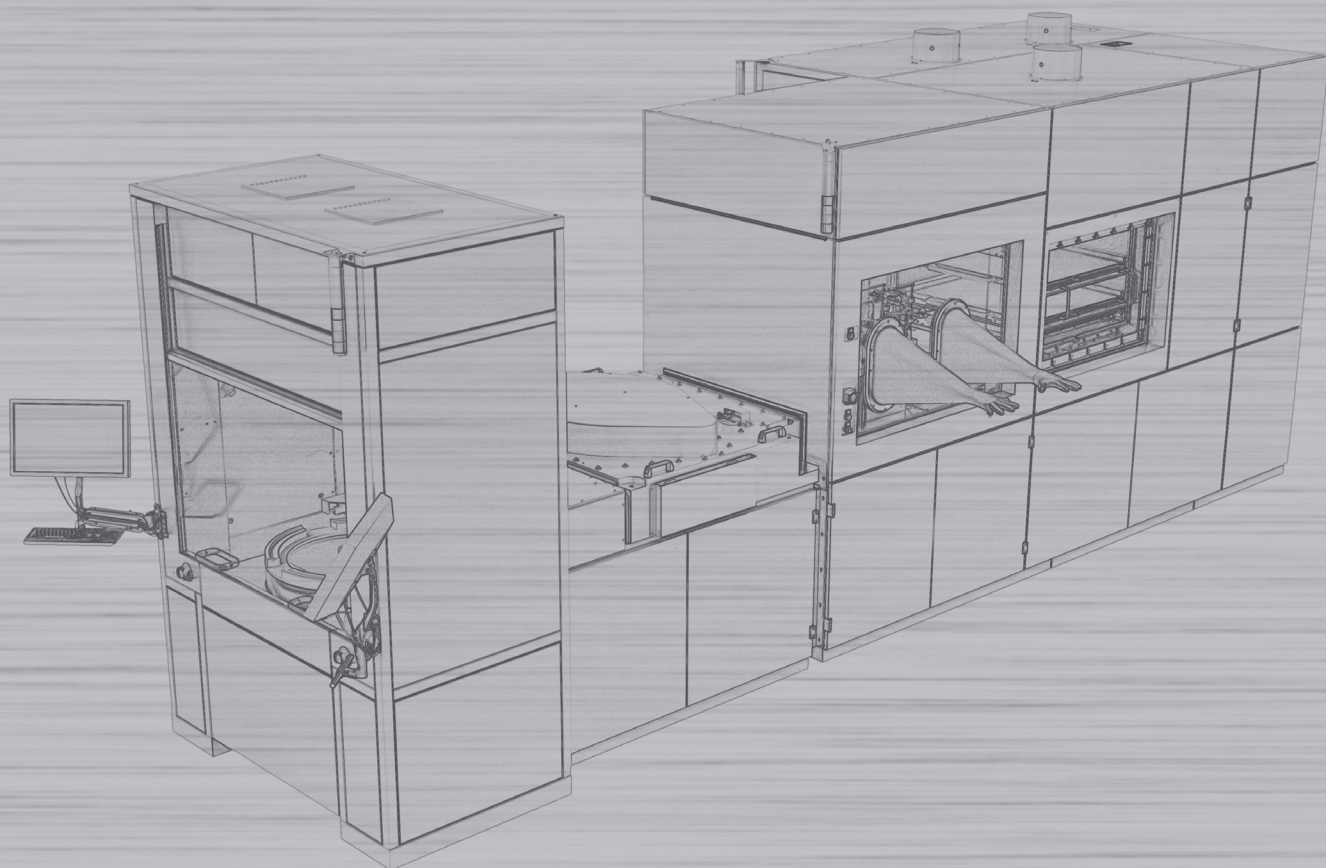
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## Lamp market to peak at \$21.2bn in 2018 then decline as LED lamp lifetime reduces replacement market

### LED lamp revenue to double to almost \$15bn in 2019

The overall market for lamps will rise from \$17.9bn now to peak at \$21.2bn in 2018 before shrinking to \$16bn by 2022, forecasts market research firm Strategies Unlimited in its most recent annual report 'The Worldwide Market for Lamps' (which covers the market for A, reflector, MR16 and tube lamps).

The short-term growth and subsequent fall is due to the increased penetration of LED lamps into all applications, notes the firm. LED lamp revenues are expected to more than double from \$7bn in 2014 to almost \$15bn in 2019. "While all LED lamp markets are forecasted to have a positive CAGR [compound annual growth rate] from 2014 through 2022, most will peak before the end of the decade as socket saturation from these

long-lived products will decrease the overall global replacement lamp market," says research director Philip Smallwood.

The report gives insight into the total lighting market through 2022 by covering all technologies, including incandescent, halogen CFL, fluorescent and LED, to get a better understanding of how LED lamps are poised to change the lighting landscape.

Government regulations are the factor with the largest impact on the lamp market today, notes Strategies Unlimited. The phasing out or banning of incandescent lamps is pushing the general population to make a choice about illumination technology. "Without these regulations, I would find it difficult to believe that the advancements in

LED lamps that we are seeing today would be taking place at such an accelerated pace," says Smallwood. "The technological feat of mimicking incandescent lamps almost perfectly is impressive, but the precipitous fall in price is astounding."

The most important theme from the report is that companies must adapt to a changing landscape to survive, notes the firm. While the market for LED lamps is poised to see growth, the market for all other technologies is expected to have a -14% CAGR in the same period. While there might be a short-term gain for more efficient incumbent technologies (mainly CFL and halogen), in the long term LED lighting will eventually be crowned king, concludes the report.

[www.strategies-u.com](http://www.strategies-u.com)

## LED market to grow at 17.9% from \$46.4bn in 2014 to \$105.5bn in 2019

### General illumination to be 85% of LED market by 2019

With the steady increase in the usability and efficiency of LEDs over traditional light bulbs during the last decade, the global market for high-brightness LEDs is projected to rise at a compound annual growth rate (CAGR) of 17.9% from nearly \$46.4bn in 2014 to \$105.5bn in 2019, according to the report 'Light-Emitting Diodes (LEDs) for Lighting Applications (SMC018E)' from market analyst firm BCC Research. LEDs for general illumination applications have the highest growth rate of any major segment, with a CAGR of 22% between 2014 and 2019. By 2019, shipments of LED for general illumination should reach \$89.2bn, or nearly 85% of the overall LED market.

The North American, European and Asia-Pacific regions have traditionally been the largest consumers of high-brightness LEDs. Over the forecast period, Chinese consumption will grow most rapidly. This migration follows the path of other products that China initially produced and then sold to the general population. By the end of the forecast period, China's percentage of consumer use will have nearly doubled, forecasts the firm.

Lighting is one of the most widespread, important and growing energy users. In the USA, recent data indicates that slightly more than 12% of electricity and 6% of all energy is consumed just to provide lighting, says BCC. Global production of energy for lighting is

about 3400TWh annually (equivalent to about 1700 power plants). Related carbon emissions are estimated to be over 400 million tons per year. Improvements in lighting efficiency should therefore have an important economic and environmental impact, adds the firm.

"LEDs already exceed the estimated life spans of conventional lighting systems and, coupled with their environmental advantages, they represent a big step into the future," comments analyst Andrew McWilliams. "Solid-state lighting could affect many phases of industry and consumer markets, as well as affect savings in dollars and environmental waste."

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

# LED chipset demand to rise from 35.8 million in 2013 to 1.4 billion in 2018

**Demand to rise for solid-state lighting through 2018 but gradually decline for display backlighting after 2014**

Demand for LED chipsets, primarily for the LED lighting market, will rise at 293% from 35.8 million in 2013 to 1.4 billion in 2018 (measured in standard units, i.e. 500µm x 500µm chip size), forecasts DisplaySearch (part of IHS) in the Q3/2014 edition of its 'Quarterly LED Lighting and Display Supply/Demand Report'.

"This forecast growth in the LED market is due

in large part to increasing demand from the LED lighting segment," says analyst Steven Sher. "As average selling prices continue to fall, shipments of all LED lighting products will remain on the rise."

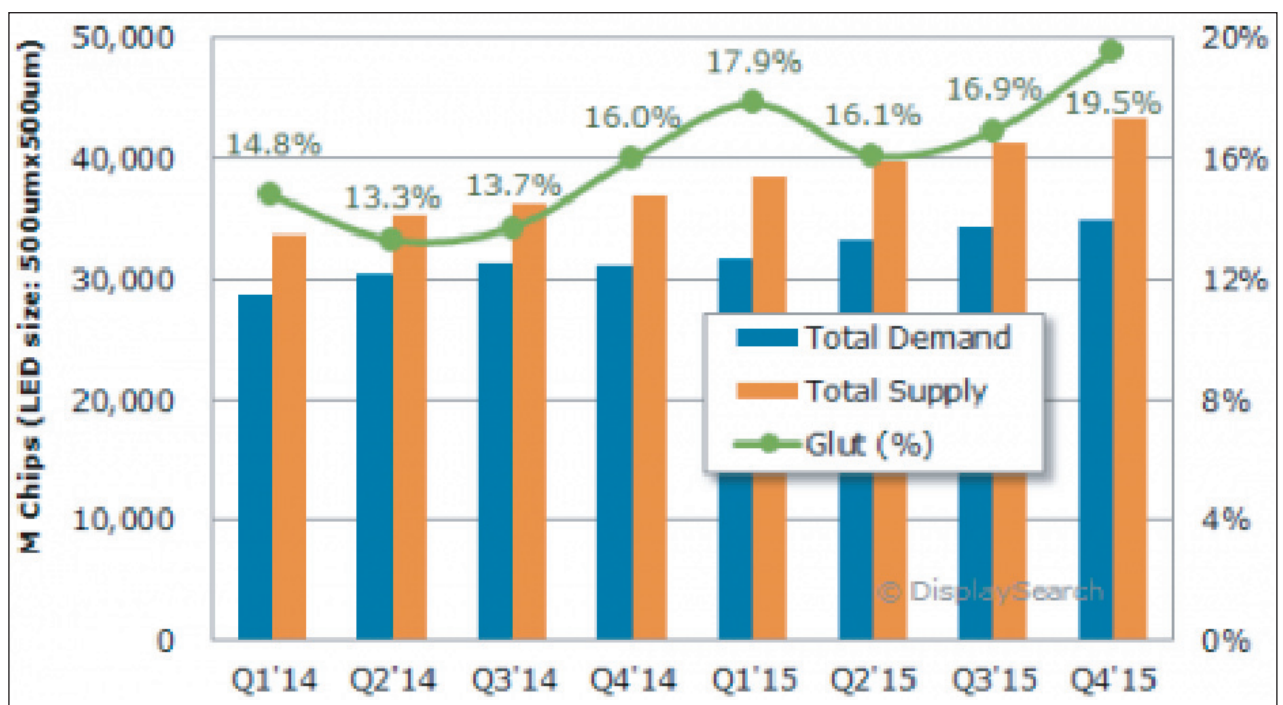
In 2014 the LED market became more integrated from chip to channel, as

competing companies merged and supply-chain companies acquired LED industry players, notes the report. "The LED chip industry is expected to fare better than the LED package industry, as demand for lighting continues to increase through 2018," Sher says.

While previously strong, chipset demand from LCD TV backlights

has slowed, due to a combination of sluggish growth in LED-backlit LCD TV sales as well as improved efficiency in the number of chips used per backlight. For those reasons, growth in global demand for chipsets used for display backlighting flattened after 2012, and a gradual decrease is forecast after 2014.

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



LED chip demand versus supply in backlights and lighting.

## Laser market growing at 12.6% CAGR to \$10.26bn in 2020

The laser diode market will rise at a compound annual growth rate (CAGR) of 12.6% from 2014 to 2020, according to the report 'Laser Diode Market — Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2014 – 2020' from Transparency Market Research. The market was valued at \$4.6bn in 2013 and is expected to be worth \$10.26bn by 2020.

The automotive segment accounted for 25.35% of the market in terms of revenue in 2013.

That year saw market domination by feedback laser diode technology, with 23.2% market share, and infrared laser diode technology held the wavelength segments by 26.2%.

Laser diodes based on aluminium gallium indium phosphide (AlGaInP) led the market in 2013 due to their increasing preference in optical discs, DVD players, laser pointers, and data communication devices. The report expects this segment to keep growing throughout the forecast period.

The report also divides the global laser diode market according to applications in consumer electronics, industries, automotives, medical, defense, healthcare, and others. Of these, the automotive segment dominated the market in 2013 because of the heavy use of laser diodes in engraving, lighting, molding and marking of automobile plastic in manufacturing plants, notes the report.

[www.transparencymarketresearch.com/laser-diode-market.html](http://www.transparencymarketresearch.com/laser-diode-market.html)



# LED modules to grow at 23.9% while packaged LEDs lighting market grows at 11% LED makers turning to modules to boost revenue and profits

The combined market for LED modules and light engines in lighting applications will reach \$1.3bn in 2014, forecasts the latest 'Next Generation Lighting' report from market research firm IHS Inc. However, the packaged LED lighting market will rise at a compound annual growth rate (CAGR) of 11% from 2013 to 2019, while the market for LED modules used in lighting will reach a CAGR of 23.9%, adds a Research Note by principal analyst Jamie Fox.

Riding the trend toward integrated products, many LED makers are increasingly turning to modules as a way to boost revenue and profits. In particular, chip-on-board (CoB) and LED light engines are two

examples of integrated products that are experiencing rapid growth. Cree, Seoul Semiconductor and other LED companies — as well as Harvard, BAG, Tridonic and other power companies — are also active in the market, notes IHS.

"LEDs used in lighting have become commoditized in many applications, and price declines in the last three or four years have been worse than expected," says Fox. "With MLS and other Chinese players increasingly entering the market, competition will remain tough."

Component makers are increasingly looking beyond the metrics of lumens per dollar and lumens per Watt as competitive differentiators. LED modules and light engines are

a logical step for many companies looking to improve their profit margin, diversify to ensure future stability, and meet the demands of their customers, adds Fox.

"During our research for the LED engines and light modules report, respondents cited the shorter supply chain, ease of production, interchangeability, quality and reliability as reasons why lighting companies chose to purchase LED modules and light engines," notes Fox.

"The report assessed the supply chain and reported on a mixture of outsourcing, contract manufacturing and in-house production of the products."

<https://technology.ihs.com/511618/led-modules-light-engines-2014>

## OLEDs to grow nearly tenfold from \$2.7m to \$26m in 2020 but inorganic LEDs to remain cheaper, more efficient & longer lasting

Until recently, the organic light-emitting diode (OLED) lighting market was far from mature. While OLED products have been available for some time, their comparatively high price has resulted in low shipment quantities. However, with recent advancements in OLED technology, interest in OLED lighting is starting to rise, according to a research note from Mike Hornung, IHS Inc's market analyst for lighting and LEDs. Also, while OLED is still more expensive than other technologies, it is a versatile and energy-efficient architectural lighting source. In fact, the market for OLED panels will grow tenfold from just \$2.7m now to about \$26m in 2020, forecasts IHS.

The main reason for OLED market growth is fast technical development of the product. Historically, the main drawbacks of OLED lighting products were their huge manufacturing costs. A comparable LED fixture costs significantly less

than the OLED equivalent and, even with all the advantages that OLEDs possess, they just could not compete with LEDs in applications such as general lighting, where the look and feel of the product was not the most important procurement consideration.

Over the past few years, developments in OLED technology have reduced average selling prices (ASPs) for OLED panels — a situation that is expected to continue. The ASP of an OLED panel in 2013 was just under \$31, but prices are expected to fall by at least 40% over the next seven years.

In terms of efficiency, lifetime and brightness, it will continue to be difficult for OLED lighting to compete with LED lighting. However, OLED has advantages in light quality, panel weight, heat distribution and stylistic effects and, as prices fall, panel shipments are forecast to increase dramatically.

It is important to remember that

as OLED technologies are rapidly developing, LED technologies are too, notes IHS. The prices of LEDs are still falling, and luminaire manufacturers are thinking of new ways of using them. Historically, OLEDs have held a stronger value proposition over LEDs in light quality, surface emission and other key functional areas. Continuous development of LEDs could soon challenge OLED in these areas, and it can be argued that they already do, adds the market research company.

In all probability, LEDs will remain significantly cheaper, more efficient and longer lasting than OLEDs, so LEDs will remain the mainstream technology for the foreseeable future, reckons IHS. Despite ongoing market growth, OLEDs will not be able to match the many benefits of LEDs before the next new technology comes along, it is concluded.

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

# Ten lighting and LED trends to watch in 2015

## Lighting companies' restructuring to allow LED makers to raise capital for investment

Last year's restructuring by major global lighting companies will allow LED makers to raise capital for investments in 2015, as it could lead to improved margins for leading companies along with the potential for lower product prices for consumers, reckons market research firm IHS in its new white paper 'Top Lighting and LEDs Trends for 2015'.

"For the big three lighting suppliers, the road was bumpy: all of them recorded falling revenue in the first three quarters of 2014," notes William Rhodes, research manager of lighting and LEDs at IHS Technology. "Industry watchers are now looking to see if these giants of the lighting industry can turn the tide in 2015."

The IHS technology research team lists the following 10 predictions for the lighting and LED industry for 2015:

### 1. China will continue to grow.

Given the growing market share of Chinese LED companies throughout the value chain, the coming year could be pivotal for the global LED industry. "To compete with international companies and maintain their growth, Chinese vendors must overcome negative perceptions of product quality that continue to plague them, even while they maintain their low pricing," Rhodes says.

### 2. The sky is the limit for cloud-based smart lighting.

The market for cloud-based smart lighting is unlikely to gain market share in 2015, because public knowledge of companies offering solutions remains limited; however, increased marketing of cloud-based smart lighting could gain mindshare in 2015, positioning the market for future growth, reckons IHS.

### 3. Changing fortunes for lighting companies expected in 2015.

The reorganization of the top three lighting manufacturers could turn

them into pure-play lighting companies focused on dynamic markets, which would offer greater growth potential. The restructuring will also allow LED makers to raise capital for further investment, and will let them reduce the hierarchical burden associated with being part of a large conglomerate. "Changes in the corporate structure could lead to improved margins for the companies, and possibly lower-priced products for consumers," Rhodes forecasts.

### 4. Li-Fi, a brighter way to communicate.

Visual light communication (Li-Fi) is a new and emerging technology, but implementations of pilot projects, along with greater media interest, is forecast for 2015.

"It will be interesting to see how many commercial projects are announced this year, and on what scale," Rhodes says.

### 5. Is lighting poised for a quantum leap?

As quantum-dot LEDs (QD-LEDs) still have some challenges to overcome, the market will not likely see vast quantities of commercially available products by 2015 or 2016. However, in the medium to longer term, QD-LEDs could kill off the organic light-emitting diode (OLED) display market and cause deep disruption to the lighting industry as a whole. "QD-LEDs still have some challenges to overcome, but we might see a very small amount of commercially available products by the end of 2015," Rhodes says.

### 6. OLED luminaires, and where to purchase them.

Mass-market adoption of OLED lighting is not projected to occur in 2015, but retailers will likely start to offer a premium range of OLED luminaires, which undoubtedly will help to create more interest in the overall OLED market in the coming year.

### 7. LED filament bulbs: incandescent beauty with an LED twist.

LED filament lamps, which combine the benefits of LED lamps with the familiar design of incandescent bulbs beloved by traditionalists, are now starting to match other LED offerings in terms of efficiency, price and color-rendering capabilities. "Ultimately it will be up to consumers to decide if filament bulbs will have their time in the limelight in 2015," Rhodes says.

### 8. Packaged LED industry is moving downstream and getting smarter.

Smart lighting is another way for companies to attempt to add value and improve profit margins. As the LED lighting market moves downstream with modules and light engines, incorporating smart lighting sensors and controls will be a key trend in 2015, reckons market research firm IHS.

### 9. Is your streetlight all that it seems?

In the coming year, a couple of smart street-lighting pilot projects (e.g. incorporating electric-vehicle charging or mobile phone masts into the luminaires) are expected to start moving to larger city-wide installations. "With developments in new technology, as well as the ever-expanding phenomenon of the Internet of Things (IoT), the role that street lights play in our world is set change completely," Rhodes says.

### 10. Automotive applications driving optoelectronic components market.

With LED headlamp penetration increasing, gesture control getting increasing interest, and hybrid and electric vehicles sales continuing to grow, 2015 will be a lucrative year for the optoelectronic components suppliers that focus on the automotive industry, the white paper concludes.

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



# Market for discrete GaN power conversion devices to reach \$1.1bn in 2024

**GaN-on-Si to reach 90% market share vs GaN-on-SiC and GaN-on-GaN**

Since gallium nitride (GaN) materials can create much more efficient devices for electric power conversion in devices from cell phone chargers to hybrid electric vehicles, the market for GaN discrete components will grow to \$1.1bn in 2024, according to Lux Research in its report 'Breaking Down the Gallium Nitride Power Electronics Market' (part of the Lux Research Energy Electronics Intelligence service).

However, the substrate on which the GaN device is grown – silicon (Si), silicon carbide (SiC), or GaN – makes a big difference in the cost and performance of the device. GaN-on-Si will dominate the GaN market for at least the next decade, growing to \$1bn in 2024 (a 90% share), forecasts Lux.

"Of the three GaN flavors, GaN-on-Si

will be the cheapest, pushing adoption of GaN-on-SiC or GaN-on-GaN out into the future," predicts research analyst Pallavi Madakasira (lead author of the report). "Even though both GaN-on-SiC and GaN-on-GaN offer performance improvements over silicon, high prices for SiC and GaN substrates will limit adoption," she adds.

Lux Research analysts evaluated the overall GaN market, besides evaluating the growth prospects of the three GaN flavors. Their findings include the following:

**● Transportation & renewables/grid are key markets.**

GaN-on-Si will be the runaway leader in the renewables and grid markets, as well as transportation, reaching market sizes of about \$350m and \$380m, respectively, in

2024. Next in adoption will be IT and electronics.

**● GaN-on-SiC growing fastest.**

GaN-on-SiC will grow at a compound annual growth rate (CAGR) of 46% from 2017 to 2024, reaching \$140m. Driven by the SiC substrates' ability to function efficiently at high temperatures, it will gain the most adoption in transportation.

**● GaN-on-GaN a non-starter for now.**

The lack of cheaper GaN substrates and a relative lack of developers mean that GaN-on-GaN will play little commercial role in the next decade, forecasts Lux. More R&D is needed on cost-saving innovations such as hybrid manufacturing processes, the firm adds.

[https://portal.luxresearchinc.com/research/report\\_excerpt/18514](https://portal.luxresearchinc.com/research/report_excerpt/18514)

## LTE handset shipments to grow from 204 million in 2014 to 676 million in 2015

**Shipments of LTE connected devices to exceed 1.89 billion by end 2019**

Shipments of 4G LTE handsets will grow from 204 million units in 2014 to 676 million in 2015, forecasts market analyst firm ABI Research in its report '4G Subscribers, Devices, and Networks Market Data' (part of the firm's LTE & 5G Market Research). Furthermore, the total number of LTE connected devices shipped worldwide will exceed 1.89 billion units by end 2019, it reckons, demonstrating the need for infrastructure and spectrum to support the stellar growth in the industry.

"With the proliferation of larger-screen smart devices driving up the insatiable appetites for content and faster speeds, ABI estimates that there will be 350 commercial LTE networks forecasted by 4Q 2014," says research analyst Cheri Wong. Furthermore, LTE-Advanced is now

commercial on 20 networks in 14 countries. To cope with the demand for higher data rates, FDD/TDD LTE carrier aggregation trials are starting to take place. For example, Ericsson, SingTel and Qualcomm demonstrated a downlink speed of 260Mbps in their trial. The first ever TDD-FDD LTE trial took place in February between Korea Telecom and SK Telecom, with assistance from Nokia Networks. The growing demand for data also emphasizes the need for additional bandwidth to support the massive strain on operator networks which can be alleviated through the re-farming of unused spectrum, says ABI.

"While commercial devices supporting FDD/TDD carrier aggregation will only debut in 2015, this has not deterred global operators like Vodafone from rolling out LTE-

Advanced technology using carrier aggregation to supplement its existing LTE mobile services," says Jake Saunders, ABI VP & practice director for 4G/5G. Fueling the growth of the TD-LTE standard is the recently concluded \$970m 4G TD-LTE deal between Nokia Networks and China Mobile. The multi-million deal will allow Nokia to equip China Mobile with its 4G TD-LTE technology to support the mobile operator's 4G wireless broadband network deployments by end 2014 and 2015. The evolution of LTE will also see the next wave of related applications like VoLTE and LTE Broadcast/Multicast become growth drivers for the LTE market in the near term, concludes ABI Research.

[www.abiresearch.com/market-research/service/4g](http://www.abiresearch.com/market-research/service/4g)

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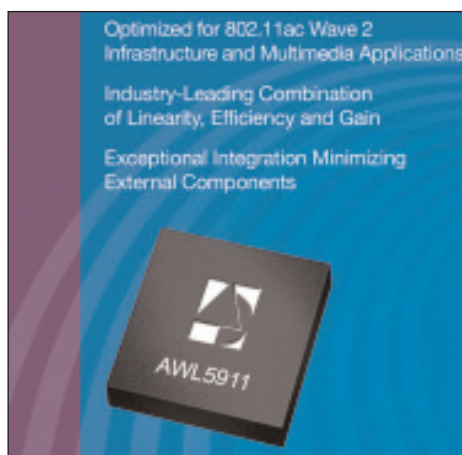


# Anadigics expands WiFi infrastructure portfolio with 4900–5900MHz power amplifier

Anadigics Inc of Warren, NJ, USA has expanded its family of 802.11ac 5GHz WiFi power amplifiers (which includes the AWL5905 launched in May 2013 and AWL5910 in May 2014) by launching the AWL5911, which is optimized for 802.11a/n/ac Wave 2 WiFi infrastructure and multimedia applications including access points, routers, media gateways and set-top boxes.

Operating in the 4900–5900MHz frequency band, the AWL5911 delivers a combination of linearity, efficiency, gain and thermal characteristics, while minimizing external components. These performance and integration advantages help 802.11ac Wave 2 solutions to enable multi-user multi-input/multi-output (MU-MIMO) functionality, take advantage of 160MHz channels, and make use of an additional transmit spatial stream, says the firm. When employed, these features can provide higher data throughput at greater range and coverage than existing Wave 1 solutions, it adds.

“The new features available with Wave 2 promise to enrich the experience for WiFi users connected to an expanding array of infrastructure and multimedia devices,” says president Dave Cresci. “Anadigics’ family of 802.11ac WiFi power amplifiers is enabling this trend by delivering exceptional



**Anadigics’ new AWL5911 5GHz 802.11ac WiFi power amplifier.**

linearity, output power and gain to enable ultra-high data throughput,” he adds. “The AWL5911 supports high-performance multi-user MIMO designs, while reducing BOM [bill of materials] costs and minimizing PCB space requirements... These advantages are being recognized and valued with specification on leading reference designs.”

Anadigics’ family of 802.11ac WiFi power amplifiers for infrastructure applications leverages its patented InGaP-Plus technology and unique design architectures to offer performance and integration. The AWL5911 PA provides 33dB of linear power gain (bettering the AWL5905’s 30dB and the AWL5910’s 31dB) and a low error vector magnitude (EVM) of

1.8% at 22dBm output power (matching the AWL5910, and bettering the AWL5905’s 2.0% EVM at 19.5dBm). This ensures stable, reliable high-throughput WiFi connectivity in the toughest 802.11ac modulation formats, says the firm. The AWL5911 also features an internal digital PA enable interface that eliminates the need for an external buffer amplifier, as well as a high-accuracy integrated detector that facilitates accurate power control over varying load conditions (3:1 VSWR) and extends the usable detector dynamic range. This level of integration reduces surface-mount passive components and simplifies RF design, saving board space, reducing the bill of materials, and accelerating time-to-market, says the firm.

The compact 4mm x 4mm x 0.8mm QFN package also incorporates RF ports internally matched to 50Ω and DC blocked to reduce PCB space requirements. In addition, a CMOS-compatible control interface improves ease of use.

Coupled with the power efficiency and thermal characteristics, these performance and integration advantages enable MIMO (multiple-input multiple-output) designs that consume less power and are more thermally efficient, says Anadigics.

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

# MACOM launches S-band 7W pulsed high-power amplifier

M/A-COM Technology Solutions Inc of Lowell, MA, USA has released an S-band high-power pulsed amplifier operating at 2.7–3.0GHz for civil air-traffic control and weather radar applications, used either individually (in a 6mm PQFN 28-lead SMT package) or in a complete MACOM chipset.

With power-added efficiency (PAE) of 28%, it has 7W of pulsed power and 23dB of small-signal gain and is designed to provide rugged per-

formance under load mismatch. The MMIC’s balanced architecture enables a robust solution with input and output return losses of 20dB across the frequency band and high performance under demanding VSWR (voltage standing wave ratio) load conditions. Output power at 1dB gain compression point (P1dB) is 37.5dBm. Drain current is 2.5A.

With +10V bias operation and 50Ω impedance, the IC utilizes a 0.5μm pHEMT processes to enable

increased integration at the MMIC level. It is encapsulated in a halogen-free, environmentally friendly mold compound, and is RoHS compliant and 260°C reflow compatible, operating at an 8% duty cycle.

“The device provides a fully matched, SMT solution with highly rugged balanced configuration that we believe will perform well under demanding conditions,” says product manager Paul Beasley.

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

# Merger of RFMD and TriQuint as Qorvo completed

On 1 January (a day later than the expected 31 December), RF Micro Devices Inc of Greensboro, NC, USA and fellow RF component maker TriQuint Semiconductor Inc of Hillsboro, OR, USA completed their merger (unveiled in February 2014) to form Qorvo Inc, a provider of what is claimed to be the industry's broadest portfolio of core technology and RF products for mobile, infrastructure and aerospace/defense applications. Following delisting of the stock of both RFMD and TriQuint, Qorvo began trading on the NASDAQ Global Stock Market on 2 January (as 'QRVO') at \$69 per share.

"Qorvo brings under one roof all the critical RF building blocks needed to simplify design, reduce size and conserve power, while improving system performance across mobile,

infrastructure, and aerospace & defense applications," says Qorvo's president & CEO Bob Bruggeworth. "Our goal is to build the most valuable company in our space."

As well as more than 6000 staff, Qorvo has ISO9001-, ISO 14001- and ISO/TS 16949-certified manufacturing facilities, and is a DoD-accredited 'Trusted Source' (Category 1A) for GaAs, GaN and BAW products and services.

As a result of the merger, TriQuint shareholders receive 1.675 shares of Qorvo and RFMD shareholders receive 1 share of Qorvo for each TriQuint or RFMD share held, and a one-for-four reverse stock split was effected at closing of the merger on 1 January. Former shareholders of RFMD and TriQuint Semiconductor each own about 50% of Qorvo.

The merger is expected to achieve at least \$150m in cost synergies (\$75m in annualized synergies exiting the first year after closing plus \$75m exiting the second year). The transaction is expected to be accretive to non-GAAP earnings per share (EPS) in the first full fiscal year following the merger.

Qorvo's new 10-member board includes four independent directors from each of the RFMD and TriQuint boards: Daniel A. DiLeo, Jeffery R. Gardner, John R. Harding, Charles Scott Gibson, David H.Y. Ho, Roderick D. Nelson, Dr Walden C. Rhines, and Walter H. Wilkinson Jr. The board also includes Qorvo's president & CEO Bob Bruggeworth and former TriQuint CEO Ralph Quinsey, who is non-executive chairman.

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

## RFMD earns Huawei's Supplier of the Year Award for second year

At a ceremony at Huawei's headquarters in Shenzhen, China, RFMD has received Huawei's Supplier of the Year Award for the second consecutive year. The award recognizes RFMD as Huawei's best supplier of RF components, which are used in mobile phones and infrastructure products.

RFMD supplies Huawei Technolo-

gies Co Ltd (which makes smartphones and mobile devices) with a growing suite of RF solutions including antenna switches and switch modules, power amplifiers, power management ICs, and Wi-Fi amplifiers for mobile devices as well as key components that support Huawei's wireless infrastructure and cellular backhaul business.

"RFMD was the only RF supplier to earn a Gold Medal from Huawei this year," notes Xiong Lening, Huawei's VP of supply chain management.

"This award reflects RFMD's ability as a key strategic partner to provide Huawei innovative technology and products, outstanding local service and support, and excellent on-time delivery," he adds.

# MwT launches GaAs MMICs compatible with both epoxy and AuSn eutectic die attach

MicroWave Technology Inc (MwT) of Fremont, CA, USA has launched a family of GaAs MMICs fully compatible with both epoxy and AuSn eutectic alloy die-attach methods.

Many GaAs based MMIC products on the market can only use epoxy for the die attach process, says MwT, while certain commercial, military and high-reliability/space applications will demand eutectic die attachment process instead of epoxy process. The eutectic die attach process provides improved electrical perform-

ance and thermal dissipation, which enhances long-term reliability of the MMIC parts under operation.

MwT has converted its key MMIC products to be compatible with both eutectic and epoxy die-attach. In this unique device technology, a special non-wet metal layer is placed to the backside via holes regions to prevent the melted AuSn eutectic alloy from penetrating through the backside via holes and causing damage to the features/circuitries on the front side of the MMIC chip

during the die attach process.

"This unique technology feature will allow our customers to utilize our high-performance GaAs-based MMIC products for applications that demand robustness and stringent long-term reliability," says MwT general manager Dr Greg Zhou.

"We have already had several key MMIC products with the eutectic die attachment compatibility designed into various sockets and have begun receiving the production orders"

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



## TriQuint's DoD Trusted Source accreditation extended

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA has earned continued Trusted Source Category 1A accreditation through 2016 from the Department of Defense (DoD).

Certification expresses the confidence of the DoD Defense Microelectronics Activity (DMEA) and the National Security Agency's Trusted Access Program Office (TAPO) that TriQuint will continue to deliver trusted foundry microelectronic goods and services (category 1A) to end users which meet mission-critical needs now and into the future.

"We've maintained this accreditation and achieved significant milestones as a technology leader to reaffirm our unwavering commitment to our customer and the defense industrial base," says VP & general manager James Klein, Infrastructure and Defense Products.

TriQuint earned original accreditation for its foundry in Richardson,

Texas in 2008. It was extended in 2012 to include post-processing services, assembly & packaging services, and RF test services. All of those accreditations have been renewed through 2016. Foundry accreditations include gallium nitride (GaN), gallium arsenide (GaAs) and bulk acoustic wave (BAW) technologies.

The accreditation certifies that TriQuint provides the DoD and intelligence community with critical system microelectronics; foundry access for mission applications; and technology support through industry partnership. In this manner, TAPO and DMEA can have confidence that national security technology is secured throughout its manufacture and distribution by TriQuint.

TriQuint says that it has focused on achieving several milestones as a supplier to the DoD. For example, the firm recently completed the Defense Production Act Title III

GaN on silicon carbide (SiC) program. TriQuint also applied the US Air Force Research Laboratory's rigorous manufacturing readiness assessment (MRA) tool and criteria to its GaN production line, which develops high-frequency, high-power devices used within military radar, communications and electronic warfare (EW) programs. This MRA process benchmarked TriQuint as the first GaN manufacturer to earn Manufacturing Readiness Level 9, with the maturity needed to support full-rate production programs. The DoD's MRA ensures that manufacturing, production and quality assurance meet operational mission needs and provide the best value for the customer. TriQuint demonstrated that its manufacturing processes met full performance, cost and capacity goals, with the capability in place to support full-rate production.

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

## Modelithics releases latest TriQuint GaN RF simulation model library

In partnership with RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA, Modelithics Inc of Tampa, FL, USA, which provides RF and microwave active and passive simulation models for electronic design automation (EDA), has released the latest update to the growing library of high-accuracy non-linear simulation models for TriQuint's gallium nitride (GaN) transistors.

The TriQuint GaN library, v1.5.0, now contains precision models for 29 of the firm's most popular GaN transistors, including the T1G2028536-FL, T1G4012036-FS and T2G4005528-FS package format transistors and the TGF2023-2-01, TGF2023-2-10 and TGF2954 die format transistors.

The GaN transistor models have been developed using Modelithics measurements and modeling technology. Each has been validated

over multiple measurements, including multi-bias S-parameters, pulsed IV, single-tone power and load pull at various frequencies. The models have broadband non-linear performance predictability, and offer temperature scaling capability. Design features included with many of the models include scalable operating voltage, control of self-heating effects, and access to intrinsic voltage/current nodes for I/V waveform analysis.

TriQuint's GaN-based solutions are said to offer greater power density, efficiency, frequency range and ruggedness, enabling RF systems to use less electricity, operate with less input voltage and deliver greater RF output power while reducing amplifier size and part counts.

"This partnership in GaN modeling with TriQuint represents a new format for getting designers toolled with the models they need for design success, with the supplier sponsor-

ing the maintenance, support and distribution of a professionally managed and well documented software library consisting of state-of-the-art non-linear temperature dependent models," says Modelithics' president & CEO Larry Dunleavy.

"TriQuint's partnership with Modelithics will provide designers with precise models for exceptional simulation development," says Brian Balut, TriQuint's VP of IDP Engineering. "Production-ready system designs and simulations can now be developed using models of TriQuint's industry-leading GaN transistor technology," he adds.

The GaN models are available now for free download and use by approved TriQuint customers. Each model comes with a model datasheet that provides detailed information about the model development, features, usage and performance plots.

[www.modelithics.com/mvpTriQuint.asp](http://www.modelithics.com/mvpTriQuint.asp)

# TriQuint's vice president of business development receives Distinguished Engineering Award

RF front-end component maker and foundry services provider TriQuint Semiconductor Inc of Hillsboro, OR, USA says that its VP of business development Glen Riley has received the Edward T. Bryand Distinguished Engineering Award from the University of Maine's College of Engineering (its highest honor for career excellence and accomplishment).

Established in 1979, the Edward T. Bryand Distinguished Engineer Award recognizes an individual "who has by his/her activities, achievements, and scholarship brought distinction to the profession of engineering". The award recognizes: achievements in engineering, research and public service; honors and publications, patents, or inventions; and other creative achievements.

"We selected Glen for this honor based on his key contributions to engineering, marketing and general management over his 30-year career in the semiconductor industry," says Dana Humphrey, dean of the College of Engineering. "In his leadership role at TriQuint, we look forward to Glen continuing to contribute to the growth of the 4G LTE market, especially with regards to acoustic filters and highly integrated RF modules."



**Glen Riley (center), flanked by Donald Hummels (left), chair of Electrical & Computer Engineering, and Dana Humphrey (right), dean of the College of Engineering at the University of Maine.**

Riley received the award on 7 November at the university's annual recognition banquet. As an electrical engineering undergraduate, he fabricated SAW filters on quartz for research in gas sensors. TriQuint is known for its expertise in applying SAW and BAW filter technology to LTE system and chipset challenges, Riley notes.

Riley joined TriQuint in 2003 and most recently completed a two-year assignment in Singapore as managing director of TriQuint International Pte Ltd. Prior roles include VP & general manager of foundry services and VP & general manager

of TriQuint Optoelectronics. Before joining TriQuint, he was CEO of the venture-funded start-up Opticalis. He also held senior executive positions with Agere Systems as VP of optical core networks, president of Asia-Pacific sales and general manager of storage products. Previously, Riley held positions in sales &

marketing at Philips Semiconductors, AT&T Microelectronics and Texas Instruments. Riley holds a B.S. degree with highest distinction in electrical engineering from the University of Maine and completed the general manager program at Harvard Business School.

After TriQuint merges with RF Micro Devices Inc of Greensboro, NC, USA under the name Qorvo Inc at the end of December, Riley will serve as general manager of Filter Solutions for the combined company.

<https://engineering.umaine.edu/home/eb>  
[www.triquint.com](http://www.triquint.com)

## Assembly & test service provider Unisem receives Supplier Performance Award from TriQuint

RF wireless communications component maker TriQuint Semiconductor Inc of Hillsboro, OR, USA has honored Unisem of Kuala Lumpur, Malaysia with its Supplier Performance Award, recognizing Unisem's "outstanding performance and contribution to TriQuint's success in 2013 and 2014".

Unisem is a global provider of outsourced semiconductor assembly & test (OSAT) services offering an integrated suite of packaging and test services such as: wafer

bumping, wafer probing, wafer grinding; leadframe and substrate IC packaging; wafer-level CSP; and RF, analog, digital and mixed-signal test. Turnkey services include design, assembly, test, failure analysis, and electrical, mechanical, and thermal characterization and modeling. Unisem is also an established MEMS OSAT with several years of experience in volume consumer and automotive production, in addition to a broad package portfolio covering multiple

applications. The firm has factories in Ipoh, Malaysia; Chengdu, China; Batam, Indonesia; and Sunnyvale, CA, USA.

"We look forward to continuing to build upon our strong partnership in the years ahead," said CS Ho, chief operating officer of Unisem Ipoh received the award on behalf of the company. "This award was the result of our consistency in meeting TriQuint's high performance standards," he added.

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



# Skyworks ramps suite of LTE solutions powering next-generation chipsets for emerging markets

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) is commencing volume production of its SkyLiTE front-end solutions powering LTE platforms in emerging markets.

Skyworks' newest family of LTE devices consists of highly integrated modules that incorporate the amplification, switching, Wi-Fi filtering and coupler functionality required to support all major FDD/TDD bands. With the addition of external duplexers, the product suite provides OEMs with a scalable and reconfigurable front-end system suitable for markets world-wide. MediaTek, a provider of system-on-a-chip (SoC) platforms for wireless communications and home entertainment, is leveraging SkyLiTE solutions for its MT6752/32 and MT6735 LTE chipsets targeting China's leading smartphone providers.

"We are delighted to be partnering with MediaTek to deliver cost-effective platforms with the highest levels of integration and performance, particularly as OEMs in China migrate to LTE," says Skyworks' VP of product marketing Carlos Bori. "Together, we are uniquely positioned to capitalize on consumers' demand for competitively priced smartphones with increased functionality," he reckons.

According to Strategy Analytics' September 2014 'Global LTE

Handset Forecast', by 2016 LTE will represent more than 60% of total handsets in China. Currently, about 30% of total handsets are LTE smartphones. The SkyLiTE platform targets the fastest-growing segment of the TDD/FDD LTE market.

The SkyLiTE family comprises the following products:

- SKY77643-11 — a hybrid multi-mode multi-band power amplifier (MMPA) module that supports 3G/4G handsets and operates efficiently in WCDMA, TD-SCDMA and LTE modes. The module is fully programmable through a Mobile Industry Processor Interface (MIPI).
- SKY77824-11 — a fully matched, 28-pad surface-mount power amplifier module developed for LTE applications. The module includes broadband coverage of FDD LTE Bands 7 and 30, TDD LTE Bands 38/40, and Band 41, all in a compact 4.0mm x 3.65mm package.
- SKY77910-11 and SKY77916-11 — transmit/receive front-end modules (FEMs) with a complete transmit VCO-to-antenna and antenna-to-receive surface acoustic wave (SAW) filter solution for advanced cellular handsets comprising quad-band GSM, and linear 2.5G operation. Developed in a very low-profile and compact form factor, the FEM supports Class 12 General Packet Radio Service (GPRS), EDGE multi-slot operation, and TD-SCDMA and TDD LTE

linear transmission.

Of MediaTek's SoC platforms, the MT6752 is a 64-bit octacore LTE SoC that incorporates eight 2.0GHz ARM Cortex-53 CPUs and a Mali-T760 GPU for next-level 64-bit mobile computing and LTE (pin compatible with the previously announced quad-core MT6732).

The MT6735 is the latest in a series of devices that MediaTek has launched to give consumers high-performing smartphones at an affordable price. MediaTek's platforms support advanced multimedia features including:

- a low-power, 1080p, 30fps video playback for the emerging video codec standard H.265 and legacy H.264 and 1080p, 30fps H.264 video recording;
- integrated 16MP camera image signal processor;
- MediaTek ClearMotion technology that eliminates motion jitter and ensures smooth video playback at 60fps on mobile devices;
- MediaTek MiraVision technology for DTV-grade picture quality;
- integrated multi-mode 4G LTE modem;
- Rel. 9, Category 4 FDD and TDD LTE (150Mb/s downlink, 50Mb/s uplink); and
- 3GPP Rel. 8, DC-HSPA+ (42Mb/s downlink, 11Mb/s uplink), TD-SCDMA and EDGE are supported for legacy 2G/3G networks.

[www.skyworksin.com/Product/3065](http://www.skyworksin.com/Product/3065)

## Custom MMIC launches 17–27GHz GaAs LNA

Monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA has added to its growing line of standard GaAs amplifier products by launching the CMD163, a 17-27GHz low-noise amplifier (LNA) in die form.

Gain is +24dB, noise figure is less than 1.3dB, and P1dB (output at 1dB compression point) is +19dBm

across the 17–27GHz bandwidth. Additionally, the CMD163 utilizes an all-positive bias scheme, eliminating the need for negative voltages and expensive sequencing circuitry. Bias conditions are  $V_{dd} = 4V$  @ 120mA and  $V_{gg} = 3V$ .

Custom MMIC says the CMD163 is suited to military & space applications as well as point-to-point and

point-to-multipoint communication systems where small die size and high linearity are needed. The LNA is an internally matched 50Ω design that needs no external components, apart from bypass capacitors.

The LNA is also available in packaged form as the CMD163C4, with similar performance.

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

## Sumitomo Electric ships samples of all-in-one RF modules for small-cell LTE base-stations

Tokyo-based Sumitomo Electric Industries Ltd has begun sample shipment of the TPM-2606P2 all-in-one RF module for long-term evolution (LTE) base-stations for small cells.

With the spread of smartphones and other mobile devices, mobile phone system traffic is increasing dramatically. As a promising means for coping with this, operators have begun to use small cells that can specifically cover small areas where traffic is concentrated. Sumitomo Electric has therefore developed an all-in-one RF module that can be used in an LTE base-station for a small cell, based on technology that has already been commercialized for remote radio heads (RRHs).

The TPM-2606P2 is intended for use in 2.6GHz-band TD-LTE base-stations, which are expected to become widely used in future. All RF circuits (transmitter and receiver amplifiers



**SEI's new TPM-2606P2 RF module.**

and transmitter/receiver switch) essential for constructing a base-station are incorporated in a compact module measuring 17mm x 143mm x 103mm. Use of the new RF module should slash LTE base-station development and production times and simplify the introduction of small cells, says the firm.

In the transmitter, a Doherty-type amplifier is used, boosting the power utilization efficiency to 40%

or more (when outputting a 6W LTE signals).

In the receiver, a balanced amplifier is used, achieving low-noise, high input power tolerance together with low reflectance properties of the antenna port.

In the transceiver/receiver switch, combination with a circulator lowers the switching loss and application power, enhancing the switching reliability.

The new RF module also includes a circuit that can compensate for distortion in the transmitter amplifier, eliminating the need to also install an expensive distortion-compensation circuit outside the module.

In addition to this RF module, Sumitomo Electric is also developing RF modules for the 2.6GHz FDD-LTE and 3.5GHz TD-LTE bands.

Different transmission powers and frequencies are available on request.

<http://global-sei.com>

## Pasternack expands lines of off-the-shelf connectorized RF amplifiers

Pasternack Enterprises Inc of Irvine, CA, USA (which makes passive and active RF, microwave and millimeter-wave products) says that it has significantly expanded its portfolio of connectorized RF amplifiers including high-power amplifiers, high-rel amplifiers, broadband amplifiers, limiting amplifiers, power amplifiers, low-noise amplifiers (LNAs), log amplifiers and gain blocks.

The firm's broad lines of coaxial amplifiers are employed across the entire spectrum of commercial and military applications including use in radar, electronic warfare (EW), satcom, wireless communications, test lab instrumentation, commercial air-traffic control, antenna ranges, telecom infrastructure, and sensors. Some of the specialty amplifiers offered in the release, such as

limiting amplifiers, are used to protect sensitive microwave receivers by 'limiting' excessive input power that could potentially create unwanted distortion or even damage the receiver, while the hi-rel amplifiers are either hermetically sealed or constructed to withstand specific military environmental specifications. Pasternack now offers 107 unique amplifier modules, all with varying performance characteristics, giving users a wide selection of components to meet application requirements.

The new RF amplifiers offer extremely broadband performance depending on application requirements. Frequencies across the amplifier line range from DC to 40GHz, while gain levels range from 10dB to 60dB, P1dB range from 2mW to 100W, and noise figures are as low as 0.8dB and gain

variation is down to  $\pm 0.3$ dB.

The majority of the RF amplifiers offered by Pasternack are equipped with SMA female connectors, while certain high-frequency models come with 2.92mm female connectors. All of the cables and components that mate with these amplifiers are also available separately from Pasternack.

"Our fast-growing lines of active components continue to be a focal point of our product development strategy, which aims to provide our customers the most comprehensive selection of in-stock and off-the-shelf RF components in the industry," says director of product management Michael Rachlin.

All of the new connectorized RF amplifiers are in-stock and available to ship.

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



# Murata completes acquisition of Peregrine

In mid-December, Murata Electronics North America Inc, a subsidiary of Murata Manufacturing Co Ltd of Kyoto, Japan completed its acquisition (announced in August) of all outstanding shares of Peregrine Semiconductor Corp of San Diego, CA, USA not already owned by Murata for \$12.50 per share (a total transaction value of \$471m, or \$465m excluding Murata's existing holding).

Peregrine is a fabless provider of radio-frequency integrated circuits (RFICs) and RF front-end (RFFE) solutions based on the UltraCMOS technology platform, a patented form of silicon-on-insulator (SOI) that delivers the monolithic integration and performance to solve RF challenges (such as linearity) for mobile and analog applications. Since 1988, Peregrine has shipped over 2 billion UltraCMOS units.

The firm will continue to market its integrated RF solutions under the

Peregrine brand, as a subsidiary of Murata Electronics North America Inc, for markets such as communications (mobile, wireless infrastructure, land mobile radio, broadband and wireless), industrial (test & measurement, automotive, Internet of Things) and aerospace.

With the close of the acquisition, Murata gains Peregrine's intellectual property portfolio, which contains over 180 filed and pending patents.

**We are eager to leverage Peregrine's innovations, such as the industry's first reconfigurable RF front-end system UltraCMOS Global 1, and expand the Murata business into all the markets that Peregrine currently offers RF solutions**

"With this acquisition, we combine Murata's world-leading mobile RF module capabilities with Peregrine's best-in-class RF products," says Norio Nakajima, executive VP & director of Murata's Communication business unit. "We are eager to leverage Peregrine's innovations, such as the industry's first reconfigurable RF front-end system UltraCMOS Global 1, and expand the Murata business into all the markets that Peregrine currently offers RF solutions," he adds.

"After years of a successful partnership, we are happy to become a part of the Murata team," says Peregrine's president & CEO Jim Cable PhD. "Murata already has deep relationships and trust built in all of our target markets," he adds. "In the case of mobile, it will speed the industry's transition to an integrated, all-CMOS RF front-end."

## Peregrine hosts ceremony after close of acquisition by Murata

Murata Electronics North America Inc (a subsidiary of Murata Manufacturing Co Ltd of Kyoto, Japan) and Peregrine Semiconductor Corp of San Diego, CA, USA have celebrated the closing of Murata's acquisition of Peregrine.

To commemorate its next chapter as Peregrine Semiconductor (a Murata company), Peregrine hosted an opening ceremony attended by Norio Nakajima (executive VP, director of Murata's Communication business unit), David Kirk (CEO of Murata North Americas) and Jim Cable (Peregrine's president & CEO), who gave presentations highlighting the synergies between the two firms.

"We welcome Peregrine Semiconductor employees to Murata — a global family that is comprised of over 100 companies in 23 nations," said Nakajima.

"From our first meeting with Murata in 2003 to our recent acquisition, our two companies



**Norio Nakajima (left, director of Murata's Communication business unit) and Jim Cable (right, Peregrine's president & CEO) celebrate Murata's acquisition of Peregrine.**

have enjoyed a successful business relationship," comments Cable.

"As Peregrine embarks on our next chapter as a Murata company, we anticipate new opportunities and

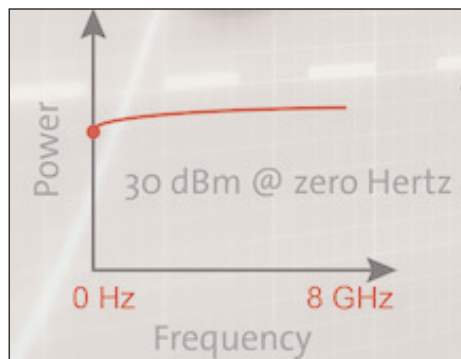
growth," he adds. "We will benefit from deeper resources and a wider reach than ever before."

[www.psemi.com](http://www.psemi.com)  
[www.murata.com](http://www.murata.com)

## Peregrine ships first true DC RF integrated switch

Peregrine Semiconductor Corp of San Diego, CA, USA — a fabless provider of RFICs based on silicon-on-insulator (SOI)— has announced the availability of the UltraCMOS PE42020, which is claimed to be the first RF integrated switch to operate at true DC, zero Hz. The True DC RF switch features high power handling and is claimed to maintain excellent RF performance and linearity from DC through 8000MHz. A reliable alternative to problematic mechanical relays and micro-electro-mechanical systems (MEMS), the PE42020 is suitable for test and measurement (T&M) and automated test equipment (ATE) applications.

"For the first time, an integrated RF switch can operate at DC and truly cover the signal over the entire frequency spectrum," claims senior manager of marketing Kinana Hussain. "Until now, only mechanical relays and MEMS switches allowed DC pass through, and these products are plagued with reliability issues and lack of integration."



**PE42020's performance to 8GHz.**

Peregrine says that UltraCMOS technology enables intelligent integration (a capability of integrating RF, digital and analog functions onto a monolithic die). The True DC RF switch integrates high-performance RF switching, analog DC tracking and digital control logic and impedance control on a single chip. By integrating these functions, RF engineers gain benefits including greater system capability, improved performance, a smaller form factor, reliability and flexibility, claims the firm.

The PE42020 is a single-pole

double-throw (SPDT) True DC RF switch that supports a wide frequency range from DC (zero Hz) through 8000MHz. A configurable 50Ω absorptive or open reflective switch, it exhibits high power handling of 30dBm at 0Hz and 36dBm at 8GHz. It also has a high linearity of 62dBm IIP3, total harmonic distortion (THD) of -84dBc and a high power 0.1dB compression point of 38dBm at 8GHz. The PE42020 features a fast switching time of 10?s, a fast settling time of 35?s and a high ESD rating of 1000V HBM on all pins. In addition, it can handle DC or AC peak voltages in the range of +10V to -10V on the RF ports and DC current through RF active ports of up to 80mA (a first for this type of switch, it is claimed).

Samples, evaluation kits and volume-production parts are available now. Offered in a RoHS-compliant, 20-lead 4mm x 4mm QFN package, the PE42020 is \$14 each for 1000-quantity orders and \$11.35 each for 5000-quantity orders.

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

## Hittite products now available through Analog Devices' global distribution network

Analog Devices Inc (ADI) of Norwood, MA, USA (which provides ICs for analog and digital signal processing applications) says that its complete RF and microwave portfolio, including Hittite Microwave Products, is now available for sale through its distribution network.

ADI's distribution network includes a variety of channel partners worldwide, consisting of: global distribution partners; a range of regional partners throughout the Americas, Europe, China and Asia Pacific; and catalog distributors. Over the past few months, these partners have been fully trained and received RF and microwave accreditation to ADI standards on the Hittite Microwave products.

With the integration of Hittite

Microwave products into ADI's supply chain management, customer service, sales operations and worldwide distribution network, customers can now work through these channel partners for virtually all their high-frequency needs with the logistics, technical training and customer service assurances of an ADI authorized distributor, says ADI.

"We have been working diligently over the past few months to integrate Hittite Microwave products into ADI's world-class supply chain management infrastructure, which includes a distribution network that has a long history of providing customers with high levels of service and support," says Thomas Wessel, senior VP, worldwide sales & marketing. "More customers are designing

RF and microwave capabilities into their applications, and from the most advanced aerospace and defense systems to emerging automotive, healthcare and instrumentation applications, we are investing in the technology, tools, and support they need to drive innovation and fast time to market."

ADI's products cover the entire signal chain, from antenna to bits and back, across the entire frequency spectrum up to 110GHz. Complemented by its data converters, the firm's RF, microwave and millimeter-wave portfolio includes more than 2000 products, from functional blocks to highly integrated solutions, development platforms and modules.

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



# Raytheon UK to develop 650V/60A SiC MOSFET for auto manufacturers

## Electric, hybrid-electric and plug-in hybrid electric vehicles targeted

Raytheon UK's semiconductor business unit in Glenrothes, Scotland, UK has been selected by a "leading automotive manufacturer" to develop a silicon carbide (SiC)-based metal-oxide-semiconductor field-effect transistor (MOSFET) for use in electric, hybrid-electric and plug-in hybrid electric vehicles.

Raytheon says that, with expertise in the development of components and modules intended for safety-critical applications within harsh environments, it will employ its SiC fabrication experience to develop a MOSFET, rated at 650V/60A, which can be mass-produced cost-effectively and be fully compliant with the stringent ISO/TS 16949 automotive quality standard.

"The use of silicon carbide overcomes many of the problems restricting the use of traditional

silicon semiconductor devices, for certain applications, within electric vehicles and their hybrid derivatives," says John Kennedy, head of Raytheon UK's Integrated Power Solutions. "The benefits of SiC include higher-temperature operation, low switching losses and low parasitics — making possible the production of reliable, high-power devices in small and lightweight packages that do not have the same cooling requirements as silicon-based components."

Raytheon is Europe's only SiC production foundry, backed by a team of engineers experienced in the fabrication of MOSFETs, Schottky barrier diodes (SBDs) and bipolar devices. Also, while known for its technical capabilities in the defence and aerospace sectors, Raytheon has been active in the automotive

industry for several years, supplying semiconductor devices for use in vehicle suspension system sensors, as employed by several well-known car manufacturers, since 1995.

"We were selected for this particular MOSFET project because of our silicon carbide expertise, proven processes and project management skills, all of which combine to produce a reduced risk engagement for the customer," says Kennedy. "Moreover, we are an established fabricator of semiconductor devices for automotive power and control applications, using either silicon carbide or traditional silicon," he adds.

The development of the 650V/60A MOSFET is a multi-phase project, and early results are promising, the firm says.

[www.raytheon.co.uk/semiconductors](http://www.raytheon.co.uk/semiconductors)

# ST launches automotive-qualified 650V SiC diodes, targeting on-board battery chargers & Little Box Challenge

STMicroelectronics of Geneva, Switzerland has unveiled new automotive-qualified silicon carbide (SiC) diodes for on-board battery chargers (OBCs) in electric vehicles such as plug-in hybrids (PHEVs) that demand high power-handling capability within a confined space.

The diodes allow designers to build smaller power modules, which suits automotive applications and makes also them a strong choice for tackling the Little Box Challenge presented by Google and IEEE. ST is a device-manufacturer partner of this new \$1m competition to design kiloWatt-scale inverters that are more than ten times smaller than existing inverters for various applications, particularly solar micro-generators.

The diodes prevent high-current spikes from damaging the device.

Until now, designers have typically over-specified the diodes for safety, whereas ST says that its new technology provides 2.5 times greater over-current capability versus rated current. This enables the use of lower-current diodes, which are smaller and more economical, without compromising reliability or losing efficiency, it is claimed.

ST's new SiC diodes are automotive qualified, and feature increased reverse-breakdown voltage of 650V, satisfying the voltage de-rating factors applied by designers and car manufacturers to ensure suitable safety margin between normal and short-term peak voltages across the semiconductors used in on-board battery chargers.

The devices build on the known energy-efficiency advantages of SiC as a wide-bandgap (WBG) technol-

ogy that enables lower switching losses and higher voltage ratings in relation to device size, compared to conventional silicon devices. The new 650V devices include the 10A STPSC10H065DY in a TO-220AC power package and the 12A STPSC12H065DY, also in a TO-220AC power package. In addition, the STPSC20H065CTY in a TO-220AB package and the STPSC20H065CWY in a TO-247 package are 2x10A dual-diode devices that help to maximize space utilization and reduce the weight of the on-board battery charger.

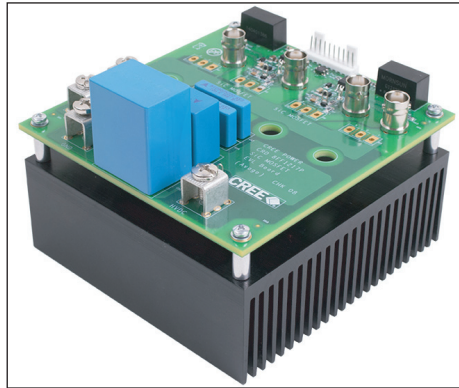
All the new devices are in production and ready for immediate delivery, priced from \$4.15 each in 100-unit quantities of the STPSC10H065DY.

[www.st.com/sic-auto-diodes](http://www.st.com/sic-auto-diodes)

## Cree releases new 1200V MOSFET design kit

Cree Inc of Durham, NC, USA, which makes silicon carbide (SiC) power devices, has introduced a new MOSFET design kit that includes all of the components needed to evaluate Cree MOSFET and Schottky diode performance in a configurable half-bridge circuit.

Claimed to be quick and easy to assemble and use, the new design kit enables comparative testing between silicon insulated-gate bipolar transistors (IGBTs) and Cree MOSFETs, and provides an effective layout example for properly driving Cree MOSFETs with minimal ringing, the firm adds. Designed to assist engineers new to the higher switching speeds of SiC devices, the kit provides access to critical test points, enabling simple and accurate measurements, including  $V_{GS}$ ,  $V_{DS}$  and  $I_{DS}$ . The kit is also con-



**Cree's new MOSFET design kit.**

figurable to several different power conversion topologies in buck or boost configurations. Half-bridge and three-phase configurations can be constructed and analyzed by respectively combining two and three kits.

The design kit includes two 80mOhm, 1200V MOSFETs; two

1200V, 20A Schottky diodes in standard TO-247 packages; a half-bridge-configured design board equipped with isolated gate drives; power supplies; and all of the other components necessary to assemble the power stage. The kit also includes a gate driver schematic and layout reference for a TO-247-packaged Cree MOSFET, as well as a comprehensive user manual and sourcing sheet with basic block diagrams and specifications.

See <http://response.cree.com/choosewisely> to view a video demonstration of the advantages of designing with Cree MOSFETs, download the user manual and SiC reference designs, or purchase the Cree MOSFET design kit through one of Cree's distributors.

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

## Cree's 1200V, 25mΩ SiC MOSFET named one of EDN's Hot 100 Products of 2014

Cree Inc of Durham, NC, USA, which manufactures silicon carbide (SiC) and gallium nitride (GaN) wafers and devices, says that EDN (Electronic Design News) has named its C2M0025120D 1200V, 25mΩ SiC MOSFET as one of the 'Hot 100 Products of 2014'. Chosen by EDN's editors and readers, the 2014 EDN Hot 100 recognizes the electronics industry's most significant products of the year based on innovation, significance, usefulness, and popularity.

Launched in May, the C2M0025120D is claimed to be the first commercially available 1200V SiC MOSFET with an  $R_{DS(ON)}$  of 25mΩ in an industry-standard TO-247-3 package. Based on Cree's proven C2M SiC MOSFET technology, the new device has a pulsed current rating ( $I_{DS \text{ Pulse}}$ ) of 250A (making it suitable for pulsed power applications) and a positive temperature coefficient (allowing it to be paralleled to achieve even



**Cree SiC MOSFET in TO2473 package.**

higher power levels). Additionally, the higher switching frequency can help design engineers to reduce the size, weight, cost and complexity of power systems in applications including: PV inverters, high-voltage DC/DC converters, induction heating systems, electric vehicle (EV) charging systems, and med-

ical CT (computer tomography) applications.

The new MOSFET has already been proven to provide a 5x reduction in switching losses, higher power density, and improved thermal characteristics in medical CT applications, claims Cree, as well as to reduce installation costs for rooftop photovoltaic (PV) inverters by enabling a compact and highly efficient 50kW grid-tied solar inverter with a power-to-weight ratio of 1kW/kg.

"One of the most important objectives for power engineers is to build smaller, cooler and lower cost power conversion solutions," says Edgar Ayerbe, Cree Power Marketing. "Our new 1200V, 25mΩ SiC MOSFET can help achieve these goals," he adds.

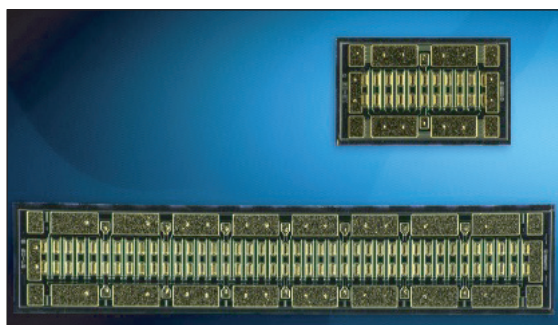
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## Cree extends 50V discrete GaN HEMT die family to 320W

Cree Inc of Durham, NC, USA, which makes silicon carbide (SiC) and gallium nitride (GaN) wafers and devices, recently extended its family of 50V discrete GaN high-electron-mobility transistor (HEMT) die with the release of three new components: a 20W (CGHV60020D), 6GHz die; a 75W, 6GHz die (CGHV60075D); and a 320W, 4GHz die (CGHV40320D). Currently consisting of five die, the first two of which were released in September 2014, the family still represents the only 50V bare GaN HEMT die publicly available on the market, Cree says.

The family of 0.4 $\mu$ m, 50V GaN HEMT die offer hybrid amplifier designers higher gain, efficiency and power density while operating over a broad, instantaneous frequency bandwidth, providing an effective alternative to silicon (Si) and gallium arsenide (GaAs) technologies, Cree claims. Additional performance benefits include



higher breakdown voltage, thermal conductivity, and saturated electron drift velocity.

Designed for operation up to 6GHz, the 20W, 40W, 75W and 170W 50V GaN HEMT die exhibit 17dB typical small-signal gain and 60% typical power-added efficiency at 6GHz and 18dB typical small-signal gain and 65% typical power-added efficiency at 4GHz. The new 20W and 75W die are suitable for two-way private radios, broadband amplifiers, cellular infrastructure, test instrumentation, and Class A linear amplifiers. The 40W die can also be used in cellular infrastruc-

ture, and the 170W die can be used in tactical and satellite communications and broadband, industrial, scientific and medical amplifiers.

Designed for operation up to 4GHz, the 320W 50V GaN HEMT die exhibits 19dB typical small-signal gain and 65% typical power-added effi-

ciency at 4GHz. Like the 170W die, it too is suited to use in tactical and satellite communications and broadband, industrial, scientific and medical amplifiers.

Additionally, all 50V die in the current product family are suitable for use in Class AB linear amplifiers.

Cree's 50V GaN HEMT die are supplied in Gel-Pak Vacuum Release trays, a non-tacky membrane that immobilizes the components to ensure damage-free transportation and storage. The order multiple is 10 GaN HEMT die per Gel-Pak tray.

[www.cree.com/RF/Products/General-Purpose-Broadband-50-V](http://www.cree.com/RF/Products/General-Purpose-Broadband-50-V)

## Freescale launches 100W, 2.5GHz GaN-on-SiC RF power transistor suiting multi-octave wideband RF amplifiers for military and industrial applications

RF power transistors supplier Freescale Semiconductor of Austin, TX, USA has introduced what are claimed to be the industry's highest thermal and wideband performance GaN device with a 125W continuous wave (CW) gallium nitride on silicon carbide (GaN-on-SiC) transistor. By offering extended operational bandwidth, the new MMRF5014H is suitable for wideband amplifiers in scientific equipment, as well as in military communications products for the US defense sector including jammers, radar implementations and electronic warfare (EW) systems.

Performance of 100W CW power over 200–2500MHz bandwidth with greater than 12dB gain across the band is demonstrated in the avail-

able reference circuit. The transistor is designed to deliver 58% efficiency and to achieve power levels in excess of 125W in narrower-band applications. In addition, the device delivers thermal performance of less than 1° C/W and offers VSWR (voltage standing wave ratio) ruggedness of 20:1.

The new GaN product is the first of several that Freescale plans to introduce to help push existing performance while addressing the stringent size, weight and power (SWaP) requirements of the defense industry and other markets.

"Radios today typically require multiple RF amplifiers to cover a wide frequency spectrum, but with the new MMRF5014H, only one is needed," says Paul Hart, senior VP

& general manager of Freescale's RF group. "Size, weight and power upgrades are critical for our customers, and by replacing several amplifiers with a single device, the MMRF5014H helps across all three of these factors."

The MMRF5014H is included in Freescale's Product Longevity Program, as are other RF products in the military portfolio.

Also, Freescale's military RF products are supported by a dedicated team of experts to assist users through all stages of device selection, implementation and system development.

Samples and evaluation circuits for the MMRF5014H transistor are available now.

[www.freescale.com/RFmilitary](http://www.freescale.com/RFmilitary)



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# Advantech Wireless launches 2.5kW Tropo C-band modular gallium nitride solid-state power amplifier with built-in redundancy

Advantech Wireless of Montreal, Canada (which manufactures satellite, RF equipment and microwave systems) has launched a 2.5kW TROPO C-band modular gallium nitride (GaN)-based solid-state power amplifier (SSPA).

The new Model ARMA-CL2500A operates over the low C-band Tropo frequency of 4.4–5.0GHz, and it is fully modular with built-in redundancy for all critical RF and power

supply modules.

The new modular SSPAs are designed to be used as a direct replacement for older-generation Klystrons or traveling-wave tube (TWT) amplifiers. The most vital feature is its modular design, which allows plug in modules, as power supplies and RF modules can be hot-swapped without any interruption of service or noticeable reduction in power.

"Our TROPO line of GaN SSPAs is a perfect match for the new generation of high-data-rate, long-haul, cost-efficient communication links using tropo scattering technologies," says Cristi Damian, VP business development. "This proves to be a viable solution when satellite links are either cost prohibitive or simply not available."

[www.advantechwireless.com/products/c-band-2-5-kw-tropo-modular-solid-state-power-amplifier](http://www.advantechwireless.com/products/c-band-2-5-kw-tropo-modular-solid-state-power-amplifier)

# Raytheon's GaN MMIC technology validated for use in space-bound equipment

Raytheon Company of Waltham, MA, USA says that satellites may soon carry its gallium nitride (GaN) technology into Earth orbit, as it has validated its GaN monolithic microwave integrated circuit (MMIC) technology for use in space-bound equipment.

Fabricated at its foundry in Andover, MA, the firm's GaN MMICs demonstrated the radiation hardness required for space through Single Event Burn-out (SEB) and Total Ionizing Dose (TID) testing. The results showed that the devices are not susceptible to catastrophic failure caused by heavy ions. Further testing showed no loss of performance at exposure levels up to 1Mrad, significantly more than is needed for typical space applications.



GaN-based components are more than five times more powerful than semiconductors currently used in radars and other types of sensors, resulting in lighter, more capable electronics.

"Raytheon's GaN technology is mature, robust, and already integrated into a number of defense systems for land, sea and air," says Paul Ferraro, VP of Advanced Technologies Programs at Raytheon's Integrated Defense Systems business in Tewksbury, MA.

"Now that our GaN is validated for space, Raytheon customers can use this game-changing technology in a wide variety of space-based applications."

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

# Custom MMIC launches 4–8GHz GaN LNA

Custom MMIC of Westford, MA, USA, a developer of performance-driven monolithic microwave integrated circuits (MMICs), has added to its growing line of standard gallium nitride (GaN) products with the CMD219, a 4–9GHz low-noise amplifier (LNA) in die form.

Gain is 23dB, P1dB (output power

at 1dB compression point) is +18dBm, and the noise figure is 1.1dB across its operating bandwidth. Typical bias conditions are  $V_{dd} = 10V$  @ 100mA and  $V_{gg} = -2.3V$ , although  $V_{dd}$  can vary from 5V to 28V. The CMD219 can also survive input power levels of up to 5W without a front-end limiter.

All ports are matched to 50Ω and do not need any off-chip components apart from the bias networks which require external bypass capacitors.

Suitable applications include point-to-point and point-to-multi-point radios, military and space, and test instrumentation.

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

# Infineon closes acquisition of International Rectifier

## Infineon pays \$40 per share in \$3bn deal for power management firm

Infineon Technologies AG of Munich, Germany has completed its acquisition (announced on 20 August) of International Rectifier Corp (IR) of El Segundo, CA, USA, following the approval of all necessary regulatory authorities and International Rectifier's shareholders. The deal is worth about \$3bn (with Infineon paying \$40 per outstanding share of International Rectifier).

Infineon (which has about 29,800 staff) had sales of Euro 4.3bn in fiscal 2014 (to end-September). Power management technology provider International Rectifier (which has 4200 staff) reported revenue of \$1.1bn for fiscal 2014 (ending 29 June).

"The acquisition of International Rectifier is an important step for Infineon to foster our position as a global market leader in power semiconductors," says Infineon's CEO Dr Reinhard Ploss. "The acquisition helps us to accelerate our strategic approach 'from product thinking to system understanding'."

The combined company is led by



**Infineon's board (L - R): Arunjai Mittal, Reinhard Ploss, and Dominik Asam.**

Reinhard Ploss (CEO), Arunjai Mittal (a member of the Management Board Regions, Sales, Marketing, Strategy Development and M&A) and Dominik Asam (chief financial officer). President of International Rectifier and of Infineon North America is Robert LeFort.

Infineon reckons that International Rectifier is highly complementary to its business, with the combined firm gaining greater scope in product portfolio and regions, especially with small and medium enterprise customers in the USA and Asia.

Also, tapping additional systems know-how in power management, the firm reckons that the merger expands its expertise in power semiconductors, combining knowledge in compound semiconductors, specifically gallium nitride (GaN). Furthermore, the acquisition should drive greater economies of scale in production, strengthening the competitiveness of the combined company.

The acquisition is expected to be accretive to pro-forma earnings per share (EPS) already in Infineon's current fiscal year. Synergies should further drive significant accretion, building on International Rectifier's existing operational restructuring. At the latest within fiscal 2017, International Rectifier's margin contribution is expected to be at least in line with Infineon's target of 15% segment result margin over the cycle.

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

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

# EPC launches 450V E-mode GaN power transistor for high-frequency applications

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has launched the EPC2027, a 450V normally off (enhancement-mode) power transistor capable of rise times of 4ns for applications requiring high-frequency switching in order to achieve higher efficiency and power density. Applications enhanced by high-voltage, higher switching speeds include ultra-high-frequency DC-DC converters, medical diagnostic equipment, solar power inverters, and LED lighting.

The EPC2027 has a voltage rating of 450V and maximum on-resistance ( $R_{DS(on)}$ ) of 400mΩ with a 4A output. It is available in passivated die form with solder bars for efficient heat dissipation and ease of assembly. The size is 1.95mm x 1.95mm for increased power density.

"As off-line adapters and inverters increasingly push toward smaller size, less weight, and higher power density, the demand for corresponding higher voltage and faster switching speeds is increasing," says co-founder & CEO Alex Lidow. "The 450 V EPC2027 allows power designers to increase the switching frequency of their off-line power conversion systems for increased

efficiency and smaller footprint."

The EPC9044 development board, featuring the EPC2027, is in a half bridge configuration with on board gate driver, gate drive supply and bypass capacitors. The 2" x 1.5" board has been laid out for optimal switching performance and contains all critical components for easy evaluation of the EPC2027 eGaN FET.

The EPC2027 eGaN FETs are priced at \$5.81 each in 1000-unit quantities. EPC9044 development boards are priced at \$137.75 each.

<http://epc-co.com/epc/Products/eGaNfets/EPC2027>

<http://epc-co.com/epc/Products/DemoBoards/EPC9044>



# GaN Systems appoints Daito Electron as Japan and Korea distributor, targeting automotive and industrial markets

GaN Systems Inc of Ottawa, Ontario, Canada, a fabless producer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, has signed an agreement for Japanese company Daito Electron (Daitron) to distribute its GaN E-HEMT power switches and integrated GaN-on-Si power system products in Japan and Korea.

The firm's gallium nitride power transistors are based on its proprietary Island Technology and offer what are claimed to be significant advantages over traditional silicon MOSFETs and IGBTs for smaller, lighter and more efficient power electronics. Daitron was selected for its strong presence in the Japanese automotive and industrial sectors, both key markets as GaN devices usher in a new era in power electronics and are poised for widespread adoption, it is reckoned.

The partnership is seen as being synergistic. Many of GaN Systems' prospective customers in the region already have a relationship with Daitron, which has technical knowledge in applications particularly suited to GaN high-power switching devices, including inverters, UPS

(uninterruptible power supplies), hybrid electric vehicles/electric vehicles (HEV/EV) and high-voltage DC-DC conversion. GaN Systems claims to be the first company to have developed and brought to the global market a comprehensive product range of devices with current ratings from 8A to 250A — its Island Technology die design, plus its GaNPX packaging and Drive Assist technology means that its GaN transistors offer a 40-fold improvement in switching and conduction per-

**Many of GaN Systems' prospective customers in the region already have a relationship with Daitron, which has technical knowledge in applications particularly suited to GaN high-power switching devices, including inverters, UPS, hybrid electric vehicles/electric vehicles (HEV/EV) and high-voltage DC-DC conversion**

formance over traditional silicon MOSFETs and IGBTs, it is reckoned.

"Gallium nitride devices are recognised to be the future of power electronics, and as our product portfolio is now ready for commercialization, it is both key and timely for us to continue to build our worldwide distribution network," says president Girvan Patterson.

"Key industries across our region from automotive through industrial and consumer can now access this new core technology and achieve competitive edge by designing GaN Systems' power transistors into their next-generation products," comments Daitron corporate officer Shinji Ikutani Sr.

"Daitron is a professional, high-productivity distribution partner with a strong teamwork ethos and a clear understanding of Japanese and Western business cultures," comments Charles Bailey, GaN Systems' senior director of Technical Marketing, Asia. "We are working in close cooperation and, based on customer feedback, we forecast significant revenue growth in the region in the consumer, industrial and transportation segments."

[www.daitron.co.jp/en](http://www.daitron.co.jp/en)

## GaN Systems releases Application Note on designing with enhancement-mode power switching transistors

GaN Systems has released a new Application Note for design engineers that sets out thermal design guidelines and PCB layout choices for its enhancement-mode (E-mode) power switching transistors, which are supplied in its proprietary GaNPX device packaging.

These are reckoned to be the first discrete power devices to be embedded in a laminate construction — conventional packaging techniques (such as clips, wire bonds and moulding compounds) have been replaced with galvanic processes. These design features of GaNPX

packaging significantly increase the current-carrying capability of GaN Systems' devices and reduce the critical loop inductance, making driving the high-speed, high-current switches far easier, it is claimed.

The Application Note gives a thermal analysis of GaN Systems' GS66508P E-mode GaN, 34A, 41mΩ power switch, together with diagrams showing its thermal dissipation paths and further explanation of how heat is dissipated by the GaNPX packaging design.

The second part of the Application Note looks at the key PCB

factors to consider when designing with GaNPX devices: the heat-spreading copper pad and the design of the thermal vias.

The third section contains a thermal analysis of three different PCB layouts with different copper layers and thicknesses and looks at details of the optimum layout.

Lastly, there is a section looking at how designers can utilize the maximum power capability of GaN Systems' devices and estimate the maximum power capacity of the system they are designing.

[www.gansystems.com/downloads.php](http://www.gansystems.com/downloads.php)

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# EpiGaN wins Global Cleantech Cluster Association Award

At the 5th annual CleanTech Investing Seminar in Lausanne, Switzerland on 3 December, III-nitride epitaxial material supplier EpiGaN nv of Hasselt, near Antwerp, Belgium was announced as winner of the 2014 Global Cleantech Cluster Association (GCCA) Later Stage Award in the category 'Energy efficiency'.

Incorporated in 2010, EpiGaN was founded by chief executive officer Dr Marianne Germain, chief technology officer Dr Joff Derluyn and chief operating officer Dr Stefan Degroote as a spin-off of nanoelectronics research center Imec of Leuven, Belgium. The founders jointly developed gallium nitride-on-silicon (GaN-on-Si) technology on 4" and 6" wafers at Imec, part of which has been licensed to EpiGaN. In mid-2012, EpiGaN closed its first capital round of €4m, to allow it to start volume production of GaN-on-Si epitaxial material. Investors include Capricorn Cleantech Fund, Robert Bosch Venture Capital, and LRM.

GaN-on-Si is seen as a promising emerging technology and enabler for clean energy generation and efficient power conversion. EpiGaN's GaN-on-Si wafer development and production facility targets global device makers for power supplies, consumer electronic goods, hybrid electric vehicles, smart grid sys-



tems, solar inverters and AC drives or RF base stations.

EpiGaN is a member company of the Flanders Cleantech Association (FCA) based in Antwerp, which provides the Flemish cleantech industry with a platform to gain exposure to worldwide business partners, networks and investor communities. FCA nominated EpiGaN to the list of contenders for the 2014 GCCCA award.

The Global Cleantech (GCCA) Later Stage Award vets the most promising later-stage high-tech companies across the globe and provides the best of them with the public exposure to succeed and grow further. Contenders for the award compete in ten categories, including solar, wind, water, and energy efficiency.

"Cleantech is thriving throughout the world as a major driver of economic growth," said Christian Haeuselmann, co-founder & chairman of the GCCA, and cluster man-

ager for swisscleantech, which hosted this year's awards. "The 2014 winners are proving that companies innovating in the new green economy are both investable and thriving."

The global top 10 contenders were selected from the 10,000 companies represented by the GCCA's nearly 52 member clusters. Over 100 companies were nominated in their regions, narrowed to the top-30 semi-finalists using the Keystone Method, a business and venture development tool developed by GCCA head judge Dr Peter Adriaens, CEO of the Keystone Compact Group.

EpiGaN was selected by the GCCA from 10 finalists for the award. "It is highly satisfying and motivating to be recognized for the hard work that our very committed research and manufacturing team has put in since the founding of the company in 2010," commented Germain. "Right now, we are expanding our production capacity for the volume manufacture of large-diameter wafers that support high-power and high-breakdown voltages," she added. "EpiGaN's continuous growth trajectory is propelled by the rising demand from our worldwide industrial customers."

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

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

## MIT's Jesús del Alamo named an APS Fellow

Jesús del Alamo, the Donner Professor of Science in the Massachusetts Institute of Technology (MIT) Department of Electrical Engineering and Computer Science, has been named a fellow of the American Physical Society (APS) for "fundamental contributions to the development of III-V compound semiconductor electronics." The APS fellowship signifies recognition by professional peers for exceptional contributions to physics.

After graduating with a PhD from Stanford University in 1985, del

Alamo joined NTT Research Laboratories in Atsugi, Japan. Over a two-and-a-half-year period there, he started investigating heterojunction transistors based on III-Vs such as GaAs, InGaAs, and InP.

In 1988, del Alamo joined MIT and, since then, has remained actively engaged in the investigation of advanced electronics based on these materials, initially for high-frequency communications and radar applications and more recently for future ultra-scaled logic complementary metal-oxide semiconductors (CMOS).

For his contributions to this field, del Alamo received the 2012 Intel Outstanding Researcher Award in Emerging Research Devices and the Semiconductor Research Corporation 2012 Technical Excellence Award. He also received the 2012 Electron Devices Society Education Award, given annually by the Institute of Electrical and Electronics Engineers (IEEE) and in recognition of innovations in electrical engineering education. Del Alamo is also a fellow of the IEEE.

[www-mtl.mit.edu/~alamo](http://www-mtl.mit.edu/~alamo)

# Keysight unveils silicon RFIC interoperability in ADS

Keysight Technologies Inc has introduced the ADS 2015 release of its Advanced Design System software. Featuring silicon RFIC interoperability with Cadence's Virtuoso, GoldenGate-in-ADS and capabilities intended to increase design efficiency, ADS 2015 aims to change how silicon RFIC and multi-technology module design is performed.

The convergence of gallium arsenide and silicon design, coupled with the move to higher frequencies in silicon designs and their tighter integration into packages or modules, have increased the need for an interoperable co-design flow, says Keysight. Silicon RFIC interoperability in ADS enables users to edit and simulate schematic designs created in either Virtuoso or ADS. Users also can open a Virtuoso IC layout cell view in ADS, instantiate the cell within a package or module, and then run an electromagnetic simulation on the complete design to validate its overall system performance.

ADS-Virtuoso interoperability works on top of a baseline Virtuoso process development kit (PDK). ADS 2015 is backed by broad PDK support from a number of RF silicon foundries. Interoperability-enabled PDKs are available from TSMC, GLOBALFOUNDRIES, TowerJazz, IBM and IHP, and have been validated by customers as part of Keysight's alpha program.

## GoldenGate-in-ADS

To provide users with a complete silicon RFIC design platform, the GoldenGate simulation, analysis and verification solution for large-scale RFIC circuit design is now integrated into ADS 2015.

"With the availability of GoldenGate-in-ADS and foundry interoperable PDKs, we have given our customers access to our leading silicon RFIC circuit simulation technology directly within the ADS Platform," says Joe Civello, ADS product manager for Keysight EEs of EDA (which supplies elec-

tronic design automation software for microwave, RF, high-frequency, high-speed digital, RF system, electronic system level, circuit, 3D electromagnetic, physical design and device-modeling applications). "Additionally, the new RFIC cockpit in ADS allows users to use the same Virtuoso simulation testbench and settings directly in ADS."

## Additional capabilities

Additional new capabilities and enhancements available in ADS 2015 include:

- new DDR Bus Simulator;
- new RFIC cockpit that expands the ADS schematic control block use model to a complete RFIC simulation cockpit;
- 2–16x faster FEM simulation performance improvements;
- layout and layout verification improvements; and
- numerous usability, performance and productivity improvements.

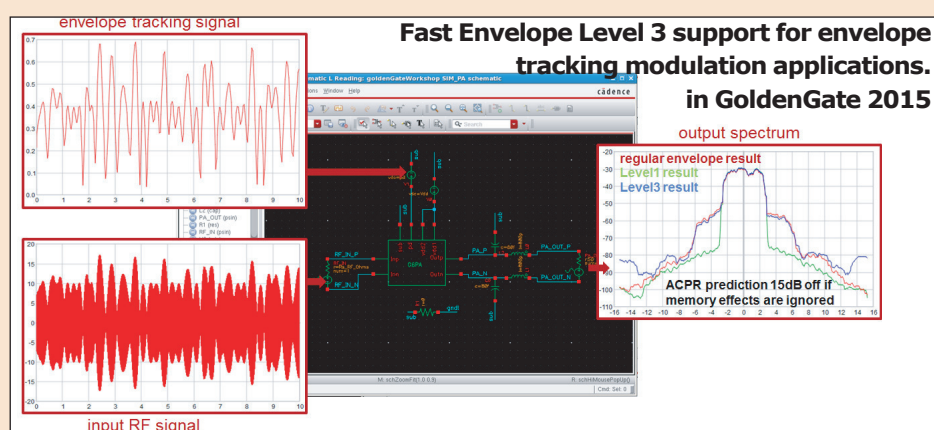
[www.keysight.com/find/eesof-ads2015.01](http://www.keysight.com/find/eesof-ads2015.01)

## GoldenGate 2015 software release brings RFIC simulation to ADS

Keysight has announced the latest release of its GoldenGate simulation, analysis and verification software for large-scale RFIC circuit design. Keysight EEs of EDA says that GoldenGate 2015.01 offers new and enhanced capabilities designed to improve productivity and efficiency for silicon RFIC designers.

Enhancements to GoldenGate's simulator include Fast Envelope 3 support for envelope tracking modulation applications and support for multiple, non-harmonically related frequency dividers. Support for the frequency dividers enables designers to more accurately predict receiver crosstalk (common in LTE-A Carrier Aggregation simulation). GoldenGate 2015.01 also features a new multi-threaded sparse matrix solver that enables 10–50% faster transient simulations, it is reckoned.

Other improvements include:



- faster crystal oscillator startup performance (five times faster out of the box, with a settled solution time of less than 20 periods versus greater than 10,000 for a full transient analysis);
- X-parameter simulation and data file improvements;
- improved Envelope Transient Noise analysis efficiency (up to 1.5 times speed-up in envelope tracking noise);
- improved multi-threading and

refactoring for harmonic balance noise (up to 2.5 times speed-up);

- improved oscillator analysis performance (up to four times faster on the ring oscillator plus a divide-by-32 circuit).

Also, GoldenGate 2015 enables access to the GoldenGate simulator from ADS using GoldenGate-in-ADS and the RFIC cockpit in ADS 2015.

[www.keysight.com/find/eesof-goldengate2015.01](http://www.keysight.com/find/eesof-goldengate2015.01)



# Veeco acquires SSEC for \$150m

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has acquired privately held Solid State Equipment Holdings LLC (SSEC) of Horsham, PA, for \$150m in cash (subject to customary adjustments).

SSEC designs and manufactures single-wafer wet etch, clean and surface preparation equipment targeting high-growth segments in advanced packaging, micro-electro-mechanical systems (MEMS) and compound semiconductors.

"SSEC is a highly successful process equipment company that is a great strategic fit with Veeco," says Veeco's chairman & CEO John R. Peeler.

"Their complementary and differentiated 'soak and spray' technology delivers single-wafer control with the low cost of batch processing," he adds. "SSEC extends our compound semiconductor and MEMS footprint, and represents a stepping stone to the high-growth advanced packaging market."

Demand for higher performance, increased functionality, smaller form factor and lower power consumption in mobile devices, consumer electronics and high-performance computing is accelerating the adoption of advanced packaging technology, says Veeco. Key drivers for this inflection are applications in 3D stacked memory, 3D system-on-chip (SoC) and MEMS. Rising shipments in smartphones and wearable electronics with more sophisticated sensing functions are further driving growth in the MEMS market. Veeco estimates that its served available markets for advanced packaging, compound semiconductors and MEMS are all growing at double-digit compound annual growth rates (CAGRs).

"Veeco is a dynamic market leader in compound semiconductor equipment for LED, power electronics, and wireless devices," comments SSEC's CEO Herman Itzkowitz. "Combining resources will enable us

to accelerate growth and to pursue market opportunities in advanced packaging and MEMS. In addition, we have significant untapped potential in Asia and Europe, where Veeco's impressive sales and service network will provide connectivity to key customers," he adds.

Veeco is forecasting that SSEC's revenues will be \$65m in 2015. Given SSEC's financial performance over the last few years, Veeco expects it to provide earnings before interest, taxes, depreciation, amortization, equity compensation, and other non-recurring items (adjusted EBITDA) of greater than 20% of sales in 2015. The transaction is expected to be significantly accretive to Veeco in fiscal 2015 on a non-GAAP earnings per share basis. "This is a synergistic transaction that will be immediately accretive and that we expect will drive growth and profitability," says Peeler.

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

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

## Veeco receives largest purchase order since 2009

Veeco says that Xiamen-based Sanan Optoelectronics Co Ltd, China's largest LED maker, has ordered 50 TurboDisc EPIK700 gallium nitride metal-organic chemical vapor deposition reactors for high-volume LED production. The order is the equivalent of 25 EPIK700 MOCVD 'C2' (cluster) systems. In keeping with its bookings policy, Veeco will record the purchase order as deposits are received.

"Sanan chose the EPIK700 due to its industry-leading cost-of-ownership model and excellent footprint efficiency," comments Sanan's vice chairman & CEO Zhiqiang Lin. "Our beta testing of EPIK700 proved its production-worthiness, and we are confident in its capabilities and value to our Xiamen business expansion plans," he adds. "Veeco has been a great partner for Sanan as we have solidified our

position as the top LED manufacturer in China and increased our business outside of China as well."

Based on Veeco's TurboDisc technology, the EPIK700 MOCVD system enables users to achieve a cost-per-wafer saving of up to 20% compared with previous-generation MOCVD systems through improved wafer uniformity, reduced operating expenses and increased productivity, says the firm.

"This large order from Sanan, the largest single purchase order Veeco has received since 2009, speaks volumes about the EPIK700's production readiness and the recovery in the MOCVD market," says chairman & CEO John Peeler.

Available in one-and two-reactor configurations and said to be LED industry's highest-productivity MOCVD system, the EPIK700 features technologies including the

new IsoFlange center injection flow and TruHeat wafer coil technologies, providing homogeneous laminar flow and uniform temperature profile across the entire wafer carrier. These innovations produce wavelength uniformity to drive higher yields in a tighter bin. Veeco says that the EPIK700 offers a 2.5x throughput advantage over other systems due to its large reactor size. Designed for mass production, it accommodates 31x4", 12x6" and 6x8" wafer carrier sizes. Users can easily transfer processes from existing TurboDisc systems to the new EPIK700 MOCVD platform for quick-start production of LEDs. Because of the flexible EPIK700 MOCVD platform, more upgrades, added benefits and future enhancements should continue to differentiate the system.

[www.sanan-e.com/en](http://www.sanan-e.com/en)

# Riber receives research MBE system order from Japanese electronics equipment maker

At the end of December Riber won an order for an MBE412 system (for delivery in 2015) from a major Japanese electronics manufacturer, to be used for developing optoelectronic devices "at the forefront of current technologies".

The firm says that this latest sale to a "leading name from the Japanese electronics industry" confirms the

market's adoption of the MBE 412, which is claimed to be one of the industry's best performing thin-film deposition systems. The MBE 412 has been chosen for its high level of flexibility, reliability and capacity to produce extremely complex and very high-quality semiconductor materials on large-format substrates on a reproducible basis.

"This latest order confirms the commercial success of our new ranges of systems," says chairman Frédéric Goutard. Riber's selection by an internationally renowned industrial firm following a stringent selection process highlights MBE's relevance as a research technology, while further strengthening Riber's leading position in Japan."

## Riber elects new chairman of Supervisory Board

Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has announced the resignation (effective on 20 December) of its Supervisory Board chairman Jacques Noels has in order to devote himself to new professional projects abroad.

In a meeting on 27 November, the Supervisory Board thanked Noels for his leadership and management of Riber's governance since 2010.

Gildas Sorin, 61, was unanimously elected as Supervisory Board chairman and will take up his new position on 20 December.

From 2003 to 2014, Sorin was CEO of Germany-based Novalad AG,

a firm specialized in organic light-emitting diode (OLED) technologies and bought out by Samsung in 2013. He has been a member of Riber's Supervisory Board since 2013. Sorin is also a Foreign Trade Advisor for France and a Knight of the National Order of Merit (Chevalier de l'Ordre National du Mérite).

## Riber wins orders for Compact 21 MBE systems

Riber says that it has received two orders for research machines.

The firm has delivered a Compact 21 research system to the MBE Center of Excellence of Russia's Saint Petersburg Academy of Sciences. Led by professor Zhores Alferov (Academician and Nobel Prize Laureate in Physics) and a long-standing partner of the firm, the centre is working to promote MBE technology and train users from various laboratories around the world. The system will be used by the center to further strengthen its development capabilities for designing semiconductor oxides.

Riber says that it has also sold a Compact 21 system to an unnamed laboratory in Asia. The order is scheduled for delivery during first-quarter 2015.

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

[www.cardiff.ac.uk/jobs](http://www.cardiff.ac.uk/jobs)



### Senior Operations Manager

As a member of the elite Russell Group, Cardiff University is recognised as one of the 24 leading UK research intensive universities. The Cardiff University Research Institute in Compound Semiconductors (ICS) will be a unique facility in Europe. It will be based in a new building, and equipped with state-of-the-art fabrication and characterisation facilities including a full 8" fabrication line as well as a related small area process capability. It will enable novel research and development and strong engagement with industry, and will position Cardiff to become the UK and European leader in translational research in this area as part of a newly formed independent organisation, the Compound Semiconductor Foundation.

As part of the initial phase of this major investment programme, we are seeking to appoint a Senior Operations Manager to be at the heart of this activity, from conception of cleanroom design and process development, through to operations and line management of the capability, reporting directly to the foundation director and servicing both academic and industrial customers. It is essential that you have a wide knowledge of semiconductor processing techniques, preferably at an industrial scale, and you will have had extensive line management responsibility in a cleanroom environment. Your skillset should include demonstrable evidence of your ability to run, maintain and cost a large scale facility of this nature for a breadth of customers.

The post is full time and open-ended.

**Salary: £47,328 - £54,841 per annum (Grade 8)**

Informal enquiries can be made to Dr Phil Buckle at [BucklePD@cardiff.ac.uk](mailto:BucklePD@cardiff.ac.uk)

To work for an employer that values and promotes equality of opportunity, please visit [www.cardiff.ac.uk/jobs](http://www.cardiff.ac.uk/jobs) and search for vacancy number 2940BR.

**Closing date: Saturday, 28 February 2015.**

Please be aware that Cardiff University reserves the right to close this vacancy early should sufficient applications be received.



# Aixtron continues reorganization in 2015

## Cost-cutting includes 60 job lay-offs out of 800 staff

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that, in continuing with its reorganization (as part of its 5-Point Program to return to sustainable profitability, launched in May 2013), it plans to cut about 60 of approximately 800 jobs across the group.

Additionally, the firm will further adapt its organizational structure in line with customer and market requirements. Alongside cost-cutting measures, Aixtron is pursuing new market opportunities, for example with its new AIX R6 metal-organic chemical vapor deposition

(MOCVD) product generation for high-volume manufacturing of gallium nitride (GaN) high-brightness light-emitting diodes (HB-LEDs), and in promising future business fields such as power and logic semiconductors as well as organic light-emitting diodes (OLEDs) — areas that are strengthened through the reorganization, reckons the firm.

"Customer needs are evolving. The focus is increasingly on process and user-oriented solutions while we are executing our productivity programs in all areas of the company," says chief operating officer

Dr Bernd Schulte. Aixtron adds that, by reducing staffing, it is accounting for these factors and for its previously defined objective of reducing operating costs.

"Letting employees go is never easy. As management, however, we have a responsibility for the whole company," comments CEO Martin Goetzeler. "Having reduced the executive board to two members in the mid of last year already should be viewed in the same light."

Aixtron will present its financial results for 2014 and provide an outlook for the 2015 on 24 February.

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

# k-Space partners with SUNY Poly to advance III-N research via in-situ thin-film characterization

## kSA ICE tool reduces MOCVD process development time

k-Space Associates Inc of Dexter, MI, USA (which supplies instrumentation and software for surface science and thin-film technology applications) and the Colleges of Nanoscale Science and Engineering (CNSE) at SUNY Polytechnic Institute (New York's high-tech educational ecosystem) have announced a joint collaborative effort in III-nitride materials research.

The focus is to improve III-nitride material quality, growth parameters, and device performance through use of the kSA Integrated Control for Epitaxy tool (kSA ICE) to provide in-situ measurements of film stress, temperature and growth rate. Real-time stress evolution information during growth should result in the substantial reduction of the number of experiments that are currently required to obtain high-quality III-nitride device structures with multiple heterojunctions, says the firm.

In the collaborative R&D effort, k-Space has donated a complete ICE tool to SUNY Poly associate professor of nanoengineering

Dr Shadi Shahedipour-Sandvik's research group and provided engineering assistance to fully integrate and test the ICE in-situ metrology tool on the college's D-180 MOCVD reactor.

"We supplied an ICE tool to the SUNY CNSE group with the goal of providing them with high-quality real-time metrology required for their research while receiving feedback on the performance of our tool," says k-Space's CEO Darryl Barlett. "Shadi and her group have far exceeded our expectations. For example, their research in III-nitride buffer development for integration on to both sapphire and silicon substrates makes excellent use of our in-situ film stress technology kSA MOS. We are anxious to share these results when published," he adds.

"Furthering [New York State] Governor Andrew Cuomo's high-tech public-private partnership blueprint for growth and educational opportunities, we are thrilled to work with k-Space, utilizing their top-of-the-line k-Space Integrated Control for Epitaxy tool to enable

in-situ measurement of growth stress evolution," says Shahedipour-Sandvik. "This system, one of only a few available to academics, is an enabling tool that is sure to speed up the process of discovery and development," she adds. "Our current NSF-, Army- and NASA-funded projects are focused on the development of novel single-photon UV detectors, high-power transistors, and fundamental research into non-polar III-nitride growth," Shahedipour-Sandvik continues, commenting that her group will be able to gain real-time growth-related information using the kSA ICE system. "The use of this tool ensures greater process control and it furthers the advanced research that is ongoing at the world-class \$20bn Albany NanoTech Complex," she notes, adding that they will provide k-Space with detailed data that can advance their knowledge of materials behavior, as the tool enables a platform for educating undergraduate and graduate students.

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

[www.k-space.com/products/ksa-ice](http://www.k-space.com/products/ksa-ice)

## Epiluvac receives order for SiC reactor from European research center

Epiluvac AB of Lund, Sweden has received an order for its EPI-1000X silicon carbide (SiC) reactor from a "leading European research center". Installation and commissioning of the system will be completed during first-quarter 2015.

As a management buyout from Aixtron, Epiluvac designs and manufactures chemical vapor deposition (CVD) reactors consisting of SiC reactors (both bulk and epitaxy), GaN-pi reactors, and graphene/SiC reactors as well as other types of reactor, such as CVD for SiGeSnC and hydride vapor phase epitaxy (HVPE).

The new EPI-1000X system comprises a reactor design in which both gas flows and heating system are unique, it is claimed, with the potential to drastically reduce problems with particles and parasitic depositions. While still a hot-wall reactor, the new reactor type has been simulated in detail, so the



**Epiluvac's EPI-1000X silicon carbide reactor.**

temperature profile inside the reactor can be adjusted during the

growth cycle with a number of different heat zones in order to optimize uniformity.

The reactor is a single-wafer reactor but, due to the very high growth rate and efficient use of the precursors as well as minimal parasitic deposition, it is also applicable for production.

"This is another step in our ambition to supply the best possible CVD tools to R&D labs around the world," says managing director Bo Hammarlund.

"There is nothing like this anywhere in the world today," he claims.

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

## SAMCO announces MOCVD demonstration availability for VPE's GaN-550 system for power device manufacturing

SAMCO Inc of Kyoto, Japan, a supplier of plasma etch, chemical vapour deposition (CVD) and surface treatment systems to compound semiconductors device makers, has announced metal-organic chemical vapour deposition (MOCVD) demonstration capability on the new GaN-550 gallium nitride on silicon (GaN-on-Si) system from Valence Process Equipment Inc (VPE) of Branchburg, NJ, USA.

Following an agreement last April, SAMCO sells and distributes VPE's GaN-550, which is equipped with a 550mm-diameter carrier for mass production of GaN power devices. The demo system will be available for customer demonstrations at SAMCO's R&D facility in early 2015.

SAMCO is expanding its range of dry etching and plasma-enhanced

chemical vapor deposition (PECVD) systems for wide-bandgap semiconductor applications such as LEDs, laser diodes and RF devices, with the firm reckoning that the processing of nitride semiconductors is one of its strengths.

VPE is a start-up company, providing MOCVD systems for GaN-based LEDs. Its GaN-500 MOCVD system employs a unique reaction chamber design and can reduce gas consumption by up to 40 % compared with other MOCVD systems, it is claimed.

SAMCO installed a new GaN-550 MOCVD system, which was developed from the GaN-500 (launched in 2011) and is claimed to have low process gas consumption, high-speed gas switching, and superior temperature control. The specially

designed gas injector requires less frequent reactor cleaning, increasing system availability and uptime. The GaN-550 system can grow more than 5µm/hour of GaN at the uniformity of less than 1%. While the carrier diameter of the GaN-500 is 500mm, the carrier diameter of the GaN-550 is 550mm for higher throughput, accommodating up to 72x2", 20x4", 7x6" or 4x8" wafers per batch.

SAMCO aims to utilize the GaN-550 demo system to accelerate sales of VPE's MOCVD systems for GaN-power device manufacturing, adding that it now provides a turn-key 'one-stop solution' for nitride semiconductors, comprising MOCVD, PECVD, dry etch and dry cleaning processes.

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



## USC professor Dapkus wins John Tyndall Award for contributions to MOCVD and quantum well lasers

The Optical Society (OSA) and the IEEE Photonics Society have named Paul Daniel Dapkus, the W. M. Keck Distinguished Professor of Engineering at the University of Southern California (USC), as recipient of the 2015 John Tyndall Award for his "pioneering and sustained contributions to the development of metal-organic chemical vapor deposition [MOCVD] and high-performance quantum well semiconductor lasers".

Dapkus is currently a faculty member of the Ming Hsieh Department of Electrical Engineering, the Mork Family Department of Chemical Engineering and Materials Science, and the Department of Physics and Astronomy at USC. He also is the director of a Department of Energy (DoE) Energy Frontier Research Center. Prior to USC, Dapkus received his B.S., M.S. and Ph.D. degrees in Physics at the University of Illinois at Urbana-Champaign (UIUC). He later led the group at Rockwell International that demonstrated the device utility of MOCVD, and he served as a member of the technical staff at Bell Laboratories. "Dan Dapkus developed an efficient



**University of Southern California professor Paul Daniel Dapkus.**

deposition process that produced high-quality film, which is now widely used," says OSA's CEO Liz Rogan.

Dapkus' current research involves the study of semiconductor nanostructures for application to energy devices, photonic materials and devices, semiconductor microresonators and optoelectronic integration.

Previously, Dapkus was named an IEEE LEOS Distinguished Lecturer,

awarded an IEEE LEOS Engineering Achievement Award (1995), given the IEEE David Sarnoff Technical Field Award in electronics (2001), named winner of The Optical Society's Nick Holonyak Jr Award (2005), given the Heinrich Welker Award of ISCS (2009) and awarded the USC Associates Award for Creativity in Research (2009). He is currently a member of the National Academy of Engineering (2004) and a Fellow of IEEE, OSA, APS and AAAS.

Co-sponsored by OSA and the IEEE Photonics Society, the John Tyndall Award is named for the 19th century scientist who was the first to demonstrate the phenomenon of internal reflection. First presented in 1987, the award recognizes an individual who has made pioneering, highly significant, or continuing technical or leadership contributions to fiber-optics technology. Corning Inc endows the award, which is a glass sculpture that represents the concept of total internal reflection.

[www.osa.org/en-us/awards\\_and\\_grants/awards/award\\_description/johntyndall](http://www.osa.org/en-us/awards_and_grants/awards/award_description/johntyndall)

## IQE's Wafer Technology substrate division wins new \$3.25m order

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has received a new purchase order for indium phosphide (InP) materials worth \$3.25m from a leading global substrate manufacturer.

Produced by IQE's Wafer Technology division based in Milton Keynes, UK, InP crystal is the source material for the manufacture of InP wafers used in the production of high-performance photonic components for a wide range of applications in infrared sensing, communications and gesture recognition applications.

Demand for photonics products is continuing to grow as new and

emerging technologies increasingly rely on the properties of light for a growing range of technological applications, notes IQE. InP is the material of choice due to its advantageous photonic properties, particularly in the short-wavelength infrared (IR) range commonly used for sensing applications as well as high-speed optical communications, high-definition night vision and gesture recognition, adds the firm.

"We are very pleased to receive this order from a long-term customer of our InP products and the scale of this commitment reflects our status in the semiconductor

industry for the supply of a diverse range of semiconductor materials in addition to substrates and epi-wafers," says IQE's CEO & president Dr Drew Nelson.

"We continue to see growing demand for products with optoelectronic properties, and it is apt that IQE's first significant order of the year should relate to photonics products," Nelson adds. "This order underlines the importance of the photonic industry sector over the coming years and decades, as recognised by 2015 being designated the International Year of Light."

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

## Evatec acquires Oerlikon Advanced Technologies Segment Semiconductor & Nanotechnology businesses to supplement thin-film deposition portfolio

Evatec Ltd of Flums, Switzerland, which makes thin-film deposition and etch processing equipment for semiconductor, MEMS, optical and optoelectronic applications, has agreed to acquire the Advanced Technologies Segment of Oerlikon of Pfäffikon, Switzerland to expand its existing thin-film deposition systems business. The transaction is expected to close during first-quarter 2015.

Specifically, Evatec says that it is continuing its rapid growth by acquiring the Semiconductor & Nanotechnology businesses of Oerlikon's Advanced Technologies Segment. The firm reckons that both capital equipment businesses are well positioned in their respective markets by delivering complete thin-film production solutions and services worldwide.

Oerlikon notes that, for its Advanced Technologies Segment, applications for the semiconductor market include advanced packaging, power devices, read/write heads for hard disks, LEDs and micro-electro-mechanical systems (MEMS). Solutions in the nanotechnology sector comprise photovoltaics, touch panels and thermoelectrics. Oerlikon adds that in 2013 the Advanced Technologies Segment generated sales of CHF114m and EBIT of CHF4m, and that the 200 staff will be taken on by Evatec. The divestment of the segment marks Oerlikon's 11th strategic transaction since 2010, allowing it to further allocate resources and management attention to areas of strategic importance: "another step toward repositioning and balancing our portfolio, and focusing on our

core growth businesses," says Oerlikon's CEO Dr Brice Koch.

Evatec says the acquisition brings an enhanced technology portfolio and opens up possibilities to exploit synergies in technology and process expertise for access to new markets and overall business growth.

As home of the Balzers BAK evaporator, the MSP and the Radiance sputter tools, Evatec delivers thin-film deposition solutions for optoelectronic, semiconductor and optical applications. After continuous growth since its foundation in 2004, it has already delivered more than 300 systems and supports an installed base of 1500 systems with global services and retrofits.

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

[www.oerlikon.com/en/company/company-overview/segments-advanced-technologies](http://www.oerlikon.com/en/company/company-overview/segments-advanced-technologies)

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# CRAIC launches flexible UV-visible-NIR microspectrophotometer

CRAIC Technologies of San Dimas, CA, USA has launched the FLEX UV-visible-NIR microspectrophotometer concept, which is designed to be flexible in configuration, capabilities and pricing.

Tailored for cost-effective spectroscopic analysis of many types of microscopic samples, FLEX operates from the deep ultraviolet to the near infrared. Depending on its configuration, samples can be analyzed by absorbance, reflectance, luminescence and fluorescence with high speed and accuracy. FLEX can also be used to image microscopic samples directly with DirecVu optics and with high-resolution color digital imaging. Also, a number of packages can be added to allow measurement of ranging from the refractive index of microscopic samples to thin-film thickness.



**CRAIC's FLEX UV-visible-NIR microspectrophotometer.**

Combined with CRAIC Technologies Traceable Standards, which are specifically designed for use with microspectrophotometers and calibrated using Standard Reference Materials from NIST, FLEX is built as a multi-functional tool for laboratories and manufacturing facilities.

FLEX integrates a sensitive spectrophotometer, high-resolution digital imaging, a UV-visible-NIR range microscope and easy-to-use software. It is designed to acquire spectra and images from microscopic samples by absorbance, reflectance, fluorescence and emission. With the high-resolution digital imaging, color photos of microscopic samples can be stored as their spectra are acquired. Additional features such as the ability to measure thin-film thickness or the refractive index can also be added.

[www.microspectra.com/products/flex](http://www.microspectra.com/products/flex)

## CRAIC adds UV-visible-NIR range polarization spectroscopy capabilities to microspectrophotometers

Microscope and microspectrometer manufacturer CRAIC Technologies of San Dimas, CA, USA has added UV-visible-NIR polarization spectroscopy capabilities to its microspectrophotometers.

The feature (claimed to be unique) is offered as a package that allows the measurement of polarization spectra in either transmission or reflectance modes. With the ability to measure polarization microspectra in the ultraviolet, visible and near-infrared regions, the package represents a new tool for both materials science and biological research.

"Now our customers are able to measure the polarization spectra of samples across the UV, visible and NIR spectral range," says president Dr Paul Martin. "Our engineers worked with our customers to create a flexible package that allows one to measure the



**Filter-UV-vis-NIR Polarization-1800x1200.jpg**

polarization spectra of micron-scale sample areas in both transmission and reflectance," he adds. "This allows for maximum versatility in experimental microspectroscopy."

CRAIC's polarization package consists of optics and hardware designed to be added to its microspectrophotometers. As such, it can be used to measure the polarization spectra in both transmission

and incident illumination modes. Uniquely, the optics are designed to operate in the spectral range from the ultraviolet through to the near-infrared regions.



## University of Alberta nanoFAB facility adds Oxford Instruments plasma etch systems

UK-based etch and deposition system maker Oxford Instruments says that Canada's University of Alberta nanoFAB open-access fabrication and characterization facility has purchased three plasma etch systems to provide upgraded capabilities to its installed base and to facilitate the growing demand for its purpose-built cleanroom.

The PlasmaPro 100 Estrelas, PlasmaPro 100 Cobra and PlasmaPro 80 PE/RIE dual-mode systems will soon be installed in the nanoFAB, offering users a wide range of process options.

The most recent addition to the PlasmaPro family of tools, the

PlasmaPro Estrelas100 deep silicon etch technology was developed with the R&D market in mind, offering maximum process flexibility. Nano and micro structures can be realised as the hardware has been designed with the ability to run Bosch and cryo etch technologies in the same chamber. The PlasmaPro 100 Cobra and PlasmaPro 80 PE/RIE systems have equally high specifications, are versatile and suitable for both R&D and production needs.

"Over 15 years of operation, the nanoFAB has proven to be a great learning, R&D and small-volume production environment," says nanoFAB's director Dr Eric Flaim.

"Our decision to purchase Oxford Instruments plasma systems was based on their flexibility, quality and ease of use, in addition to their extensive process offering and ability to scale from research to production," he adds.

"As an open-access facility we aim to offer our users the broadest range of processing opportunities possible," notes operations manager Keith Franklin. "The customer support we receive is excellent; from maintenance to user training, Oxford Instruments has demonstrated excellent and reliable service from its global support network."

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

### Plasma etch system for nanofabrication research at Vanderbilt

Vanderbilt University in Tennessee, USA is expanding its research capabilities with the addition of a PlasmaPro 100 Cobra plasma etch system from Oxford Instruments, to be installed in the Vanderbilt Institute of Nanoscale Science and Engineering (VINSE) cleanroom laboratory. Oxford Instruments says that its highly configurable PlasmaPro 100 Cobra system offers ICP dry etching supported by an extensive range of

processes, making it suitable for nanofabrication research.

"Until now we have needed to access other regional shared laboratories to undertake the type of processing that will now be facilitated at VINSE using the PlasmaPro 100," says professor Anthony Hmelo, associate director for operations at VINSE. "We look forward to working together with Oxford Instruments to take advantage of this highly versatile tool."

"Our broad range of plasma etch systems offers compact ICP and RIE tools through to multi-wafer and cluster tools," notes Dr David Haynes, sales & marketing director at Oxford Instruments Plasma Technology. "As well as providing systems for production, our systems are used globally for fundamental research and development, utilizing many new and advanced techniques," he adds.

[www.vanderbilt.edu/vinse](http://www.vanderbilt.edu/vinse)

## City University of New York orders etch & dep systems

Oxford Instruments Plasma Technology (OIPT) has won an order from The City University of New York (CUNY) for its PlasmaPro etch and deposition systems. The PlasmaPro 100 ICP and PECVD systems, and PlasmaPro 80 RIE tool will offer an extensive range of process capability for this new facility, which is being developed for the colleges of The City University of New York.

"The CUNY Advanced Science Research Center (ASRC) will bring the university to a landmark moment in its decade-long, multi-billion-dollar commitment to becoming a national

leader in visionary scientific research of vital, real-world consequence," says vice-chancellor for research Gillian Small. "The ASRC and its core facilities, including the nanofabrication facility, expand on the research capabilities of CUNY and New York City," she adds.

"Receiving a multiple system order from the USA's leading urban public university is great news for us, as we are committed to providing leading-edge flexible solutions with the very latest technology available to us," says OIPT's sales & marketing director David Haynes. "Our

PlasmaPro etch and deposition tools will be housed in the cleanroom that researchers throughout CUNY will use for nanofabrication," he adds.

"The systems will allow a very wide range of research to be undertaken."

CUNY's new Advanced Science Research Center houses 200,000ft<sup>2</sup> of facilities for increasingly inter-related disciplines of applied science, and it will focus CUNY initiatives in five of the most energized areas of global research: nanoscience, photonics, structural biology, neuroscience, and environmental sciences.

<http://asrc.cuny.edu>

# EVG establishes NILPhotonics Competence Center

## Nanoimprint lithography facilities to enable rapid development of photonics applications, feasibility studies & pilot production services

EV Group (EVG) of St Florian, Austria (a supplier of wafer bonding and lithography equipment for MEMS, nanotechnology and semiconductor applications) has established the NILPhotonics Competence Center, which is designed to assist customers in leveraging EVG's suite of nanoimprint lithography (NIL) solutions to enable new and enhanced products and applications in the field of photonics. These include light-emitting diodes (LEDs) and photovoltaic (PV) cells, where NIL-enabled photonic structures can improve light extraction and light capturing, respectively, as well as laser diodes, where photonic structures enable the tailoring of device characteristics to improve performance.

The NILPhotonics Competence Center includes dedicated, global process teams, pilot-line production facilities and services at its clean-rooms at EVG's headquarters in Austria as well as its subsidiaries in North America and Japan.

"Nanoimprint lithography is an enabling technology for the design and manufacture of all kinds of photonic structures, which can significantly shorten time to market and lower cost of production compared to conventional technologies,



**A 6-inch full-area nanoimprinted wafer processed by EVG NIL solutions.**

such as electron-beam writing and stepper systems for optical lithography," says Markus Wimplinger, corporate technology development and IP director. "For example, compared with conventional lithography, our full-wafer nanoimprinting technology can pattern true three-dimensional structures in the sub-micron- to nano-range as well as features as small as 20nm, which opens up a range of new photonic applications," he adds. "With our NILPhotonics Competence Center, we are not just providing our customers with the most advanced NIL systems; we're also working closely

with them during product development to help them determine how best to optimize their product designs and processes to take advantage of the resolution and cost-of-ownership benefits that NIL brings."

The new center builds on more than 15 years of NIL experience at EVG, which says it has the largest installed base of NIL systems worldwide. The firm's NIL equipment portfolio includes the recently introduced EVG7200 UV-NIL system, which supports EVG's next-generation SmartNIL large-area soft NIL process for high-volume manufacturing. The EVG7200 with SmartNIL provides what is claimed to be unmatched throughput and cost-of-ownership advantages over competing NIL approaches.

[www.evgroup.com/en/products/lithography/nanoimprint\\_systems](http://www.evgroup.com/en/products/lithography/nanoimprint_systems)

## Thermco Systems adds Taiwan sales manager

Thermco Systems, a division of Tetreon Technologies Ltd of Washington, West Sussex, UK has appointed Arthur Chen as sales manager for Taiwan.

As a designer and manufacturer of capital equipment for the semiconductor, MEMS, LED, photovoltaic and nanotechnology industries, Thermco Systems manufactures horizontal diffusion furnaces, and has sold more than 30,000 furnaces since the company was founded in 1962.



**Thermco Systems' new sales manager for Taiwan, Arthur Chen.**

Thermco says that Chen has many years of experience in the semiconductor industry from both a sales and a marketing perspective.

He has worked extensively with Taiwanese and Chinese chip

manufacturing companies. His previous roles have included technical sales manager, technical marketing manager, product manager and senior integration process engineer with leading companies such as Semitool, Dainippon Screen and Liteon Technology.

"His sales and product marketing experience will help drive our continued growth in the Taiwanese semiconductor market," believes Thermco's CEO Gerry Thurgood.

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

## Nanometrics launches Imperia PL system

At SEMICON Japan 2014 in Tokyo (3–5 December), Nanometrics Inc of Milpitas, CA, USA launched its latest photoluminescence (PL) system, Imperia, for compound semiconductor manufacturing.

The Imperia is a fully automated non-contact optical system offering comprehensive metrology and inspection for high-brightness light-emitting diode (HB-LED) manufacturing applications. The system enables rapid simultaneous PL measurement and defect inspection. Due to its software capabilities, the

Imperia provides critical defect analysis, classification and yield prediction for critical steps in substrate, epitaxial junction formation, and interconnect processes.

"As HB-LED technology continues to evolve with higher brightness, improved power efficiency and adoption into more demanding end-market requirements, manufacturers are increasingly requiring faster information turnaround to ensure optimal throughput and yield," notes David Doyle, VP of the Materials Characterization Group.

"The Imperia system can quickly determine LED performance long before wafers reach the expensive back-end-of-line processes, enabling HB-LED manufacturers to easily take corrective action for process tuning and contain process excursions early, resulting in lower production costs and shorter cycle times."

Imperia systems were delivered to leading manufacturers in third- and fourth-quarter 2014 and have quickly proven valuable for process control metrology and inspection in advanced devices, says Nanometrics.

## Nanometrics launches NanoSpec II film metrology system

At SEMICON Japan, Nanometrics launched the NanoSpec II stand-alone metrology system, the latest model in its NanoSpec line of film metrology systems.

With a streamlined design based on the proven NanoSpec tabletop architecture, the NanoSpec II is a fully automated non-contact optical metrology system for advanced material characterization on substrates up to 200mm. For films analysis, it enables process control

metrology and characterization on full-stack, multi-layer films and optical constant variation monitoring. New system hardware and software enhancements make the NanoSpec II the industry's most powerful and cost-effective film metrology system in its class, it is claimed, suitable for industrial and research environments.

"Our latest NanoSpec II standalone and tabletop systems continue to leverage our broad field applications

experience across all types of thin-film applications," says David Doyle, VP of the Materials Characterization Group. "The NanoSpec II enables production and R&D customers to tackle their most advanced thin-film metrology applications, all at a lower cost of ownership," he adds. For owners interested in upgrading their legacy tools, the NanoSpec II can convert and upgrade existing measurement recipes.

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

## Rubicon's interim president & CEO made permanent; VP – financial operations becomes CFO

Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, semiconductor and optical industries) says that its board of directors has appointed William Weissman to the permanent position of president & CEO. He has been interim CEO & president since 17 September and chief financial officer since 2007. Weissman has also been appointed a member of the board of directors.

"Bill Weissman has already demonstrated that he will be an effective leader for Rubicon and will be able to move the company forward with several critical initia-

tives," comments chairman of the board Don Aquilano. "Under his leadership Rubicon will be successful in winning customers for our patterned sapphire substrate (PSS) product line, improving manufacturing effectiveness, and attracting the right talent to the organization," he believes. "Bill has been instrumental in driving our vertical integration strategy for the past several years, and his industry knowledge and customer relationships are well established," Aquilano continues.

"Our leadership team is focused on the further development of our strong technology platform to continue to maintain our quality lead-

ership, reduce costs and introduce innovative new products," comments Weissman. "The sapphire industry has faced tough times over the past few years, but the LED, consumer electronics and optical markets provide excellent growth opportunities."

The board has appointed Ms Mardel A. Graffy as chief financial officer. After joining Rubicon in 2005, she rose to the position of VP – finance. In September, Graffy was appointed VP – financial operations. Prior to Rubicon, Graffy worked for FMC Technologies and KPMG.

[www.rubicon-es2.com](http://www.rubicon-es2.com)



# SEMI-GAS unveils next-generation controller for process instrumentation monitoring of high-purity gas source systems

SEMI-GAS Systems, a division of Applied Energy Systems Inc of Malvern, PA, USA and a manufacturer of high-purity gas source systems, distribution systems and control technology, has announced the latest addition to its GigaGuard controller line: the Compact Data Monitor (CDM) for continuous monitoring of process instrumentation for semi-automatic ultra-high-purity gas source systems.

With the CDM controller, SEMI-GAS provides new layers of features and configurability that give operators greater flexibility in monitoring the system conditions of semi-automatic gas cabinets and gas panels. "The controller's configuration can be tailored to our customers' unique specifications," says Applied Energy Systems' general manager Jim Murphy. "Analog and

digital inputs, alarm setpoints and even facility communications capabilities can be adjusted to meet the operator's desired safety and monitoring parameters."

As part of its next-generation functionality, the GigaGuard CDM controller:

- allows users to configure alarm setpoints in the field via an intuitive 3" LCD keypad display;
- provides eight configurable analog and digital sensor inputs for flexible monitoring control and versatility for interfacing with instrumentation such as gas analyzers, cylinder scales, pressure transducers etc;
- offers facility communications capabilities as an optional upgrade for interfacing with in-house alarm systems via Ethernet communications; and

- includes Class 1, Division 2 classification with adjustable Z-purge control as an optional upgrade.

SEMI-GAS says that multiple monitoring and alert functions, including a high-performance audible alarm and an LED display to indicate monitor status, ensure safe and continuous control of ultra-high-purity gas source systems used across a broad range of applications. "Our GigaGuard CDM controller was engineered to uphold the stringent and rigorous monitoring requirements faced by our customers in the semiconductor industry, but those same capabilities can be used to meet the similarly high demands of clients in research, manufacturing, aerospace, biotech, and other related markets," says Murphy.

<http://semi-gas.com/Products/>

# Soitec's Altatech division launches inspection system for substrates in LED and semiconductor applications

Altatech of Montbonnot, near Grenoble, France (a division of Soitec) has launched the Orion Lightspeed inspection system, which is capable of pinpointing the size and location of nano-scale defects inside compound semiconductor materials and transparent substrates. The new system helps to ensure the quality control of high-value engineered substrates used in several markets including high-brightness LEDs, power semiconductors and 3D ICs.

"Our technology solution provides customers with the most advanced, fully automated substrate inspection to predict and improve final wafer yields at an optimized cost," claims Altatech's general manager Jean-Luc Delcarri.

The Orion Lightspeed system improves the performance and cost

efficiency of identifying defects within III-V materials, transparent substrates and thin circuit layers on top of transparent substrates. Inspection is performed using Altatech's patented synchronous Doppler detection technology, which determines the exact size and position of defects by making direct physical measurements with resolution below 100nm. This methodology provides true defect sizing, claims the firm, whereas other types of inspection equipment on the market make indirect measurements using diffracted light to calculate approximate defect sizes.

The system can handle substrates up to 300mm in diameter. Throughput is more than 85 wafers per hour for 200mm substrates and more than 80 wafers per hour for 300mm substrates, contributing to

the system's high productivity and cost efficiency.

Beta systems have already been installed at customers' facilities. Shipments of production units are scheduled to begin in April.

At the SEMICON Japan trade show in Tokyo (3–5 December), Altatech showcased the new system as well as its full line of metrology and inspection products. These include the Orion series for inspecting LEDs on patterned and unpatterned substrates; the Eclipse series for front-side, back-side and edge inspection of bare substrates, epitaxial layers, silicon-on-insulator (SOI) wafers and glass substrates; and the Comet series for quality inspection of wafers mounted on film-frame or Taiko rings before and after dicing.

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

# ALLOS Semiconductors offers AZZURRO patents and technology transfer and licencing

## New firm targets LED and power semiconductor device makers growing GaN-on-Si wafers themselves

ALLOS Semiconductors GmbH of Dresden, Germany, which was founded in June, has acquired (via auction) the exclusive ownership of all technology, know-how and intellectual property of the former AZZURRO Semiconductors AG, which made gallium nitride (GaN) epitaxial wafers based on large-area silicon substrates.

Specializing in GaN-on-silicon technology and markets, ALLOS provides engineering and consulting services worldwide, and offers advice on patent landscape, market and technology strategy as well as customized developments and technology demonstrations. Also, its GaN-on-Si technology is made available to customers through technology transfers and licencing.

ALLOS says that the driving force behind its foundation was the growing demand for technology to grow GaN-on-Si substrates. An increasing number of LED and power semiconductor companies aim to master the technology to grow 150mm and 200mm GaN-on-Si wafers themselves in order to supply cost-effective high-quality GaN devices processed in standard silicon fabs, adds the firm.

There are tremendous technical challenges to making GaN-on-Si happen, comments ALLOS. For customers the opportunity is to reduce not only cost and time-to-market but also the development risk by basing their effort on proven GaN-on-Si platform and know-how, says the firm.

ALLOS says that it acquired exclusive ownership of AZZURRO's technology, know-how and intellectual property in order to strengthen its service offering with what it describes as pioneering technology that was continuously refined towards production readiness over the last decade.

ALLOS is hence now also making the proven AZZURRO technology platform available via technology transfer, licencing and customized development work, complementing ALLOS' existing service offering advice on business and technology strategies and supporting setting up GaN-on-Si operations (all the way from establishing an epitaxial wafer fab to market entry).

[www.allos-semiconductors.com](http://www.allos-semiconductors.com)

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# UK's EPSRC grants £20m to functional materials projects

## £2.65m for Bath, Bristol, Sheffield and Strathclyde universities to create nano-engineered nitride materials and device manufacturing hub

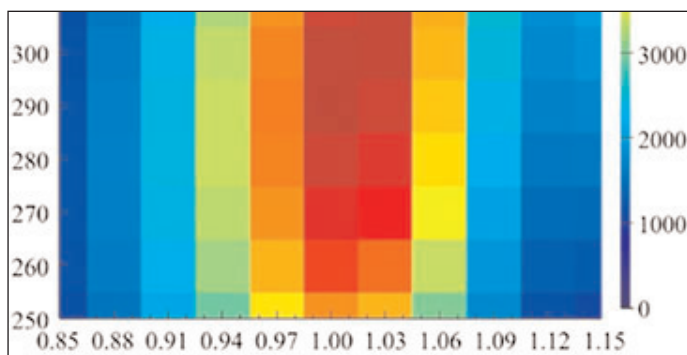
Following its Manufacturing Advanced Functional Materials (MAFuMa) call issued in February, the UK's Engineering and Physical Sciences Research Council (EPSRC) has awarded £20m to 10 new research projects that aim to advance the UK's manufacturing capability, develop new functional materials, and accelerate the translation of the science of functional materials through to application. Combined with contributions from the 17 universities involved and their industry partners, the total value of the projects is £32.1m.

The projects include:

- developing thin-film materials and novel manufacturing methods for wearable technology;
- improving the mass production of carbon nanotube materials;
- advanced manufacturing of nanoparticles for healthcare applications;
- revolutionizing the manufacture and use of specialized glass (chalcogenides);
- exploiting the potential of flexible perovskite photovoltaics to reduce costs and improve performance of solar cell technology;
- developing the materials needed for the new class of photonic integrated circuits for use in communications, sensors, imaging and lighting;
- developing advanced fabrication processes for gallium nitride and related materials, for the UK's emerging manufacturing industries.

For the latter, Bath University (as lead organization), along with the Universities of Bristol, Sheffield and Strathclyde plus industrial partners, have been given a £2.65m five-year grant for the project 'Manufacturing of nano-engineered III-nitride semiconductors.

The grant will fund equipment and researchers to develop advanced manufacturing techniques for nano-engineered semiconductors, particularly the III-nitrides, with



the aim of developing the UK into a future hub for advanced semiconductor material manufacturing. The industrial partners include Plessey, Seren Photonics, Lumerical Solutions, CNRS-CRHEA, NuNano, CIP Technologies, Tyndall National Institute, LayTec UK Ltd, Compound Semiconductor Tech Global Ltd, NMI, and EV Group.

Of the £2.65m, Bristol in particular has been awarded £450,000 to develop manufacturing techniques for nano-engineered semiconductors, particularly gallium nitride (GaN). The research will be led by Martin Cryan, professor of Applied Electromagnetics and Photonics in the Department of Electrical and Electronic Engineering and Dr Andrei Sarua in the School of Physics.

GaN underpins emerging solid-state lighting and power electronics technologies, and the impact of such materials was recognized by the award of the 2014 Nobel Prize for Physics to professors Isamu Akasaki, Hiroshi Amano and Shuji Nakamura for their development of GaN-based blue LEDs.

Creating three-dimensional structures at the nanoscale provides a route to improving the quality of these materials and in turn the performance of devices. Ultimately this can increase the energy efficiency in these and other emerging applications, such as water purification, where ultraviolet (UV) LEDs are used to prevent viruses reproducing.

"We hope to propel the UK forward to become much more competitive

in the manufacture of advanced semiconductor materials," says professor Gary Hawley, Dean of Bath University's Faculty of Engineering & Design.

"This grant will enable us to develop

the nanostructuring processes on a manufacturing scale along with reproducible device designs and measurement techniques to unlock the potential of these properties in a range of materials and innovative nano-devices," says project lead Dr Philip Shields of Bath University's Department of Electronic & Electrical Engineering.

"This grant will enable nanoscale manufacturing, such as nanoimprint lithography, currently being pursued within universities, to be scaled up to 4" and 6" wafers in partnership with leading UK companies such as Plessey Semiconductors," says Cryan.

The funding should also enable the design and scale-up of a new generation of medical diagnostic sensors based on nanophotonics, exploiting the unique optical and piezoelectric properties of III-nitride materials.

Cryan's group will work with numerical modeling firm Lumerical Solutions Inc of Vancouver, BC, Canada — which provides photonic and optoelectronic TCAD device simulation and photonic integrated circuit (PIC) design products — to use design centering techniques, which use detailed knowledge of manufacturing tolerances to create very high-yield processes. They will use this approach to design highly efficient LEDs and a range of nanoscale sensors that exploit resonant enhancement based on photonic crystals, nanobeams and nanopillars.

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



# Hybrid quantum and molecular modelling reveals why blue LEDs need so much magnesium doping

## Investigations into heavily defective GaN target alternative doping strategies to improve solid-state lighting efficiency

Researchers at the UK's University College London (UCL), in collaboration with groups at the University of Bath and Daresbury Laboratory's Scientific Computing Department in Warrington, UK, are said to have uncovered why blue light-emitting diodes (LEDs) are so difficult to make, by using computer simulations to reveal the complex properties of their main component, gallium nitride ('Determination of the Nitrogen Vacancy as a Shallow Compensating Center in GaN Doped with Divalent Metals', Buckeridge et al Phys. Rev. Lett. 114, 016405). Blue LEDs were first commercialized two decades ago and have been instrumental in the development of energy-saving lighting, earning their inventors the 2014 Nobel Prize in Physics.

The desired properties of a semiconductor layer are achieved by growing a crystalline film of a particular material and doping it by adding small quantities of an impurity element, which has more or fewer electrons taking part in the chemical bonding. Depending on the number of electrons, these impurities donate an extra positive or negative mobile charge to the material. The key ingredient for blue LEDs is gallium nitride (GaN), a robust material with a large energy gap between electrons and holes (crucial in tuning the energy of the emitted photons to produce blue light). But, while doping to donate mobile negative charges in the material proved to be easy, donating positive charges failed completely. The breakthrough, which won the Nobel Prize, required doping it with surprisingly large amounts of magnesium.

"While blue LEDs have now been manufactured for over a decade, there has always been a gap in our understanding of how they actually



**Lead author John Buckeridge.**

work, and this is where our study comes in," says lead author John Buckeridge (UCL Chemistry). "Naïvely, based on what is seen in other common semiconductors such as silicon, you would expect each magnesium atom added to the crystal to donate one hole. But in fact, to donate a single mobile hole in gallium nitride, at least a hundred atoms of magnesium have to be added," he adds. "It is technically extremely difficult to manufacture GaN crystals with so much magnesium in them, not to mention that it's been frustrating for scientists not to understand what the problem was."

The team's study unveils the root of the problem by using computer simulations to examine the unusual behaviour of doped GaN at the atomic level.

"To make an accurate simulation of a defect in a semiconductor such as an impurity, we need the accuracy you get from a quantum mechanical model," explains co-author David Scanlon (UCL Chemistry). "Such models have been widely applied to the study of perfect crystals, where a small group of atoms form a repeating pattern," he adds. "Introducing a defect that breaks the pattern presents a conundrum, which required the UK's largest supercomputer to solve. Indeed, calculations on very

large numbers of atoms were therefore necessary but would be prohibitively expensive to treat the system on a purely quantum-mechanical level."

The team's solution was to apply an approach pioneered in another piece of Nobel Prize winning research: hybrid quantum and molecular modelling (the subject of 2013's Nobel Prize in Chemistry).

In these models, different parts of a complex chemical system are simulated with different levels of theory.

"The simulation tells us that when you add a magnesium atom, it replaces a gallium atom but does not donate the positive charge to the material, instead keeping it to itself," says co-author Richard Catlow (UCL Chemistry). "In fact, to provide enough energy to release the charge will require heating the material beyond its melting point. Even if it were released, it would knock an atom of nitrogen out of the crystal, and get trapped anyway in the resulting vacancy," he adds. "Our simulation shows that the behaviour of the semiconductor is much more complex than previously imagined, and finally explains why we need so much magnesium to make blue LEDs successfully."

The simulations crucially fit a complete set of previously unexplained experimental results involving the behaviour of GaN. "We are now looking forward to the investigations into heavily defective GaN, and alternative doping strategies to improve the efficiency of solid-state lighting," says Aron Walsh (Bath Chemistry).

<http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.114.016405>  
[www.ucl.ac.uk/chemistry](http://www.ucl.ac.uk/chemistry)  
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[www.stfc.ac.uk/1903.aspx](http://www.stfc.ac.uk/1903.aspx)

# UK's Anvil Semiconductor & Cambridge Centre for GaN grow cubic GaN-on-Si wafers by MOCVD

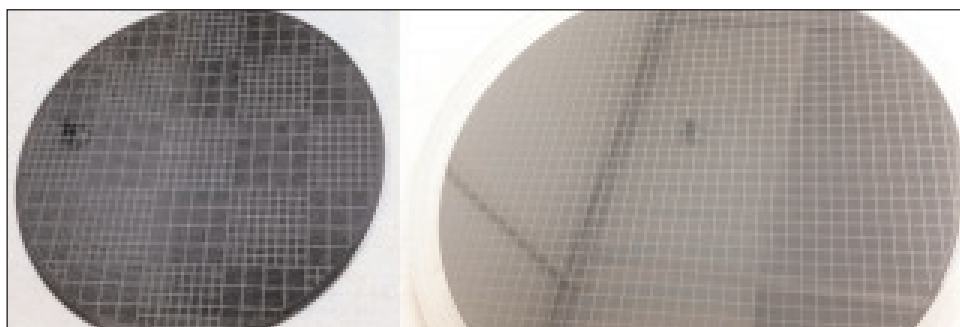
## Cubic GaN on 3C-SiC on silicon promises lower-cost, more efficient LEDs

Anvil Semiconductors Ltd of Coventry, UK and the Cambridge Centre for GaN (part of the University of Cambridge's Department of Materials Science and Metallurgy) have grown cubic GaN on 3C-SiC on silicon wafers by metal-organic chemical vapor deposition (MOCVD).

The underlying 3C-SiC layers were produced by Anvil using its patented stress-relief intellectual property (IP) that enables growth of device-quality silicon carbide on 100mm-diameter silicon wafers. The proprietary process is said to overcome mismatches in lattice parameter and thermal coefficient of expansion and can be readily migrated onto 150mm-diameter wafers (and potentially beyond) without modification and is therefore suitable for large industrial-scale applications.

Conducted under a project funded by Innovate UK, the MOCVD growth trials at Cambridge have resulted in single-phase cubic GaN. The layers, characterized by x-ray diffraction (XRD), transmission electron microscopy (TEM), photoluminescence and atomic force microscopy (AFM), show promise for LED applications, it is reckoned.

The availability of cubic GaN has the potential to remove the strong internal electric fields which plague conventional green LEDs and which impair electron-hole recombination and make it difficult to improve internal quantum efficiency (IQE). Also, cubic GaN has a narrower bandgap and improved p-type electrical properties compared with the standard hexagonal GaN phase normally used for LEDs and therefore it offers several advantages. The ability to produce cubic GaN from a readily commercializable process on large-diameter silicon wafers is recognised as a key enabler for increasing the efficiency and reducing the cost of LED lighting.



Anvil Semiconductor's wafers.

The team intends to continue development to the point of fabricating sample LEDs before looking for an industry partner to help commercialize the technology.

"This is a very promising development and fits well with our current research activities to develop state-of-the-art LEDs," comments professor Sir Colin Humphreys, director of research in the Department of Materials Science and Metallurgy and head of the Cambridge Centre for GaN. "It has the potential to overcome many of the challenges currently seen for green devices and could contribute significantly to the ongoing solid-state lighting revolution," he adds.

"This is a very exciting result which potentially opens up the LED market for our 3C-SiC on silicon material," says Anvil's CEO Jill Shaw. "We will certainly be looking for partners to help us take this opportunity forward".

Anvil was spun off in August 2010 from the University of Warwick's School of Engineering by its tech-

nology commercialization subsidiary Warwick Ventures Ltd in order to exploit patented developments in SiC power semiconductor technology. The firm's technology enables the growth of device-quality 3C-SiC epitaxy on 100mm silicon wafers to thicknesses that permit the fabrication of vertical power devices. The material has applications ranging from power devices and LEDs to medical devices and MEMS.

The Cambridge Centre for GaN has been involved in developing GaN growth technologies for over 15 years, supplying epitaxial layers to groups involved in GaN research in both the UK and internationally. It has experience in growing GaN layers on to sapphire, bulk SiC, bulk GaN and large-area silicon substrates. In 2011, the IP developed for GaN growth on silicon was acquired by Plessey Semiconductors, which is using this technology to manufacture LEDs commercially. The centre has a range of EPSRC, EU and industrially funded programs including a 'Lighting the Future' grant, focused on developing LED structures in GaN and understanding the factors limiting their performance. It also has projects developing GaN for a diverse range of applications, including electronics, lasers and single-photon sources based around its MOCVD growth reactors.

[www.anvil-semi.co.uk](http://www.anvil-semi.co.uk)

[www.gan.msm.cam.ac.uk](http://www.gan.msm.cam.ac.uk)



# SemiLEDs sells 15% stake to XiaoQing Environmental Protection Group's chairman for \$5m

## Joint projects to target waste-water treatment plants and LED luminaire packaging in China

LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has entered into a definitive common stock purchase agreement for XiaoQing Han, chairman & CEO of Beijing XiaoQing Environmental Protection Group, to acquire a 15% stake in the firm's common stock at a purchase price of \$1.00 per share (totalling \$5m). Han will join the SemiLEDs' board of directors upon closing of the transaction.

Founded in 2005, SemiLEDs' manufactures proprietary white, blue, green and ultraviolet (UV) LED chips and components, mainly for general lighting applications, including street lights and commercial, industrial and residential lighting, as well as specialty industrial applications such as UV curing, medical/cosmetic, counterfeit detection, horticulture, architectural

lighting and entertainment lighting.

Han is a veteran of China's national environmental protection industry, having studied water supply and drainage at TsingHua University and Beijing University of Civil Engineering and Architecture and having spent the past 20 years focused on the water treatment sector. In 1988, he founded Beijing XiaoQing Environmental Protection Group, which contracts construction projects such as municipal water treatment, industrial wastewater treatment, garbage disposal, recycling, sludge treatment, sewage, and rural biogas. Customers span industries including pharmaceutical, chemical, industrial and consumer foods and products across more than 14 provinces and regions throughout China.

By aligning the interests of both

SemiLEDs and Beijing XiaoQing Environmental Protection Group, both firms expect to benefit from operating synergies generated through the potential formation of several joint projects including utilizing LED technology into waste-water treatment plants as well as packaging LED luminaires in provinces and regions throughout China. What is claimed to be a unique combination of environmental protection and energy-saving technology is expected to generate significant growth opportunities for both companies in the years ahead.

"We expect the joint opportunities ahead will enable our two firms to grow our business units and revenue while satisfying both our customers and shareholders alike," says SemiLEDs' CEO Trung Doan.

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

## SemiLEDs' quarterly revenue grows 29%

For fiscal first-quarter 2015 (to end-November 2014), SemiLEDs has reported revenue of \$2.9m, down 15% on \$3.4m a year ago but up 29% on \$2.3m last quarter, due to both design wins in target end-markets and the completion of previously announced facility consolidation activities.

Revenue from LED chips grew by 40% sequentially (comprising 24% of total revenue). Revenue from LED components grew 50% (comprising 55% of total revenue). However, this was offset by revenue from lighting products falling 15% (comprising 13% of revenue).

Gross margin has improved from last quarter's negative 134% to negative 53% (also better than the minus 75% a year ago).

While R&D expenses have been cut further by \$81,000 from

\$0.83m to \$0.75m, selling, general & administrative (SG&A) expenses have risen by \$300,000 from \$1.85m last quarter to \$2.15m. So, total operating expenses have risen slightly from \$2.67m to \$2.9m (though still less than \$3.5m a year ago). Despite this, operating margin has improved from last quarter's negative 251% to negative 152% (better than the negative 159% a year ago).

On a non-GAAP basis, net loss was \$3.9m, cut from \$5m last quarter and \$5.9m a year ago.

Although better than \$4.2m a year ago, cash used in operations has risen from \$1.9m last quarter to \$2.7m. So, despite capital expenditure being cut from \$0.93m a year ago and \$0.77m last quarter to \$0.6m, free cash outflow has hence worsened from

\$2.7m last quarter to \$3.3m (though still better than \$5.1m a year ago). Consequently, during the quarter, cash and cash equivalents fell from \$12.6m to \$8.7m.

"As discussed last quarter, while relocation efforts were largely complete by the end of the fourth quarter, we continued to experience lingering effects of these activities in the first fiscal quarter as we completed the hook-up and start-up of this equipment," chairman, president & CEO Trung Doan. "With our facility consolidation now concluded and new design wins in our target markets, we look forward to realizing further benefits from these efforts in the second fiscal quarter."

Consequently, for fiscal Q2/2015 (to end-February), SemiLEDs expects revenue to grow further, to \$3.4–3.7m.



# Plessey's GaN-on-Si LEDs powering 8point3's linear lighting

Plessey has entered a long-term commercial agreement to supply its gallium nitride on silicon MaGIC (Manufactured on GaN-on-Si I/C) LEDs to UK-based LED luminaire manufacturer 8point3 Ltd for use in its new Sabre Architectural range of LED linear lighting products.

Plessey says that recent performance improvements have enabled its MaGIC LEDs to be competitive

with any LED technology. Sabre Architectural combines the benefits of remote phosphor with a unique delivery system, offering high system efficiencies and economic life. With a wide range of colour temperatures, Sabre Architectural is said to provide a uniform and diffuse luminance and appearance, ensuring no reflections or pixilation (even when dimming), offering designers a

flexible solution for high-lumen areas and decorative lighting systems.

"A technology agreement has also been reached, whereby Plessey will design bespoke LED solutions in the UK to complement 8point3's ongoing lighting projects," says Mark Pinnock, Plessey's regional sales manager for Northern Europe and account manager for 8point3.

[www.8point3led.co.uk](http://www.8point3led.co.uk)

## Plessey's dotLED named as one of EDN's Hot 100 Products of 2014

The editors and readers of EDN (Electronic Design News) have included Plessey's smallest packaged GaN-on-Si LED (the dotLED) in its 'Hot 100 Products of 2014' list, which highlights the industry's most significant products of the year based on innovation, significance, usefulness, and popularity.

The PLW13D003, a white LED in a 1005 SMT package, is designed for the demands for ever smaller LED components, producing highly collimated light. It is targeted at the wearable electronics market and small-display applications. The 1005-size (1.0mm x 0.5mm) is a standard for components, handled by the common surface-mount machines used in high volume

consumer electronics. Weighing 0.2mg and with a profile of 0.25mm, dotLEDs provide an option for any wearable application with LED content that demands low-profile components, says Plessey.

The dot-sized LEDs delivers up to 0.7lm of white light with a 130° viewing angle from a 5mA drive current. A blue version (PLB138003) is also available. Further additions to the dotLED family will be colour variants and a series in the larger 1608 footprint. Plessey also has a range of blue LED die for users needing a further step in size.

Plessey's LEDs are produced using its proprietary MaGIC technology. By using standard silicon semiconductor production tech-

niques, the firm is able to produce high-volume, industry-standard LEDs for the consumer electronics market. The 1005-size dotLEDs represent the latest product family using this technology.

"Plessey is demonstrating its commitment to bringing to market a comprehensive range of LED products across all performance points, markets and applications, and the recognition as one of EDN's Hot 100 products is an honour and reflects the focus on innovation through our GaN-on-silicon LED technology," says Plessey's marketing director David Owen.

[www.edn.com/electronics-products/other/4437460/EDN-Hot-100-products-of-2014](http://www.edn.com/electronics-products/other/4437460/EDN-Hot-100-products-of-2014)

## Plessey presents lighting products in collaboration with Zeta

At November's LuxLive show in London, Plessey presented the results of its three-year collaboration with UK-based LED and solar-powered lighting system maker Zeta Specialist Lighting, showcasing a new solid-state lighting product based on Plessey's MaGIC GaN-on-Si I/C LED die. The product follows Zeta securing grant approval from the UK Government under the Advanced Manufacturing Supply Chain Initiative (AMSCI) in 2013.

The Zeta ZD LED Bulkhead is said to eliminate point-source glare and solve heating issues associated with LED lighting in an IP-rated housing. Also, higher efficiency leads to longer

lamp life and reduced maintenance and energy consumption costs.

Zeta designs and makes products for applications including custom luminaires for street lighting, amenity lighting, signage and LED commercial lighting solutions.

"As the lead partner in the project, we have invested heavily in plant and machinery, test equipment and staff, and the imminent launch of the Zeta ZD LED Bulkhead with Plessey's GaN-on-Si MaGIC LEDs is the first of many new lighting innovations," says Zeta's managing director Phil Shadbolt. "It is our aim to incorporate Plessey die into as many Zeta products as possible," he adds.

"Zeta has an excellent reputation for high quality and innovation and has won several awards for its lighting products," says Plessey's marketing director David Owen.

"Recent performance improvements in the efficacy of our LEDs have enabled Plessey's GaN-on-silicon MaGIC LEDs to be competitive with any LED technology," he adds. "Plessey's technology has already shown how we can overcome what up to now has been a significant cost barrier in large-scale LED illumination."

[www.zetaled.co.uk](http://www.zetaled.co.uk)

[www.plesseysemiconductors.com/led-plessey-semiconductors.php](http://www.plesseysemiconductors.com/led-plessey-semiconductors.php)

## Soraa completes its line of PAR30 and AR111 LED lamps with 12.5W range

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has extended its line of PAR and AR111 lamps to offer a full range of halogen replacement lamps from 50W- to 120W-equivalent.

The new 12.5W line features a lower-wattage addition to its full-visible-spectrum PAR30 and AR111 LED lamps, while maintaining the high-peak-intensity characteristic of Soraa's lamps. Featuring Soraa's third-generation GaN-on-GaN LED, the firm's new 12.5W PAR30 lamps provide a suitable lighting solution for 75–120W-equivalent applications in retail, hospitality and museum environments, while the 12.5W AR111 lamps offer an efficient choice for retail applications.

"The market is awash in low-performance, poor-light-quality PAR30 and AR111 LED lamps, so when we introduced our full-visible-spectrum large LED lamp portfolio earlier this year, the reception was outstanding," claims Nick Faraway, senior VP international sales & marketing,



**Soraa's PAR30 and AR111 LED lamps.**

who adds that the lamps have low power consumption, a unique 8° beam enabled by the firm's Point Source Optics, and VP<sub>3</sub> Vivid Color and VP<sub>3</sub> Natural White technologies.

Soraa says its Point Source Optics technology produces high-intensity and uniform beams, enabling it to offer an 8° narrow spot version with a peak intensity of 20,000Cd — twice the peak intensity of other LED maker, it is claimed.

Soraa's Violet-Emission 3-Phosphor (VP<sub>3</sub>) LED technology allows the rendering of colors and whiteness. Utilizing every color, especially deep red emission, VP<sub>3</sub> Vivid Color renders warm tones accurately, and achieves a color-rendering index

(CRI) of 95 and deep red (R9) rendering of 95. Also, unlike blue-based white LEDs without any violet/ultraviolet emission, the VP<sub>3</sub> Natural White is achieved by engineering the violet emission to properly excite fluorescing brightening agents including natural objects like human eyes and teeth, as well as manufactured white materials such as clothing, paper and cosmetics.

Soraa's PAR30 and AR111 lamps are now available in 50–100W (Soraa 95CRI VIVID) and 60–120W (Soraa 80CRI BRILLIANT) halogen-equivalent light output; 8°, 9°, 25°, 36°, 50° and 60° beam angles; and 2700K, 3000K, 4000K and 5000K color temperatures. Both lamps are compatible with a broad range of enclosed, non-ventilated, indoor and outdoor fixtures. Additionally, Soraa's 8° lamps work with its magnetic accessory SNAP system. With a simple magnetic accessory attachment, beam shapes can be altered and color temperature can be modified, allowing flexibility in design and display.

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

## Lattice Power's GaN-on-Si LED PAR38 lamp selected as a top product by Architectural Record

Lattice Power Corp of Nanchang, China, which claims to be the first firm to commercialize GaN-on-silicon LEDs, says that its new NUP-PAR38 LED lamp has been chosen by Architectural Record magazine as one its 2014 Record Products. The new proprietary GaN-on-Si PAR38 LED lamp delivers outstanding efficiency, superior brightness and excellent color rendering.

Growing GaN material on a silicon substrate has been a vexing problem for the industry as a result of the material lattice mismatch and thermal expansion mismatch between GaN thin film and silicon substrate, says Lattice Power.

These mismatches contribute to defects in the material, cracking on the wafer, and poor quantum efficiency of the epi-layer.

By developing a series of proprietary technologies to overcome the mismatch problems, Lattice Power says that it is able to manufacture high-performance, consistent-quality and extremely reliable LEDs. The firm's GaN-on-Si LEDs offer high light density and better thermal dissipation, says the firm.

The NUP-PAR38 lamp has what is claimed to be the industry's highest lumen output without active cooling (2000 lumens at 27W). An thermal pipe heat-sink provides efficient

heat dissipation and eliminates the need for active cooling. The lamp also has what is claimed to be the highest power and lumen density from a single emitter LED and the lowest thermal resistance from an integrated package at 0.25C/W. The 27W PAR38 LED lamp is available in various color temperatures.

A jury of six professionals selected the best new products of the year — rated on the criteria of innovation, usefulness and (where applicable) aesthetics — from entries submitted for Architectural Record magazine's annual competition.

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

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

# LED lighting pioneers win Draper Prize for Engineering

## National Academy of Engineering's highest honor awarded to Akasaki, Craford, Dupuis, Holonyak and Nakamura

The US National Academy of Engineering (NAE) is awarding the 2015 Charles Stark Draper Prize for Engineering to Isamu Akasaki, M. George Craford, Russell Dupuis, Nick Holonyak Jr and Shuji Nakamura for "the invention, development, and commercialization of materials and processes for light-emitting diodes (LEDs)". The prize will be presented at a gala dinner in Washington DC on 24 February, along with the Fritz J. and Dolores H. Russ Prize.

The \$500,000 annual Draper Prize was established in 1988 at the request of the Charles Stark Draper Laboratory Inc in Cambridge, MA, to honor the memory of 'Doc' Draper, the 'father of inertial navigation', and to increase public understanding of the contributions of engineering and technology. It is the NAE's highest honor and is given to engineers for achievements that have significantly benefited society by improving the quality of life, and/or expanding access to information.

"These prize-winning engineers were the pioneers in a technology that has changed the world we live in, from the aesthetics in our homes, to advancements in our visual capabilities, and to environmental stewardship," comments NAE president C D. Mote Jr.

The first visible red LED was created by Nick Holonyak Jr in 1962 while working at General Electric Co, where his work involved the study of III-V materials including gallium arsenide (GaAs). Holonyak found that when he added phosphorus (P) to gallium arsenide, the result was a shortened wavelength, which allowed him to make use of the light-emission properties of diodes, ultimately turning the infrared light to red. Holonyak hence created the GaAsP LED (the underpinning of all



**Isamu Akasaki, George Craford, Russell Dupuis, Nick Holonyak Jr and Shuji Nakamura.**

high-brightness LEDs made today).

In 1972, George Craford invented the first yellow LED and increased its brightness by adding nitrogen to the GaAsP LED. Craford also participated in developing processes for the first large-scale commercial production of red LEDs. He subsequently led work that resulted in the first high-brightness yellow and red LEDs, available in 1992, and later contributed to the development of high-power white LEDs.

Russell Dupuis developed and refined the metal-organic chemical vapor deposition (MOCVD) process in 1977, which enabled the production of high-brightness LEDs and is now the basis of virtually all production of high-brightness LEDs, laser diodes, solar cells, and high-speed optoelectronic devices.

In 1987 Isamu Akasaki used MOCVD to grow high-quality gallium nitride crystals on sapphire substrates, creating the first blue LED (which subsequently enabled bright, energy-saving white light sources).

In 1992, Shuji Nakamura made major contributions to InGaN-based high-brightness double-heterostructure blue LEDs, as well as laser diodes that allowed development of the high-density digital video disk (Blu Ray DVD). The commercialization of high-brightness blue and white LEDs hence grew rapidly and led to the many LED and laser diode applications in use today. Nakamura, who is a

professor of materials and of electrical & computer engineering at University of California Santa Barbara (UCSB), last year received the 2014 Nobel Prize in Physics (shared with professors Isamu Akasaki and Hiroshi Amano) in recognition of the development of the first high-brightness blue LED.

Long-lasting, low-heat-generating and highly energy-efficient LEDs have been used as indicator lamps and read-out displays since its early days. As the lights got brighter and different colors were developed, the applications proliferated. LEDs are now found in the latest computer monitors, cell-phone screens, TV screens, traffic lights, vehicle lamps, home lighting, and as solar-powered night-time lighting in parts of the world where people have no access to electricity. The \$33bn LED industry has stimulated global job growth and dramatically lowered the cost of energy. In 2012 alone, more than 49 million LEDs were installed in the USA, with an estimated annual savings of \$675m in energy costs. In 2013, LEDs in general lighting applications saw rapid growth, saving the USA more than 12 million tons of CO<sub>2</sub> emissions, according to the US Department of Energy (DOE). LEDs also produce the greatest amount of light for the energy used, and have the longest lifetime of any lighting source available.

[www.nae.edu/Projects/Awards/DraperPrize.aspx](http://www.nae.edu/Projects/Awards/DraperPrize.aspx)





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# Cree launches first XHP LED, using SC5 platform to double output of single LED

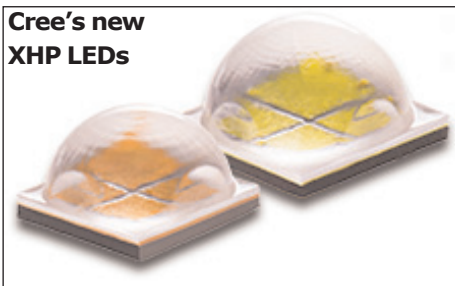
Cree Inc of Durham, NC, USA has announced commercial availability of XLamp Extreme High Power (XHP) LEDs, a new class of LEDs enabling a system cost reduction of up to 40% for lighting applications, it is claimed.

The first LEDs powered by Cree's SC5 Technology Platform, the XLamp XHP50 and XHP70 LEDs provide twice the lumen output and improved reliability compared with previous LEDs of the same size, it is reckoned.

"The breakthrough performance of XHP LEDs enables both new design possibilities and dramatically lower system costs for LED lighting," says Nate Heiking, Advanced Lighting product manager at US-based Kenall Lighting. "Cree's new class of Extreme High Power LEDs will accelerate customer adoption of LED lighting," he reckons.

XHP LEDs allow lighting manufacturers to drastically reduce the size and cost of their lighting system design by using fewer, more reliable LEDs to achieve the same brightness, says Cree. They enable new lighting designs that require fewer optics,

Cree's new XHP LEDs



a smaller printed circuit board, a smaller housing and less handling. XHP LEDs also achieve longer lifetimes even at higher operating temperatures and currents than previous LED technology, it is claimed, allowing lighting manufacturers to reduce heat-sink size and cost without impacting the rated lifetime.

In addition, XHP LEDs enable other cost reductions at the system level not possible with other LED solutions, it is claimed. For example, in roadway and outdoor area lighting, on top of the luminaire cost savings, XHP LEDs can produce a much smaller and lighter luminaire that requires a less expensive pole. Similar cost savings over existing solutions may be achieved in a wide variety of lighting applications, including track,

stadium and high bay.

As the first LEDs to incorporate the SC5 Technology Platform, the new XHP LEDs introduce what are reckoned to be significant advances in light output, color consistency and design flexibility. The XHP50 and XHP70 deliver up to 2546 lumens at 19 watts from a 5.0mm x 5.0mm package and up to 4022 lumens at 32 watts from a 7.0mm x 7.0mm package, respectively. Through improvements in the light conversion process, Cree has reduced LED-to-LED color variations and, among other options, offers XHP LEDs in 2- and 3-step EasyWhite bins for correlated color temperatures (CCTs) of 3500K through 2700K in 80 and 90 CRI (color rendering index). The XHP LEDs also introduce a new package that allows manufacturers to choose either 6V or 12V configurations from the same LED through the solder pad design on the circuit board.

Samples of both the XHP50 and XHP70 are available now, and production quantities are available with standard lead times.

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

## Connected LED Bulb compatible with Wink and ZigBee certified hubs

The Connected Cree LED Bulb is a new smart LED bulb that delivers multi-platform compatibility.

Available in a 60-watt replacement option delivering 815 lumens in a soft-white (2700K) color temperature, the new bulb is compatible with Wink and ZigBee-certified hubs. These allow consumers to control the bulb from anywhere by simply installing the bulb and compatible hub, syncing the devices and customizing the settings using an iOS or Android smartphone (in order to dim or brighten the lights to the desired setting, schedule lights to come on at the start of each day, or turn lights on while away for added security).



The Connected Cree LED Bulb.

Just like the Cree LED Bulb, the Connected Cree LED Bulb emits a warm, omnidirectional light due to its 4Flow Filament Design. This

The Connected Cree LED Bulb is also designed for compatibility with future Cree-supported hubs and platforms such as the Apple HomeKit platform as consumers adopt new platforms for home connectivity.

creates a compact, optically balanced light source inside a durable, shatter-proof housing.

Backed by a three-year warranty, the Connected Cree LED Bulb consumes 81% less energy (based on Cree LED Bulb 60W replacements at 11.5W, \$0.11 per kW-hr, 25,000 hour lifetime and average usage of 3 hours per day), has a rated lifetime of 25,000 hours, and is dimmable via smartphone app.

Consumers can purchase the Connected Cree LED Bulb before the end of January both online and in The Home Depot stores (for \$14.97, which the firm reckons will drive adoption by consumers).

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

# Cree files US lawsuits against Feit and Unity Opto alleging infringement of ten LED lighting patents

LED maker Cree Inc of Durham, NC, USA has filed complaints with the US International Trade Commission (ITC) and the US District Court for the Western District of Wisconsin against Feit Electric Company Inc and its Asian supplier Unity Opto Technology Co Ltd in order to curb what Cree claims is infringement on its patented technologies and to address Feit's false and misleading advertising claims that certain of its products meet ENERGY STAR specifications. The suits allege infringement of 10 patents related to LED lighting.

"Cree fully supports competition, but it should be fair competition," comments Cree's chairman & CEO Chuck Swoboda. "We have invested nearly \$1bn in R&D over the past 10 years to create fundamental technology that has enabled the

LED lighting revolution. With more than 4000 issued patents, we have an obligation to act to protect our shareholders and our licensing partners," he adds.

As part of the complaint, Cree is requesting that the ITC issues an order to exclude infringing and falsely advertised articles from entry into the USA, and a cease and desist order that requires the respondents to cease selling infringing and falsely advertised LED bulbs in the USA. Cree claims that Feit and Unity Opto are infringing on its patents and misleading consumers with their advertising, thereby enjoying an unfair advantage in the market and discouraging the development of new products that benefit consumers.

Cree claims that it was first to develop technology to achieve

omnidirectionality of light to replicate the experience of an incandescent bulb. As a result, the firm introduced the first sub-\$10 LED light bulb to US consumers that looks and lights like an incandescent bulb, it is claimed. Cree says that, through a series of tests, it determined that certain of Feit's bulbs that carry the ENERGY STAR label fail critical performance requirements such as omnidirectional light distribution, hence consumers are purchasing bulbs, based on the ENERGY STAR label, that do not perform as promised.

Cree notes that its licensing program, which includes over 20 licensing partners, allows other companies to use its proprietary technology, and supports these organizations' pursuit of new markets and products.

## Epistar buying TSMC's 94% stake in TSMC SSL

The board of directors of Hsinchu-based Taiwan Semiconductor Manufacturing Co (TSMC, the world's biggest silicon wafer foundry) has approved the sale of its stake in TSMC Solid State Lighting (TSMC SSL). Taiwan's Epistar Corp (the world's largest manufacturer of LED epiwafers and chips) will acquire all shares of TSMC SSL held by TSMC and its subsidiary TSMC Guang Neng Investment Ltd for NT\$825m (NT\$1.46 per share). After the transaction, Epistar will own 94% of TSMC SSL, and TSMC will completely exit TSMC SSL. The firm will be hence operated by Epistar and TSMC SSL's current team.

TSMC SSL has recently developed high-efficiency LED lighting products using phosphor-on-die (PoD) chip-scale packaging technology. However, due to oversupply following the massive expansion of the LED industry in the past several years, the firm has struggled to reach profitability. As a late entrant,

TSMC SSL also faced difficulties overcoming patent obstacles and establishing sales channels.

In contrast, as the world's largest manufacturer of LED epitaxial wafers and dies, Epistar has patents recognized by the major industry players, cross-licensing with Philips and Toyoda Gosei, and a network of sales channels covering customers worldwide. "We can reach a win-win-win scenario with TSMC SSL led by Epistar and SSL's present team," believes TSMC SSL's chairman Dr Steven Tso. "Epistar's operations can take off with redoubled strength, the development of the LED industry will accelerate, and consequently TSMC SSL's shareholders and employees will benefit," he adds.

LED lighting demand is expected to increase significantly between 2014 and 2017, with a rapid increase in the penetration rate. Epistar acquired Formosa Epitaxy at the end of 2014 with the goal of

obtaining the capacity and talent needed for the next several years of growth. Less than one month after its last acquisition, Epistar has decided to invest in TSMC SSL.

"We hold an open and positive attitude towards anything that can enhance Epistar's competitiveness and shareholder value, and is beneficial to the development of the LED industry," says Epistar's chairman Dr Biing-Jye Lee. "TSMC SSL's capacity may be far less than Epistar, but by working with TSMC we can be introduced to different thinking, different talent, and different systems from across industries to spark new ideas and strengthen Epistar's future operations," he adds. It is believed that, once TSMC SSL joins Epistar, its diverse personnel and management systems inherited from the foundry business will accelerate Epistar's innovation.

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

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

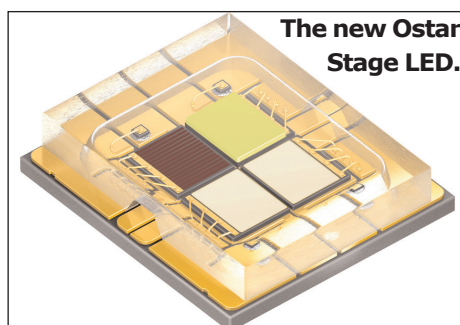


# Osram's new Ostar Stage LED boosts brightness by up to 2.6x from component surface just 30% larger

Osram Opto Semiconductors GmbH of Regensburg, Germany has introduced a new Ostar Stage LED for stage lighting that, compared with previous members of the product family, offers more than twice the lumen output but with a component surface that is only 30% larger.

The new Ostar Stage is the latest high-output addition to Osram's LED product family for stage, exhibition and architectural lighting. "We are continually developing the chips and the package for the Osram Ostar Stage family so that we can offer our customers high-quality products in different output classes," says Andrew Lin, NAFTA product marketing manager LED Industry. "Our aim with this new LED is to raise the standard for moving heads in the high-output category."

The new Ostar Stage is Osram's latest step on the path toward high-power LEDs for stage spotlights that emit a large amount of light from a small surface area, leading to more compact spotlight designs. The new version contains



2mm<sup>2</sup> high-current chips per color that can handle a maximum of 4.5A per chip. Despite the area being twice as large as the previous chips, the 5.7mm x 6.4mm x 1.3mm package size is only slightly larger than the 4.8mm x 5.9mm x 1.23mm previously. This can enable moving heads for stage and exhibition lighting to be both more powerful and more compact at the same time.

The new Ostar Stage LED (LE RTDUW S2WP) is equipped with four high-current chips based on Osram's latest thin-film and UX:3 chip technologies: thin-film chips for 625nm red and UX:3 chips for 530nm green, 453nm deep blue and white (x=0.32; y=0.33 to CIE 1931)

wavelengths. Since up to 4.5A can be applied to each chip, more light can be produced from such a small surface area. With a binning current of 1.4A, the red chips achieve typical values of 140lm, and the green chips 280lm. The 'deep blue' chip provides a light output of 1.8W. If the LED is operated at the maximum current of 4.5A, then the brightness per color increases by a factor of 2.6 (360lm in red, 680lm in green, 4.7W in deep blue, and 1040lm in white, compared with previously 290lm). The white chip in the new Ostar Stage will have a lifetime of 20,000 hours (L50/B50) at full output due to a new C2 ceramic converter, enabling it to achieve brightness of over 1000lm.

This family of products is suitable not only for stage lighting but also moving heads and spotlights for trade fairs and architectural lighting, says the firm. The new Ostar Stage LED was unveiled at the International Consumer Electronics Show (CES) in Las Vegas (6-9 January).

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

## Osram launches its first 810nm infrared LED for biometric unlocking

The main application of Osram's new IR Oslux SFH 4780S (its first infrared emitter with a wavelength of 810nm) is biometric unlocking of cell phones and tablet computers.

Biometric identification is becoming popular as cell phones and tablet computers are used increasingly for sensitive applications such as online banking and shopping. As well as fingerprint scans, many manufacturers are considering iris scanning for unlocking. The eye is illuminated with infrared light and the device's camera images the iris so that its characteristic features can be identified.

The SFH 4780S is the first IRED in the new high-performance Oslux package. "Oslux LEDs have long been established for visible lighting

applications in mobile devices, such as camera flash," says Sevugan Nagappan, product marketing manager for infrared. "We are now extending the range to include infrared emitters."

A special feature of Oslux is the flat component surface despite the use of a lens. By matching the lens to the internal reflector, Oslux components have a very narrow emission beam angle of  $\pm 10^\circ$  at a height of just 2.4mm, optimizing performance. Despite its compact size of 3.5mm x 3.5mm x 2.4mm, the SFH 4780S hits record radiant intensity of typically 2900mW/sr at an operating current of 1A.

This high output comes from a highly efficient thin-film chip with an edge length of 750µm in which

two emission centers lie one above the other via Osram's nanostack technology. The emitter can even be operated with current of up to 2A in pulsed mode. Due to its black package, the SFH 4780S can be integrated unobtrusively behind the covers of mobile devices.

For mobile devices, the emitter must consume minimal power. A centroid wavelength of 810nm is ideal as it provides high-contrast pictures of irises of any color at comparatively low levels of light.

Osram says the SFH 4780S is its answer to the problem of lack of space in mobile devices. Existing designs can use several IREDs, but the new IRED's radiant intensity enables the iris scanner to operate with only one compact emitter.

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# Sheaumann Laser acquires Axcel Photonics

## DPSS and fiber-coupled laser maker adds diode laser chip maker

Privately held laser and photonics company Sheaumann Laser Inc of Marlborough, MA, USA has acquired Axcel Photonics Inc in a stock and cash deal, effective from 1 January.

Axcel is a multidisciplinary semiconductor laser manufacturing company with capabilities in metal-organic chemical vapor deposition (MOCVD) growth, processing and fabrication of laser chips for industrial, medical, military & aerospace

applications. Sheaumann Laser has broad-based technology for designing and delivering custom diode-pumped solid-state (DPSS), flash-lamp and fiber-coupled laser modules and equipment. The combined team expects growth and expansion into areas previously beyond the capabilities of the firms individually.

Having extensive experience in management and technical support

in the laser field, Axcel's president & chief technology officer John 'Gary' Sousa has been appointed president of the merged company.

The first significant opportunity to demonstrate the combined firm's new identity and combined offerings is at SPIE Photonics West 2015 in San Francisco (10–12 February).

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

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

<http://spie.org/photonics-west.xml>

# Daylight achieves over 1 million hours of QCL operation

Daylight Solutions Inc of San Diego, CA, USA — which makes molecular detection and imaging systems based on mid-infrared quantum cascade lasers (QCLs) for scientific research, life science, industrial process control and defense applications — says that it has reached two major milestones as part of its ongoing reliability characterization and growth program for QCL technology.

Over 1 million hours of QCL device operation, and over 250,000 hours of fully packaged QCL module operation, have been accumulated as part of this program. All units under test were sampled from high-yield commercial production. The units maintained optical power levels

above specifications throughout the test, and continue to operate without failure.

Over 80 individual QCLs sampled from five different epitaxial wafers are being evaluated as part of the current reliability characterization program. Lasers are running in both continuous-wave (CW) and pulsed (quasi-CW) modes of operation to explore the reliability effects of each operating condition.

While some of the devices are operating at standard room temperature, most of the tests are being conducted with the QCL devices running at a higher temperature of 60°C. Elevating the device operating temperature has been demonstrated to accelerate

the aging effects of standard group III-V semiconductor diode lasers, and creates an added stress component for these tests.

In practice, the thermal management system of the QCL-based products will maintain device temperatures around 25°C while allowing the ambient temperature to increase beyond 71°C while maintaining performance.

"The achievement of this milestone demonstrates the inherent reliability of our QCL technology," claims CEO Dr Timothy Day. "Our team is committed to the continuous execution of reliability growth programs to support the demanding requirements of our customers."

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

# DILAS appoints business development director

DILAS Diode Laser Inc in Tucson, AZ, USA, a subsidiary of diode laser maker DILAS of Mainz, Germany, has appointed Dr Chris Ebert as its new business development director & regional sales manager (East).

The firm says that Ebert has an extensive background in working together with customers on complex, technical projects, and delivering sustainable value. In his new position at DILAS, he will focus on servicing commercial and defense customers, while also providing



strategic direction to DILAS Diode Laser Inc to ensure that customers' needs continue to be met into the future.

Before joining DILAS, Ebert was business development manager at Advanced Energy, responsible for expanding sales of in-situ temperature measurement technology to capital equipment OEM's, specifi-

cally in high-technology fields such as semiconductor equipment. Previously, from 2005–2011, he held several positions at nLight Photonics, including product line manager for fiber-coupled diode modules. His earlier experience includes numerous positions in the semiconductor industry.

Ebert earned a B.S. in Applied Physics from Yale University and he has a Ph.D., also in Applied Physics, from Stanford University.

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



# ProPhotonix appointed franchised distributor for Panasonic diode lasers in EMEA

ProPhotonix Ltd of Salem, NH, USA, a designer and manufacturer of diode-based laser modules and LED systems for OEMs and medical equipment companies (as well as a distributor of laser diodes for Panasonic, Ushio (formerly Oclaro), Osram, QSI, and Sony), has been appointed as a franchised distributor of Panasonic's new range of red, infrared and dual-wavelength laser diodes in the European, Middle East, and African (EMEA) region. Samples are available for order from ProPhotonix in first-quarter 2015.

Panasonic's laser diodes have been designed to reduce size and weight while still exhibiting stable power output at high temperatures. The red (661nm) and infrared (783nm) single-mode, 5.6mm-can packaged laser diodes are available with output powers of 100mW and 200mW, respectively. Applications include inspection, identification and alignment applications.

The 661nm and 783nm wavelengths are also available in several dual-wavelength packages utilizing Panasonic's proprietary manufacturing technology. Both laser diodes are packaged on a single chip and maintain their respective optical characteristics. They are available in three package types: 5.6mm can, frame package or small frame package. The frame packages are specifically designed to reduce size and weight and operate at up to 85°C. Dual-wavelength packages have applications in sensing, industrial and biomedical equipment.

"These innovative additions to the Panasonic product line strengthen our portfolio of high-quality laser diodes," says Jeremy Lane, managing director of ProPhotonix Ltd's Laser business unit. "Where a laser module solution is required, these laser diodes can be integrated into the wide range of ProPhotonix modules as well as custom OEM solutions," he adds.

"The long-standing relationship between our companies together with the market presence and technical expertise of ProPhotonix will enable us to find many new opportunities in a broad range of applications," believes Keith Burlison, head of Lighting Solutions, Semi-

conductor Product Marketing Department, with Panasonic Automotive & Industrial Systems Europe GmbH (PAISEU), which manufactures electronic components, devices and modules up to complete solutions.

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

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# Huawei partners with Imec on high-bandwidth optical data link technology research

## Collaboration builds on Huawei's acquisition of silicon photonics transceiver spin-off Caliopa

Nanoelectronics research center Imec of Leuven, Belgium and Huawei Technologies Co Ltd (one of the world's largest telecom networking equipment manufacturers) say that they have taken a further step in their strategic partnership focusing on optical data link technology. The joint research on silicon-based optical interconnects is expected to deliver benefits to speed, power consumption and cost savings.

Silicon photonics is reckoned to be a key enabling technology for optical communications, paving the way for the creation of highly integrated, low-power optical transceivers used for data transmission and telecoms.

Huawei has now joined imec's research program which focuses on optimizing bandwidth density, power consumption, thermal robustness and cost at the system level. Huawei engineers will work with imec's R&D team, with a view

to achieving technological progress for delivering connectivity matching Europe's future needs.

In 2013, Huawei added silicon photonics research to its European R&D portfolio by acquiring photonics company Caliopa (which was spun off from imec and UGent in 2010). Delivering on its commitment of boosting Caliopa's development, Huawei has been investing in its human resources and infrastructure, prompting it to move offices to keep step with its rapid growth.

"This collaboration, together with Huawei's recent acquisition of our spin-off Caliopa that focuses on developing silicon photonics-based optical transceivers for the telecoms industry, shows that our silicon photonics research is important for advancing next-generation high-bandwidth ICT solutions," says imec's president & CEO Luc Van den hove. "We expect this partner-

ship to give a further boost to our silicon photonics research over the coming years," he adds.

"By combining our strengths in this strategic area, we can deliver ICT innovation that translates into value for businesses and consumers in Europe and beyond," reckons Hudson Liu, CEO at Huawei Belgium. It is reckoned that, due to its global platform and network, Huawei can bring silicon photonics research results to market, speeding up commercialization of its products.

The collaboration further deepens Huawei's engagement with European research. The latest announcement follows the recent purchase of UK-based Internet of Things company Neul, the launch of an innovation centre in Walldorf, Germany, and the opening of an R&D site in Sophia Antipolis, France.

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

[www.imec.be](http://www.imec.be)

## Advanced Photonix receives 2015 commitment from major customer for 100G coherent receivers

Picometrix LLC, a subsidiary of Advanced Photonix Inc (API) 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 completed its annual negotiations to supply high-speed optical receivers to a "leading tier-1 OEM telecom systems customer". The firm estimates that 2015 annual revenue from these negotiations will be \$3-4m.

The 2015 commitment includes the full suite of Picometrix's 100G coherent receiver products, including the CR-100D with integrated variable optical attenuator (VOA), designed for 100G long-haul communications in dense wavelength

division multiplexing (DWDM) systems that use DP-QPSK and DP-BPSK modulation. The CR-100D receiver increases dynamic range and improves optical signal-to-noise ratio (OSNR) performance. The firm's 100G receivers operate over the entire extended C- and L-band wavelength ranges and can be used in 'colorless' coherent networks that enable service providers to better manage network capacity. Colorless capabilities allow communication equipment to use any wavelength for any port at the add/drop site. This allows faster data throughput and lower costs per bit transport (both big concerns for the industry, says the firm).

"We have a strong relationship

and close collaboration with this strategic customer and are looking forward to supporting the growth in their long-haul and metro 100G product platforms," says Rob Risser, chief operating officer of API and general manager of Picometrix.

"The market for upgrading the long-haul and metro networks from 10G to 100G coherent equipment is entering its growth stage as full motion video and social media continue to place demands for increased bandwidth on the network infrastructure," he adds. "We are well positioned to participate in this growth with our current- and next-generation 100G product offerings."

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

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



# Koch Industries completes purchase of Oplink

## Oplink to be managed by Koch subsidiary Molex

Koch Optics Inc, a subsidiary of Koch Industries Inc of Wichita, KS, USA, has completed its tender offer to purchase all issued and outstanding shares of common stock of optical communications component, module and subsystem maker Oplink Communications Inc of Fremont, CA, USA (announced on 19 November) at a price of \$24.25 per share. Koch Optics has hence merged into Oplink.

A total of 14,701,501 shares were validly tendered and not withdrawn in the offer, representing about 83.8% of Oplink's outstanding shares. Koch Optics has accepted for payment all shares tendered.

Koch Optics and Oplink subsequently completed the merger without a vote or meeting of Oplink's shareholders, with Oplink surviving the merger as a wholly owned subsidiary of Koch Industries. Oplink shares hence ceased trading on the NASDAQ Global Market prior to the opening of the market on 23 December.

Oplink provides telecoms, datacoms and cable TV equipment makers with solutions in DWDM and CWDM bandwidth creation, optical amplification, switching & routing, wavelength conditioning, monitoring & protection, connectiv-

ity and system-level integration, as well as a broad portfolio of optical transceivers for metro WDM, aggregation and access applications.

Koch is one of the largest private companies in the USA, with annual revenue of about \$115bn, according to Forbes, and more than 100,000 staff in about 60 countries (including about 60,000 in the USA). It owns a diverse group of companies involved in refining, chemicals, grain processing and biofuels; forest and consumer products; fertilizers; polymers and fibers; process and pollution control equipment and technologies; electronic components; commodity trading; minerals; energy; ranching; glass; and investments. Since 2003, Koch companies have invested \$65bn in acquisitions and other capital expenditures.

Koch said on 19 November that Oplink will be managed by electronics components maker Molex (a Koch Industries subsidiary, acquired in Autumn 2013). The transaction represents an expansion of Koch's technology platform operated under Molex. "Oplink will significantly expand Molex's fiber-optic capabilities for technology development and new product

innovation," said Tim Ruff, Molex's senior VP, business development & corporate strategy. "We are growing our capabilities in our target markets by combining Molex's global presence and technological leadership with key industry leaders to provide customers with innovative solutions," he added.

"This compelling transaction provides our shareholders with immediate and substantial cash value for their investment," commented Oplink's CEO Joe Liu at the time the deal was announced. "Our board is confident that this combination is in the best interests of our shareholders and will create a stronger and more comprehensive offering for the fast-growing wireless, datacom, metro and long-haul telecom markets," he added.

"Oplink's team brings a broad range of talent and capabilities that are complementary to Molex," noted Doug Busch, VP & general manager of Molex's Global Fiber Optic business. "Our combined organizations will enable us to create more value for our customers and will accelerate our development of complete integrated optical solutions."

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

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

## MACOM completes \$230m acquisition of BinOptics

M/A-COM Technology Solutions Inc (MACOM) of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) has completed its acquisition (announced on 18 November) of BinOptics Corp of Ithaca, NY, USA (an ISO-certified merchant provider of indium phosphide lasers for data centers, mobile backhaul, silicon photonics and access networks) in an all-cash transaction valued at \$230m.

"Our goal with this acquisition will be to further extend MACOM's preeminent position in the optical space, as we now have an even broader platform to benefit from what we anticipate will be a strong secular growth driver for many years to come," says MACOM's president & CEO John Croteau, who said in November that BinOptics' wafer-scale model for InP lasers would play to MACOM's strength in compound semiconductor manufacturing, allowing it to address a supply-constrained part of the

optical component industry. "Based on feedback from our optical customers thus far, we continue to expect significant operational and sales synergies as we integrate the acquired business," Croteau adds.

MACOM funded the purchase price of the acquisition from a combination of cash on hand and incurring \$100m of additional indebtedness from its existing revolving credit facility.

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

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



# GigOptix raises guidance for Q4/2014 revenue; highest since Q3/2012

## Full-year revenue to rise 14% to \$33m

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) says that it expects revenue for fourth-quarter 2014 to be about \$9m, up 6% on \$8.5m in Q3/2014 and 15% on \$7.8m a year ago (and exceeding the guidance range of \$8.5–8.8m provided on 27 October). This is

also the firm's highest revenue since third-quarter 2012.

The primary reasons for the higher revenue are continued robust demand in GigOptix's datacom and industrial businesses, as well as stable telecom demand.

In addition, based on the preliminary Q4 revenue outlook, GigOptix expects revenue for full-year 2014 to be about \$33m,

up 14% on 2013's \$28.9m.

GigOptix cautions that its anticipated revenue results are preliminary (based on the best information currently available) and are subject to completion of the financial statements for fourth-quarter and full-year 2014.

The firm will report full results on 9 February.

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

## GigOptix amends and restates stockholder rights plan

GigOptix has entered into an amended and restated rights agreement to extend the expiration date of its stockholder rights plan, which provides that it issue rights to purchase shares of Series A Junior Preferred Stock. The plan would otherwise have expired on 16 December.

This amends the rights agreement previously adopted by:

- (i) extending the expiration date by three years to 16 December 2017;
- (ii) decreasing the exercise price per right issued to stockholders pursuant to the stockholder rights plan from \$8.50 to \$5.25; and
- (iii) making certain other technical

and conforming changes. The amended and restated rights agreement was not adopted in response to any acquisition proposal, the firm says.

The agreement is designed to provide stockholders with the opportunity to benefit from the long-term prospects and value of the firm and to ensure the fair and equal treatment of stockholders in the event of a proposed takeover of the firm.

On 16 December 2011, GigOptix's board of directors declared a dividend to all stockholders of record of the firm's common stock as of 6 January 2012 of one right to purchase Series A Junior Pre-

ferred Stock for each share of common stock outstanding. The board also previously determined that one preferred stock purchase right will also attach to each share issued by the firm between 6 January 2012 and the earlier of either the exercisability of the rights or the expiration of the stockholder rights plan, which will now occur on 16 December 2017. The preferred stock purchase rights will be exercisable only as provided for under the amended and restated rights agreement. The rights will expire on 16 December 2017, unless earlier redeemed or exchanged by the company.

## GigOptix appoints chief financial officer

GigOptix has appointed Darren Ma as VP & chief financial officer. Ma replaces Curt Sacks, who has left the firm to pursue other interests.

"He is the perfect partner to assume the CFO position at GigOptix as the company moves to the next phase of its growth and scalability," says chairman & CEO Dr Avi Katz. "I am very impressed with Darren's leadership, business acumen, financial expertise and understanding of the semiconductor high-speed communication industry, and I'm confident that his appointment to the

CFO role will provide GigOptix with solid financial leadership," he adds.

Katz thanks Sacks for "important contributions he made since joining GigOptix through the Endwave acquisition in 2011... He leaves GigOptix in a much stronger financial position".

Ma has more than a decade of financial management and leadership experience in the semiconductor industry. Prior to joining GigOptix, Ma worked in roles of increasing responsibility at Semtech, most recently as controller, where he led

the financial performance for the Power Management and High Reliability and Systems Innovation business units. Prior to Semtech, Ma served in finance roles at Intel, where he began his career, and senior finance and financial planning and analysis positions at Fisher Investments.

Ma has a Bachelor's degree in Managerial Economics, graduating with honors, from the University of California, Davis. He also received his Masters of Business Administration from Arizona State University.



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# Emcore completes sale of tunable laser & transceiver product lines for \$17.5m

Emcore has completed the sale of its tunable laser and transceiver product lines (announced on 23 October) to NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems for high-speed communications networks.

Emcore received \$1.5m in cash and a promissory note from NeoPhotonics for \$16m. The promissory note will mature two years from the closing date of the transaction, subject to repayments under certain circumstances, and is secured by certain assets sold to NeoPhotonics in the transaction.

The purchase price is subject to certain post-closing adjustments for inventory, net accounts receivable and pre-closing revenue levels, which will increase or decrease the principal amount of the promissory note as applicable.

The assets sold include intellectual property for the external-cavity laser (ECL)-based integrable tunable laser assembly (ITLA), micro-ITLA, tunable XFP transceiver and integrated coherent transmitter (ICT) products for 10, 40, 100 and 400Gb/s telecom networks. Emcore retains its broadband fiber-optic product lines including cable TV (CATV) transmitters and modules, fiber-to-the-premise (FTTP) transceivers, indium phosphide (InP)-based lasers, photo-

**Emcore's external-cavity tunable laser has the narrowest linewidth in the industry, which will become increasingly important for advanced modulation schemes at 400G**

diodes and modulators, RF-over-fiber satellite communications products, video transport equipment, and microwave and specialty photonics technologies

for defense and homeland security applications (i.e. the firm's broadband business). "Emcore's narrow-linewidth tunable laser product line is highly complementary to our broad existing portfolio of optical components for 100Gb/s coherent transport systems, and this acquisition significantly expands our footprint in this rapidly growing segment," says NeoPhotonics' chairman & CEO Tim Jenks. "Emcore's external-cavity tunable laser has the narrowest linewidth in the industry, which we believe will become increasingly important for advanced modulation schemes at 400G and beyond," he adds. Combining this business into NeoPhotonics will allow us to provide customers with a full product suite that serves the full coherent market." The acquisition is expected to be accretive to NeoPhotonics on a non-GAAP earnings per share (EPS) basis by second-quarter 2015.

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

## NeoPhotonics grants equity inducement awards to staff acquired with Emcore's narrow-linewidth tunable lasers product line

NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems for high-speed communications networks, says that, in connection with completing its acquisition of the narrow-linewidth tunable laser product line of Emcore Corp of Alhambra, CA, USA (which provides optical components, subsystems and systems for the broadband and specialty fiber-optics market), it has granted special inducement equity awards under the NeoPhotonics 2011 Inducement Award Plan to retain certain former Emcore staff (23 in

total) as staff of NeoPhotonics.

The firm has granted equity awards for a total of 115,000 shares (stock options to purchase 110,000 shares and 5000 restricted stock units). Each option vests 25% on 5 January 2016 (approximately the first anniversary of the closing of the Emcore asset acquisition) and the remainder 36 substantially equal monthly installments thereafter, subject to such optionees being employed by the NeoPhotonics group on the applicable vesting dates. The stock options have a ten-year term and an exercise price equal to \$3.34 per share, which was the closing price of NeoPhotonics stock on the New York Stock Exchange

(NYSE) on the date of grant. The restricted stock units vest in equal installments on each anniversary over four years.

The equity awards were approved by the Compensation Committee of NeoPhotonics' board of directors and were granted as a material inducement to employment with the NeoPhotonics group.

NeoPhotonics' board approved the 2011 Inducement Award Plan based on the employment inducement exemption provided under the NYSE listing standards. As a result, the 2011 Inducement Award Plan did not require shareholder approval.

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



# Emcore closes sale of Space Photovoltaics business

Emcore Corp of Alhambra, CA, USA, which manufactures compound semiconductor-based components and subsystems for the fiber-optics market, has completed the sale of its Space Photovoltaics business (announced on 17 September) to SolAero Technologies Corp (formerly known as Photon Acquisition Corp), an affiliate of private equity firm Veritas Capital, following approval at a special meeting of Emcore's shareholders.

Founded in 1998 and based in Albuquerque, Emcore's Space Photovoltaics business provides products for space power applications including high-efficiency multi-junction solar cells, cover-glass interconnected cells (CICs) and complete satellite solar panels, along with terrestrial applications including high-efficiency multi-junction solar cells for concentrating photovoltaic (CPV) power systems. The assets sold comprise substan-

tially all of Emcore's Photovoltaics reporting segment, as well as all rights to the buildings owned, and includes about 275 staff in Albuquerque. The Space Photovoltaics business' fiscal 2013 revenue was \$70.5m.

In connection with the closing of the transaction, Emcore received \$150m in cash, subject to a post-closing working capital adjustment.

[www.veritascapital.com](http://www.veritascapital.com)  
[www.emcore.com](http://www.emcore.com)

## Emcore announces new CEO to replace Hong Hou

Emcore has named Jeffrey Rittichier as CEO. He succeeds Dr Hong Hou, who has served as president & CEO since March 2008. Rittichier has also been appointed to the board of directors to fill the vacancy created when Hou steps down as CEO.

Rittichier formally took on his new position on 3 January at Emcore's corporate headquarters (now in Alhambra, CA).

Emcore says Rittichier is a 16-year optical communications veteran with a record of identifying and realizing optical networking growth opportunities. Accomplishment in the optical components industry include having held the positions of CEO of Xponent Photonics Inc, VP & general manager of Lucent's Access Business, and VP of market-

ing at Ortel Corp. He joins Emcore from NanoStatics, a developer of solutions for the production of high-throughput nanofiber production systems, where he was CEO.

"He is a great fit for our organization and we expect his experience will help Emcore take full advantage of its industry-leading position while turning Emcore into a profitable company," believes co-chairman Dr Gerald Fine.

Rittichier has a B.S. in Mechanical Engineering from The Ohio State University. He was awarded the title of Distinguished Alumnus by Ohio State University's College of Engineering in 2011, and has completed the Financial Management Program at Stanford University.

In conjunction with closing the

divestiture of the Space Photovoltaics business and the sale of its Telecom business unit, Emcore is reducing its corporate expenses, due to its smaller scale, to focus on being EBITDA break-even by September 2015.

In addition, general counsel & corporate secretary Alfredo Gomez will leave the firm on or about 13 February. He joined Emcore in September 2007 and has managed the legal and compliance affairs. Also, chief administration officer Monica Van Berkel left the firm on 2 January. She joined last May and has been responsible for driving the strategic direction of human resources and information technology functions. Chief financial officer Mark Weinswig remains with Emcore.

## Emcore names chief scientist Hank Blauvelt as CTO

Emcore has appointed Dr Hank Blauvelt as chief technology officer, reporting to CEO Jeffrey Rittichier.

Blauvelt joined Emcore in December 2007 as chief scientist with principal responsibility for the development of technologies for linear fiber-optic applications. Recent contributions include the development of linear externally modulated laser (LEML) technology, advanced dispersion compensation techniques for 1550nm distributed feedback (DFB) fiber links, and linear low-noise optical receivers.

Prior to joining Emcore, Blauvelt, whose career in lightwave communications spans over 35 years, was chief technology officer for Xponent from October 2001 until 2007. He was employed by Ortel Corp between 1985 and 2000, when the firm was acquired by Lucent Technologies. Blauvelt made key contributions in the design of optical transmitters and receivers for transmission of CATV signals over fiber-optic links and was the principal inventor on the Ortel patents related to reducing noise and distortion in the links.

In 1992 he was promoted to VP Fiber Optics Technology at Ortel and, after the firm's acquisition, Blauvelt was chief technologist for Optical Access Products at Lucent Technologies/Agere Systems.

Blauvelt earned his Ph.D. in Applied Physics from Caltech. He has been awarded more than 60 US patents.

"Hank's long track record of technology innovation in the industry uniquely positions him to lead us in the next phase of our technology development," comments Rittichier.

# Fraunhofer ISE, Soitec and Leti raise solar cell efficiency record from 44.7% to 46%

## Four-junction cell splits 300–1750nm wavelengths evenly between sub-cells

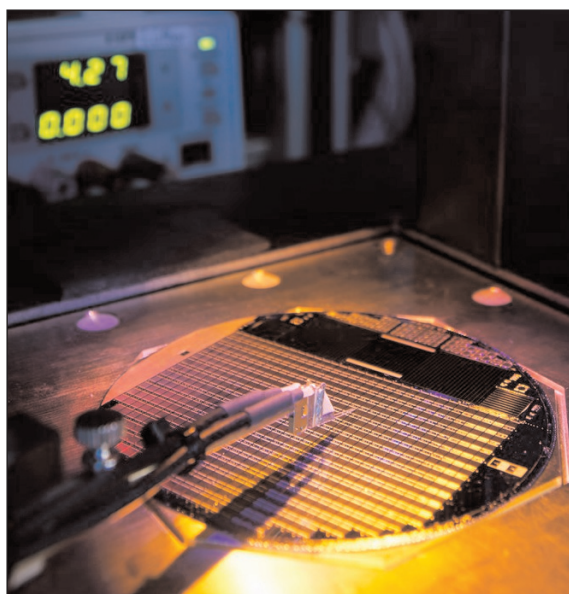
Bernin-based Soitec (which makes engineered substrates and CPV systems) and Grenoble-based micro/nanotechnology R&D center CEA-Leti of France, together with the Fraunhofer Institute for Solar Energy Systems ISE of Freiburg, Germany, have developed a multi-junction solar cell that has raised the record for the direct conversion of sunlight into electricity from 44.7% (set by Fraunhofer ISE, Soitec, CEA-Leti and Helmholtz Zentrum Berlin in September 2013) to 46%.

Based on III-V semiconductor materials, multi-junction cells are used in concentrator photovoltaic (CPV) systems to produce low-cost electricity in photovoltaic power plants, in regions with a large amount of direct solar radiation.

The record cell is a four-junction cell, and each of its sub-cells converts a quarter of the incoming photons in the wavelength range 300–1750nm into electricity. When applied in CPV systems, a very small cell is used with a Fresnel lens, which concentrates the sunlight onto the cell. The new record efficiency was measured at a concentration of 508 suns and has been confirmed by the Japanese AIST (National Institute of Advanced Industrial Science and Technology), one of the leading centers for independent verification of solar cell performance results under standard testing conditions.

A special challenge that had to be met by the cell is the exact distribution of the photons between the four sub-cells. This was achieved by the precise tuning of the composition and thicknesses of each layer inside the cell structure.

"This is a major milestone for our French-German collabor-



**Record solar cell on 100mm wafer, yielding about 500 concentrator solar cell devices.**

©Fraunhofer ISE/Photo Alexander Wekkeli.

ation," says Dr Frank Dimroth, project manager for the cell development at Fraunhofer ISE. "CPV is the most efficient solar technology today and suitable for all countries

with high direct normal irradiance," he adds.

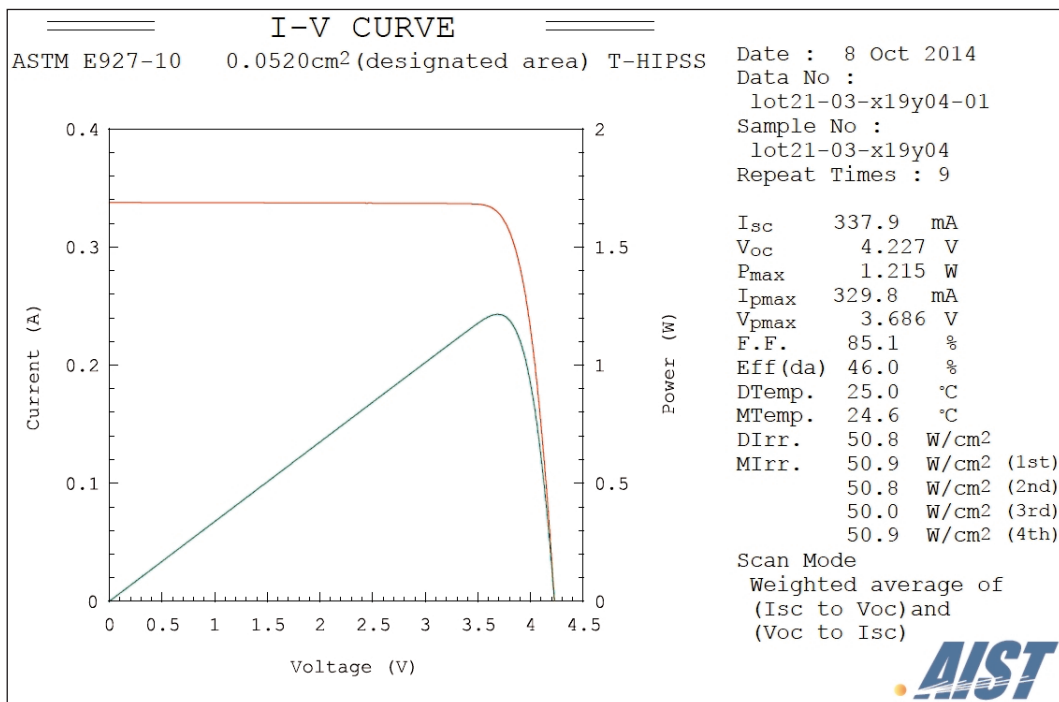
"It confirms we made the right technology choice when we decided to develop this four-junction solar cell and clearly indicates that we can demonstrate 50% efficiency in the near future," believes Jocelyne Wasselin, VP Solar Cell Product Development for Soitec. "To produce this new generation of solar cells, we have already installed a line in France," she adds. "It uses our bonding and layer-transfer technologies and already employs more than 25 engineers and technicians. This successful cooperation with our French and German partners will drive further

increase of CPV technology efficiency and competitiveness."

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

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

[www.ise.fraunhofer.de](http://www.ise.fraunhofer.de)



**I-V characteristics of new four-junction solar cell with 46% efficiency at 50.8W/cm<sup>2</sup>, corresponding to concentration ratio 508 times solar AM1.5d (ASTM E927-10) spectrum.**

## NREL demonstrates 45.7% efficiency for CPV solar cell

The US Department of Energy (DOE)'s National Renewable Energy Laboratory (NREL) has demonstrated a conversion efficiency of 45.7% for a four-junction solar cell at 234 suns concentration, representing one of the highest photovoltaic research cell efficiencies achieved across all types of solar cells.

The new cell, which is designed for operation in a concentrator photovoltaic (CPV) system where it can receive more than 1000 suns of concentrated sunlight, greatly improves earlier designs by incorporating an additional high-quality absorber layer to achieve an ultra-high efficiency.

Since multi-junction solar cells harvest sunlight by dividing the solar spectrum into portions that are absorbed by a material with a bandgap tuned to a specific wavelength range, combining materials with optimal bandgaps is critical for high efficiency. The challenge is to maintain the high quality of the materials while integrating them into a complex cell capable of efficient photoconversion.

"The distinction of this multi-junction device is the very high quality of the lattice-mismatched subcells," says NREL scientist Ryan France,

designer of the solar cell. "Lattice-mismatched materials require the introduction of defects (dislocations) into the device, which can drastically hinder device performance," he adds. "NREL has learned to control and confine these dislocations to inactive regions of the device, allowing even highly mismatched material to be used in a multi-junction cell."

NREL invented and developed the four-junction inverted metamorphic (4J IMM) cell with these challenges in mind. The new design consists of a gallium indium phosphide (GaInP) junction, a gallium arsenide (GaAs) junction, and two gallium indium arsenide (GaInAs) junctions that are lattice-mismatched to the substrate. The cell's peak efficiency of  $45.7 \pm 2.3\%$  was measured under the AM1.5 direct spectrum at 234 suns concentration, but the device performs nearly as well at even higher concentrations, having 45.2% efficiency at 700 suns.

The device has numerous other improvements over previous designs, including a broadband four-layer anti-reflection coating, a novel metamorphic tunnel junction interconnect, and what is claimed to be unprecedented performance from the GaInP top cell. Compared

to standard GaInP subcells, this subcell has both higher voltage and reduced series resistance, which is essential for high efficiency at high solar concentrations.

The cell measurements lab at NREL validated the efficiency. Notably, the measurements at high concentration were taken with a new flash simulator — a Tunable High Intensity Pulsed Solar Simulator (T-HIPSS) — that more accurately controls the spectrum of the concentrated light. This tool ensures that each junction of the device receives an amount of light representative of the solar spectrum, and greatly reduces the error of measurement. The cell is being sent to an external accredited laboratory for further testing and confirmation.

The work is supported by the DOE's SunShot Initiative, which is a national effort to make solar energy cost-competitive with traditional energy sources by the end of the decade. Through SunShot, the DOE supports private companies, universities and national laboratories working to drive down the cost of solar electricity to \$0.06 per kilowatt-hour.

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

## Invenergy closes financing and starts operation of Soitec-powered Desert Green Solar Farm

Invenergy Clean Power LLC of Chicago, IL, USA, which develops, owns and operates large-scale renewable and other clean-energy generation and storage facilities in North America and Europe, has closed the financing and begun commercial operation of its 6.3MW<sub>AC</sub> Desert Green Solar Farm in Borrego Springs, CA, USA, about 90 miles northeast of San Diego. Construction on Desert Green began in April. Blattner Energy Inc served as general contractor and Westwood Professional Services performed engineering duties.

Originally acquired from Soitec Solar Development LLC, Desert Green features more than 3500 concentrator photovoltaic (CPV) modules made by Soitec of Bernin (Grenoble), France at its factory in San Diego. Invenergy gained financing from PNC Energy Capital LLC, a subsidiary of PNC Bank. The plant's output is sold to San Diego Gas & Electric (SDG&E) under a long-term power purchase agreement.

"We look forward to expanding our relationship with PNC to include future solar opportunities," says Invenergy's chief financial officer &

chief operating officer Jim Murphy. "We're also delighted to complete construction of our first power generation facility in California, and to have expanded our solar portfolio to include Soitec's high-efficiency CPV technology," he adds.

"Invenergy completing construction of its Desert Green Solar Farm and securing project financing from a premier capital provider to the renewable energy industry demonstrates the bankability of Soitec's CPV technology," says Soitec's CEO André-Jacques Auberton-Hervé.

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



# Australia's University of New South Wales and RayGen set record solar system efficiency of over 40%

**Prior record of 36.7% exceeded using CPV receiver combined with heliostat collector field**

Researchers at The University of New South Wales (UNSW Australia) have achieved what is claimed to be record solar system energy conversion efficiency of 40.4% (presented on 8 December at the Australian PV Institute's Asia-Pacific Solar Research Conference at UNSW and to be published by Progress in Photovoltaics journal).

This exceeds the record solar photovoltaic module efficiency of 36.7% reported in July by Fraunhofer Institute for Solar Energy Systems ISE of Freiburg, Germany, using four-junction cells of concentrated photovoltaic (CPV) solar system maker Soitec of Bernin, France. The 40% efficiency is the latest achievement by UNSW solar researchers spanning four decades, including the first PV system with over 20% efficiency in 1989.

The efficiency of the UNSW system was achieved in outdoor tests in Sydney, before being independently confirmed by the US National Renewable Energy Laboratory (NREL) at their outdoor test facility.

"We used commercial solar cells, but in a new way, so these efficiency improvements are readily accessible to the solar industry," says Dr Mark Keevers, the UNSW solar scientist who managed the project.

"The new results are based on the use of focused sunlight, and are particularly relevant to photovoltaic power towers being developed in Australia," says Martin Green, UNSW's Scientia Professor and Director of the Australian National Energy Agency-supported Centre for Advanced Photovoltaics (ACAP). Green was formerly a director of CSG Solar, which was formed to commercialize the UNSW's thin-film polycrystalline-silicon-on-glass solar cell. His group's contributions to photovoltaics include developing record-efficiency silicon solar cells



**The 40% efficiency milestone is the latest achievement by UNSW solar researchers spanning four decades - Dr Mark Keevers.**

as well as spinning off several companies.

According to the Australian government's funding documents the central receiver concentrator photovoltaic (CSPV) technology combines a CPV receiver with an optimized heliostat collector field (an array of sun-tracking mirrors). The heliostats concentrate sunlight onto the photovoltaic cells in the central receiver at the top of a mast alongside

the heliostat field. By using large arrays of inexpensive mirrors, the CSPV technology can side-step cost issues facing other solar technologies and significantly reduce the cost of large-scale solar energy, it is claimed.

The power towers are being developed by Australian firm RayGen Resources Pty Ltd, which provided design and technical support for the high-efficiency prototype. Another partner in the research was Boeing subsidiary Spectrolab Inc of Sylmar, CA, USA, which manufactures multi-junction

solar cells and panels for concentrated photovoltaic and spacecraft power systems, and provided some of the cells used in the project.

A key part of the prototype's design is the use of a custom optical bandpass filter to capture sunlight that is normally wasted by commercial solar cells on towers and to convert it to electricity at a higher efficiency than the solar cells themselves ever could. Such filters reflect particular wavelengths of light while transmitting others.

The work was funded by the Australian Renewable Energy Agency (ARENA) and supported by the Australia-US Institute for Advanced Photovoltaics (AUSIAPV). "We hope to see this home-grown innovation take the next steps from prototyping to pilot-scale demonstrations," says ARENA's CEO Ivor Frischknecht. "Ultimately, more efficient commercial solar plants will make renewable energy cheaper, increasing its competitiveness."

[www.pv.unsw.edu.au](http://www.pv.unsw.edu.au)

**The central receiver concentrator photovoltaic technology combines a CPV receiver with an optimized heliostat collector field. The heliostats concentrate sunlight onto the photovoltaic cells in the central receiver at the top of a mast alongside the heliostat field.**

## Spectrolab produces record 4 millionth space solar cell

Boeing subsidiary Spectrolab Inc of Sylmar, CA, USA, which makes multi-junction solar cells and panels for concentrated photovoltaic and spacecraft power systems, says it is the first firm to produce 4 million gallium arsenide (GaAs)-based solar cells for use in space. The cells have powered over 380 spacecraft flights over more than 23 years.

Spectrolab provides products to the commercial satellite industry, the US Department of Defense, NASA and domestic and global aerospace companies.

"Spectrolab cells are providing power for the International Space Station [ISS], and hundreds of satellites and other spacecraft that help keep our world connected with communications and information,"



**A satellite in Boeing's Satellite Development Center in El Segundo, powered by solar panels built by Spectrolab.**

says president Troy Dawson. "Our extensive space solar cell experience, combined with continuing invest-

ments in the business and technology, continues to strengthen our competitiveness in both space and ground-based markets," he adds.

Since 1956, Spectrolab has made technological advances including most recently creating a new solar cell wafer that is projected to reduce customer costs by

up to 15%, through design and manufacturing improvements.

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

## Stanford awards seed grant for laser lift-off project to produce low-cost, single-crystal GaAs PV films

Stanford University's Precourt Institute for Energy, the Precourt Energy Efficiency Center and the TomKat Center for Sustainable Energy have awarded eight seed grants totaling about \$1.5m for new research in clean technology and energy efficiency.

"Seed funding supports early work on concepts that have the potential for very high impact on energy production and use," says Precourt Institute director Sally Benson, a professor of energy resources engineering. "This year's grants support

an exciting array of bold, new ideas for advancing energy technology and policy — from revolutionizing power electronics, to the energy-neutral conversion of waste-water into drinking water and waste heat from computers into usable energy."

Of the eight projects in total, there are three funded by the Precourt Institute for Energy specifically, namely on nanoscale heat transmission, on power electronics, and the following project on photovoltaics: 'A novel technique for producing high-efficiency photovoltaic

devices': Since solar cells made of gallium arsenide (GaAs) hold the record for photovoltaic efficiency but are extremely expensive to produce, this project proposes using a novel laser lift-off technique to produce low-cost, single-crystal GaAs films for PV applications. The principal investigator (PI) for the project is Bruce Clemens, a professor in the Department of Materials Science and Engineering and the Walter B. Reinhold Professor in the School of Engineering.

<http://web.stanford.edu/group/>

## Fraunhofer ISE's director elected as president of EUREC

During its College of Members in Wuppertal, Germany on 26 November, Brussels-based EUREC (European Association of Renewable Energy Research Centers) unanimously elected professor Eicke R. Weber, director of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany, as its president for the term 2015–2017.

Fraunhofer ISE is the largest solar energy research institute in Europe and was one of EUREC's founding members in 1991. Weber has broad international experience in research and R&D management, and holds a professorship of physics/solar energy at the University of Freiburg.

"It is my goal to strengthen EUREC as the representation of

European research & development in renewable energy technologies," says Weber. "EUREC should become one of the most important partners for both the EU Commission as well as the EU Parliament when it comes to decisions in renewable energy policy," he adds.

[www.ise.fraunhofer.de](http://www.ise.fraunhofer.de)

[www.eurec.be](http://www.eurec.be)



# First Solar enters residential market with strategic investment in Clean Energy Collective

## Community solar aims to expand addressable market

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services, has formed a strategic partnership with Clean Energy Collective LLC (CEC) to develop and market community solar offerings to residential customers and businesses directly on behalf of client utilities. The two firms will jointly pursue opportunities in the community solar market to offer an affordable and convenient alternative to rooftop generation.

CEC claims to have pioneered the model of delivering clean power generation through large-scale solar PV facilities accessible to all utility customers. Since establishing the first community-owned solar garden in the USA in 2010 near El Jebel, CO, CEC has built or has under development more than 40 community solar projects with 18 utility partners across eight states, representing 36MW of community solar capacity.

As part of the deal, First Solar has made a strategic investment in CEC and obtained an equity interest, and First Solar's CEO Jim Hughes and VP of strategic marketing Marc van Gerven will join CEC's board.

The move is an integral part of First Solar's distributed generation strategy, strengthening its entry as a solutions provider in the residential and business solar markets. As the USA's leading community solar provider, CEC pioneered the community solar model, through which a broad range of customers have access to solar energy regardless of the suitability of their rooftop or property ownership status. Through the new relationship, CEC will accelerate the rollout of community solar generation aided by the efficient access to capital and hardware solutions afforded by First Solar.



**CEC's 1.12MW San Miguel Power Association community solar array in Paradox Valley, CO, currently the largest community-owned solar array in the USA.**

"Distributed generation in the form of community solar expands the addressable market dramatically beyond the traditional residential or commercial sectors, and CEC has led the way in making that happen," comments First Solar's CEO Jim Hughes. "This deal is a natural fit that leverages CEC's residential experience on the ground with First Solar's expertise in utility-scale generation and panel technology. This innovative and cost-competitive approach will further establish solar, and specifically community solar, as a critical part of the global energy mix for all markets," he adds.

**First Solar has made a strategic investment in CEC and obtained an equity interest, and First Solar's CEO Jim Hughes and VP of strategic marketing Marc van Gerven will join CEC's board. The move is an integral part of First Solar's distributed generation strategy, strengthening its entry as a solutions provider in the residential and business solar markets**

"Community solar is affecting a major shift in the broader solar industry," claims CEC's founder & CEO Paul Spencer. "Joining forces with First Solar further validates community solar and provides us the opportunity jointly to accelerate this shift with the combined power of our proven model and the economics and efficiency of First Solar as a world-class R&D, manufacturing and construction partner," he adds. "This collaboration will allow us to accelerate our expansion to new markets and customers, and will provide both customers and our utility partners with the added confidence that CEC and our community solar projects will deliver long-term, scalable energy solutions at the most cost-effective pricing."

Community solar utilizes sizable ground-mounted installations that provide energy to a utility's grid, and allows consumers the ability to buy into a specific community installation and directly benefit from the solar power generated by that resource. This aims to allow any power consumer to 'go solar', including those who live in multi-tenant buildings, rent, or whose rooftops cannot accommodate solar panels. Community solar can hence expand the addressable market beyond solutions limited to rooftop only, especially in urban residential settings.

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



# First Solar reaches 10GW of installed PV capacity

At the start of the World Future Energy Summit in Abu Dhabi, United Arab Emirates (where it is showcasing a range of solar energy solutions), cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA announced that it has achieved 10GW of photovoltaic (PV) solar capacity installed globally, making it the first thin-film PV module maker to achieve this.

Founded in 1999, First Solar made its first commercial shipment in 2002. Its thin-film modules have since been used in applications ranging from kilowatt-scale mini-grid and rooftop applications to multi-megawatt utility-scale solar energy plants. First Solar's 10GW of installed module capacity (enough to circle the planet three-and-a-half times) produces an estimated 14,000 gigawatt hours

(GWh) per year. This is equivalent to the annual energy consumption of the city of Washington DC, or sufficient to power five million average households (displacing the need for as many as 20 average coal-powered plants).

"Solar is no longer a subsidy-driven extra; it has evolved into a valued component of the global generation portfolio, able to hold its own in terms of cost competitiveness and energy yield," comments First Solar's CEO James Hughes.

With what is reckoned to be the smallest carbon footprint of all solar technologies, First Solar says that its installed capacity displaces an estimated seven million metric tons of carbon dioxide per year (equivalent to planting 180 million trees). Also, with the lowest water use on a lifecycle basis, the use of First Solar's thin-film modules helps to

displace an estimated 18 billion liters of water per year (sufficient to fill 7000 Olympic-sized swimming pools), the firm adds.

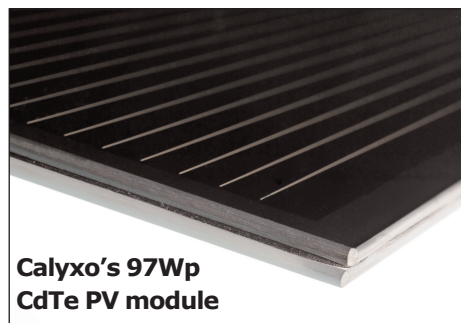
A fully vertically integrated solar energy company, First Solar was also ranked as the world's largest solar engineering, procurement & construction (EPC) contractor in 2014 (according to market research firm IHS Technology's EPC and Integrator Market Share and Project Market Tracker), and has built some of the world's largest solar power plants such as Agua Caliente (290MW) and the Topaz Solar Farm (550MW) in the USA and Luz del Norte (141MW) in Chile. Additionally, with a portfolio of over 2GW, First Solar says that it is also the industry's operations and maintenance (O&M) services leader.

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

## Calyxo's new-generation CdTe PV module reaches aperture-area efficiency of 14.3% CX4 product scheduled for mass production at beginning of 2015

Calyxo GmbH of Bitterfeld-Wolfen in Germany's 'Solar Valley', which is a manufacturer of cadmium telluride (CdTe) thin-film solar modules and a supplier of turnkey photovoltaic systems, says that its development and technology team has reached an aperture-area efficiency of >14.3% (97Wp from 0.72m<sup>2</sup>; 13.5% full size area) with a new product generation that will be introduced in 2015.

Manufacturing of the new product generation has been carried out on the firm's new production line opened a year ago. "It's a great achievement to concurrently both ramp-up a new production line and use it to meet the targeted performance goals for the new product development," says chief technology officer/chief operating officer Dr Michael Bauer. "We can achieve over 14% efficiency with the new



**Calyxo's 97Wp CdTe PV module**

product generation," he believes. "We are convinced that the unique Calyxo deposition process, in addition to its cost advantages, has the potential for the highest semiconductor layer qualities."

Calyxo has set new product generation goals for 2015. "The pressure for us to supply higher power classes is clearly evident in the market by competitive crystalline silicon module supplier offerings," says CEO Dr Florian Holzapfel. "In the intermediate term, Calyxo's

new-generation modules will produce more energy per installed area compared to the crystalline competition due to the better temperature coefficient [the relative change of a material property per Kelvin compared with measurement at the reference temperature: -0.25%/°K for CdTe versus -0.43%/°K for c-Si]." At temperatures above 25°C, Calyxo's modules produce up to 10% more energy than comparable crystalline silicon (c-Si) solar modules.

"We also work on other product characteristics, which will reduce the cost of installation on the customer side," adds Holzapfel.

The transition of development concepts into mass production is scheduled for the beginning of 2015, designated under the new module product name CX4.

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

# Hanergy to build 300MW flexible CIGS PV module production line in Hunan, China

**Changde Government to build factories; Hanergy subsidiary Beijing Jing Cheng to buy back project over six years**

Hong Kong-based Hanergy Thin Film Power Group Ltd says that its subsidiary Beijing Jing Cheng is investing in the construction of a 300MW flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) module production line in the Economic Development Zone of Changde City, Hunan Province, China, to be completed by June 2016.

Following a supplemental agreement of 8 December between Beijing Jing Cheng, the Government of Changde City, and the Council of Changde Economic & Technological Development Area (ETD Council), the Changde Government will be responsible for constructing the PV production factories and relevant ancillary engineering facilities, and lease the land use rights and factories to Beijing Jing Cheng at a concessionary rate (payable on a semi-annual basis). The Changde Government and Beijing Jing Cheng will separately enter into formal project agreements for construction, management, leasing and buyback of the factories.

Specifically, Beijing Jing Cheng will buy back the project (at its original total construction cost) by 31 December of the sixth year after the date on which the project obtained its industrial and commercial business license.

In recent years, Beijing-based clean-energy power generating firm Hanergy Holding Group Ltd (parent of thin-film photovoltaic module maker Hanergy Solar) has been developing downstream solar power business sectors, and is developing photovoltaics power generation projects and application businesses both in China and worldwide. In the last few years, Hanergy

**Hanergy believes that producing its own thin-film PV modules will not only help it to diversify its revenue and customer base but also open up the whole industry chain, reducing overall cost**

Solar has acquired three CIGS PV firms: Germany's Solibro GmbH (from Q.Cells SE) and US firms MiaSolé Inc of Santa Clara, CA and Global Solar Energy Inc of Tucson, AZ.

Hanergy says that the new project represents a milestone in its capability to produce its own thin-film PV modules. With financial support from the Changde Government and the ETD Council, Hanergy says that the new CIGS thin-film product line will help to complete its industry chain, and that the synergy between the businesses should enhance its competitiveness.

Hanergy believes that producing its own thin-film PV modules will not only help it to diversify its revenue and customer base but also open up the whole industry chain, reducing overall cost. It also believes that strategic synergy can be realised by exercising effective management and monitoring in different areas such as the R&D, production and application of thin-film technology.

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

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

## Magnolia receives US patent on high-efficiency flexible multi-junction solar cells

Magnolia Solar Corp of Woburn, MA and Albany, NY, USA says that on 25 November the United States Patent and Trademark Office (USPTO) issued its subsidiary Magnolia Solar Inc a patent (US Patent No. 8,895,838) describing an improved multi-junction solar cell structure employing high-performance III-V absorber materials and nanostructured anti-reflection coatings that can improve solar cell performance.

Magnolia is working on the development of flexible, lightweight, high-efficiency solar cell technolo-

gies for a wide range of portable power applications. The firm's technology portfolio includes nanostructured anti-reflection coatings, advanced photovoltaic absorber structures, and novel, low-cost manufacturing processes. In addition, Magnolia has filed a patent application for what it describes as an innovative design of portable power application. These patents are at various stages of evaluation by the USPTO.

"We have been aggressively pursuing more than a dozen US patent

applications as a means to protect our intellectual property (IP) in the field of flexible photovoltaics," says president & CEO Dr Ashok K. Sood. "The 8,895,838 patent pertains to a novel device structure for increasing the efficiency of high-performance multi-junction solar cells," he adds. "When combined with advanced epitaxial liftoff fabrication processes, this technology can be employed in the construction of ultra-high performance flexible solar photovoltaic modules."

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

# Solar Frontier supplies CIS PV modules to Zero Energy Nano building at SUNY Poly

Tokyo-based Showa Shell Sekiyu subsidiary Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — has been chosen to supply its modules to the Zero Energy Nanotechnology (ZEN) building at the State University of New York Polytechnic Institute's (SUNY Poly) Colleges of Nanoscale Science and Engineering (CNSE). A series of deliveries has started (for completion this summer). The total project will result in a PV plant with a capacity of 2.4MW<sub>DC</sub>.

The project is part of a \$25m partnership announced in September by CNSE and Japan's New Energy and Industrial Technology Development Organization (NEDO) to install, commission, test and demonstrate technologies including solar PV, lighting, fuel cells, and smart building energy management systems.

"The ZEN building will serve as a platform to demonstrate how

leading-edge, clean-tech systems enable greater energy savings in buildings," says Dr Pradeep Halder, VP of Entrepreneurship Innovation and Clean Energy Programs at CNSE.

Under construction at the \$20bn Albany NanoTech Complex, the 356,000ft<sup>2</sup> building will be one of the world's largest net-zero-energy buildings, and will serve as a 'living laboratory' for renewable energy and energy-efficiency technologies. It will be used to design ultra-high energy-efficient technologies that can be adopted to cut the operating costs of buildings.

"Net-zero-energy technologies are essential to an energy-efficient future in an urban world," comments Charles Pimentel, chief operating officer of subsidiary Solar Frontier Americas. "CIS solar modules generate a higher electricity yield than crystalline silicon modules in real operating conditions," he adds.

Solar Frontier says that, in urban environments, its CIS modules

have performance benefits including, being less affected by shadow cover from nearby objects like buildings or other module arrays (leading to more kilowatt-hours than competitors in crowded urban areas). As well as their all-black appearance, the modules' anti-glare properties are also more suitable where sun glare can have significant negative effects on the surrounding area and its inhabitants, the firm notes.

Solar Frontier's Americas operations are based at the firm's regional office in San Jose, CA. The New York region remains a candidate for future plans to establish production bases for its proprietary technology outside Japan, with ongoing collaboration with the State of New York. The firm says that the USA is an important market as it implements a renewed focus on global expansion, based on demand for its thin-film CIS solutions in markets worldwide.

[www.sunyit.edu](http://www.sunyit.edu)

[www.solar-frontier.com](http://www.solar-frontier.com)

## Construction starts on 15MW PV plant at former golf course; Japan's first extra-high-voltage megasolar plant using small inverters

Solar Frontier says construction has started on a 15MW solar power plant on a 400,000m<sup>2</sup> site at a former golf course in Nakagawa, Tochigi Prefecture, Japan owned by developer Takara Leben Co Ltd. Takara Leben already has eight operating solar power plants in Japan with a combined capacity of 10MW, but aims to expand its capacity to 100MW. Hitachi Zosen is providing engineering, procurement & construction (EPC) services for the new project.

Output of the 120,000 x 165W modules amounts to 19.8MW. With power conditioning (750 x 20kW), the capacity is 15MW. The plant's projected annual capacity is about 21,000,000kWh (equivalent to 3700 homes), reducing annual CO<sub>2</sub> emissions by 11,000 tons.

Power generated by the plant will be sold to the grid.

Solar Frontier says that its CIS thin-film PV modules have a higher tolerance for partial shading and heat compared with crystalline silicon modules, providing higher energy output as well as enabling the plant to provide more stable output on north-facing slopes.

The project is said to mark the first time that small inverters have been used in an extra-high-voltage megasolar plant in Japan.

As well as the overall design reducing the initial investment cost, the use of small inverters should provide lower ongoing operating expenses and risk. Fairways and other areas in golf courses differ in size, requiring a more complex array layout and electrical system

design. Central inverters have, until now, limited this design. However, this project uses small 20kW inverters to overcome the configuration issue. The system design also spreads the risk of power loss since equipment can be replaced on the same day.

The plant's design is reckoned to reduce the burden on the environment by negating the need for site work due to its use of a one-pile foundation structure. This means that not only is the height difference between modules in east-west installed arrays smaller, but the number of pile-drivers used in the installation is less than half that of previous installations, resulting in shorter installation time and a reduction in environmental burden.



# GaAs/InP wafer bonding with low electrical resistance

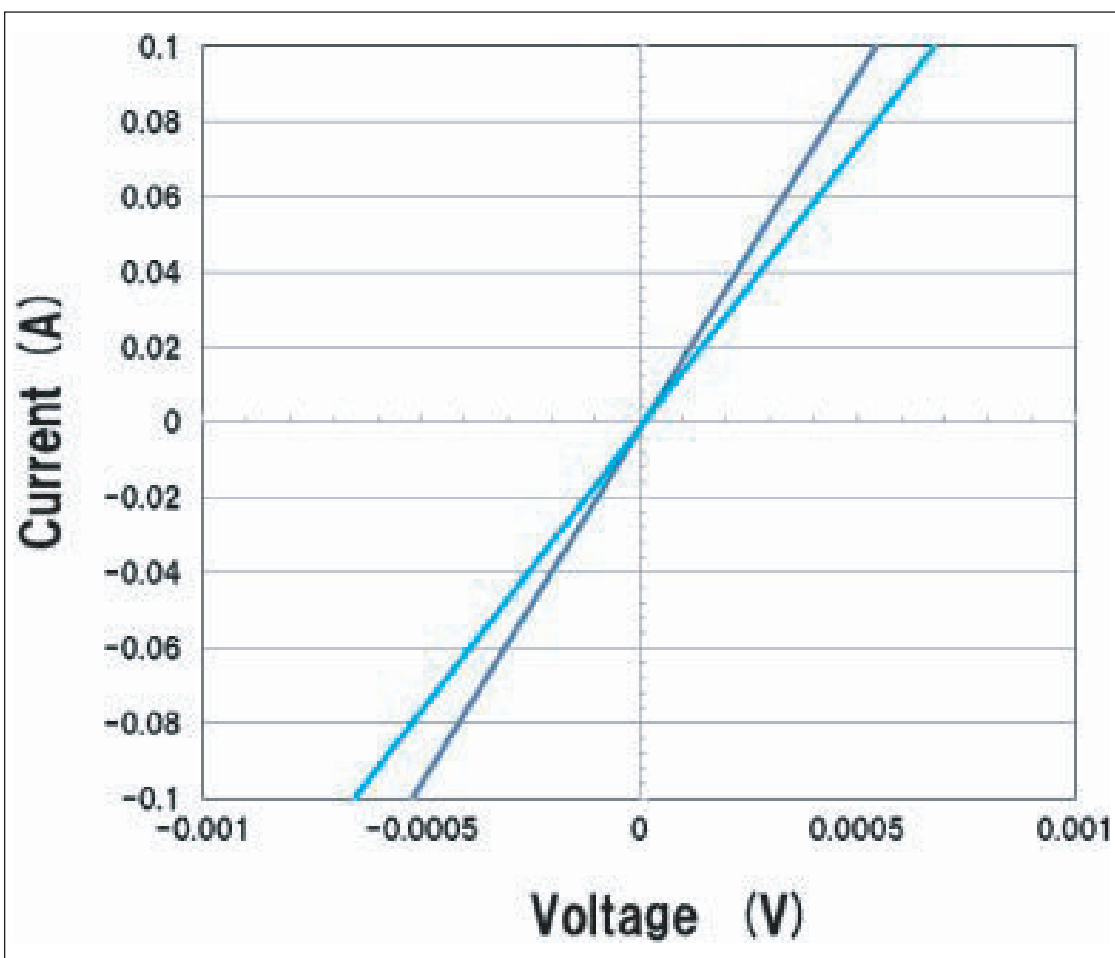
**Researchers see good prospects for room-temperature wafer bonding process in multi-junction solar cell applications.**

**R**esearchers based in Japan and China have developed a room-temperature wafer bonding process for gallium arsenide (GaAs) and indium phosphide (InP) with 'extremely low resistance' [Shiro Uchida et al, Appl. Phys. Express, vol7, p112301, 2014]. The team from Sony Corp and Suzhou Institute of Nano-tech and Nano-bionics see their process as being "a promising technique for fabricating multi-junction solar cells with more than four junctions in order to obtain high conversion efficiencies."

Up to now, wafer bonding techniques have added unacceptable levels of electrical resistance to multi-junction solar cell structures, limiting the options for creating photovoltaic sub-cells. In their new research, the Sony/Suzhou team found that bonding n-type GaAs and n-type InP resulted in unwanted diode-like current-voltage performance, but paradoxically that bonding p<sup>+</sup>-GaAs to n-InP gave an ohmic contact. In addition, the researchers claim the lowest resistance yet achieved for GaAs/InP wafer bonding.

Although some groups have used higher-temperature bonding (400–700°C) to lower the resistance of GaAs/InP bonded wafers, the ohmic values have still been higher than desired. Lower-temperature processes also avoid structural problems such as wafer bending, defects, voids, and cracks.

In solar cell applications, the heavily doped p<sup>+</sup>-GaAs layer would need to be as thin as possible to reduce optical losses due to free carrier absorption. However,



**Figure 1. Characteristics for 3mmx3mm p<sup>+</sup>-GaAs/n-InP bonded samples fabricated under (a) conventional and (b) optimized conditions.**

in these first experiments the researchers used 450µm p<sup>+</sup>-GaAs substrates.

The researchers bonded zinc-doped p<sup>+</sup>-GaAs and 600µm-thick sulfur-doped n-InP wafers in Mitsubishi Heavy Industries' MWB-06-R room-temperature wafer bonding machine. The equipment includes an argon ion gun to activate the wafer surfaces and to form dangling bonds. The wafers were prepared for bonding with an alkali cleaning solution. The bonding force was 5000N.

Ohmic contacts of titanium/platinum/gold were applied to the remaining surfaces of the bonded wafers. The contact metals were alloyed at the relatively low temperature of 260°C. The material was diced into 3mmx3mm chips for testing.

**Figure 2. Characteristics for 0.5mmx0.5mm p<sup>+</sup>-GaAs/n-InP bonded samples between 50K and 320K for (a) currents between -200A/cm<sup>2</sup> and 200A/cm<sup>2</sup> and (b) bias voltages between 0.5 and 1.0V.**

The resistance across the bond was estimated to be  $1 \times 10^{-3} \Omega$  ( $8.9 \times 10^{-5} \Omega\text{-cm}^2$ ), after correcting for the resistance of the materials and the metal contacts. The resistance of the whole structure was  $6.7 \times 10^{-3} \Omega$  with good ohmic current-voltage linearity (Figure 1).

The researchers achieved a lower resistance through the bond of  $2.8 \times 10^{-4} \Omega$  ( $2.5 \times 10^{-5} \Omega\text{-cm}^2$ ) by optimizing bonding time, temperature, applied voltage, and applied pressure, along with increasing the alloying temperature of the ohmic contacts to 340°C. "To the best of our knowledge, this is the lowest interface resistance ever reported for a direct GaAs/InP bond," the researchers comment.

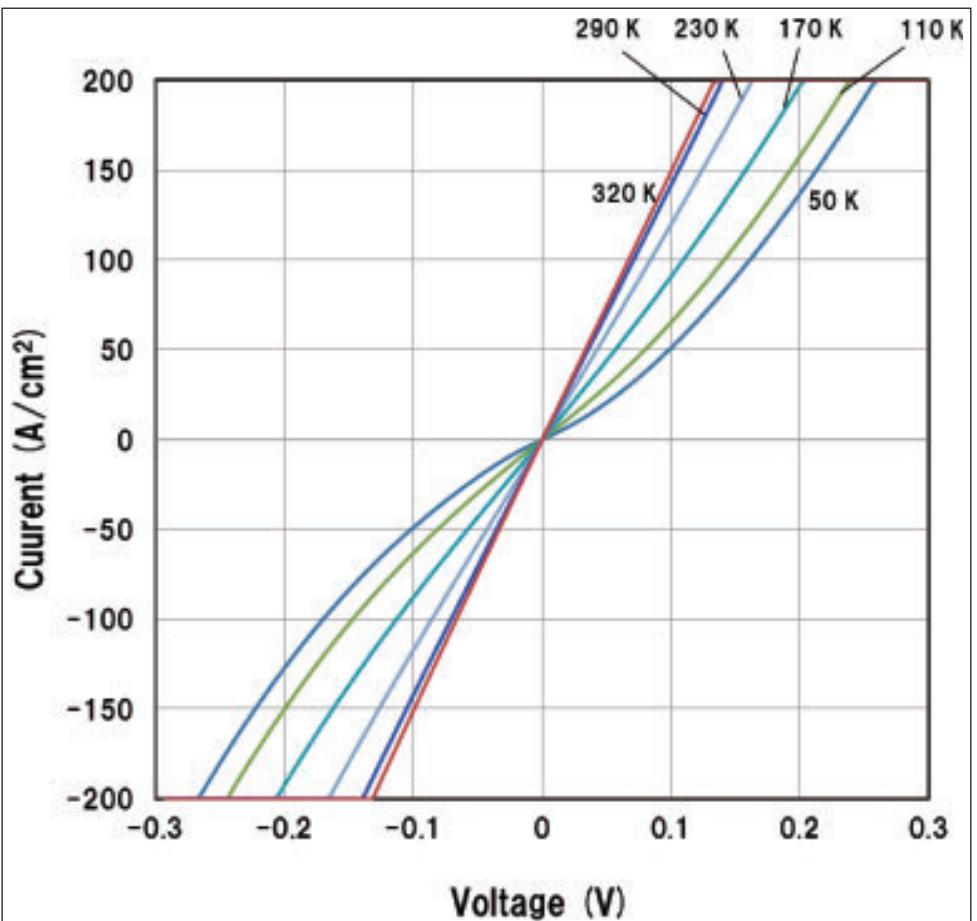
Since solar cells should be designed to operate at high current density, the researchers tested 0.5mmx0.5mm chips at high current (Figure 2). The chips operated at up to 200A/cm<sup>2</sup> without breakdown, a much greater density than that needed for concentrated sunlight photovoltaics ( $>5\text{A/cm}^2$ ).

The researchers believe that the ohmic current-voltage characteristics of the p<sup>+</sup>-GaAs/n-InP bond was the result of a complex combination of tunnel and trap-assisted currents. Analysis of the bond region found an amorphous interlayer region where one would expect a high density of interfacial defect states.

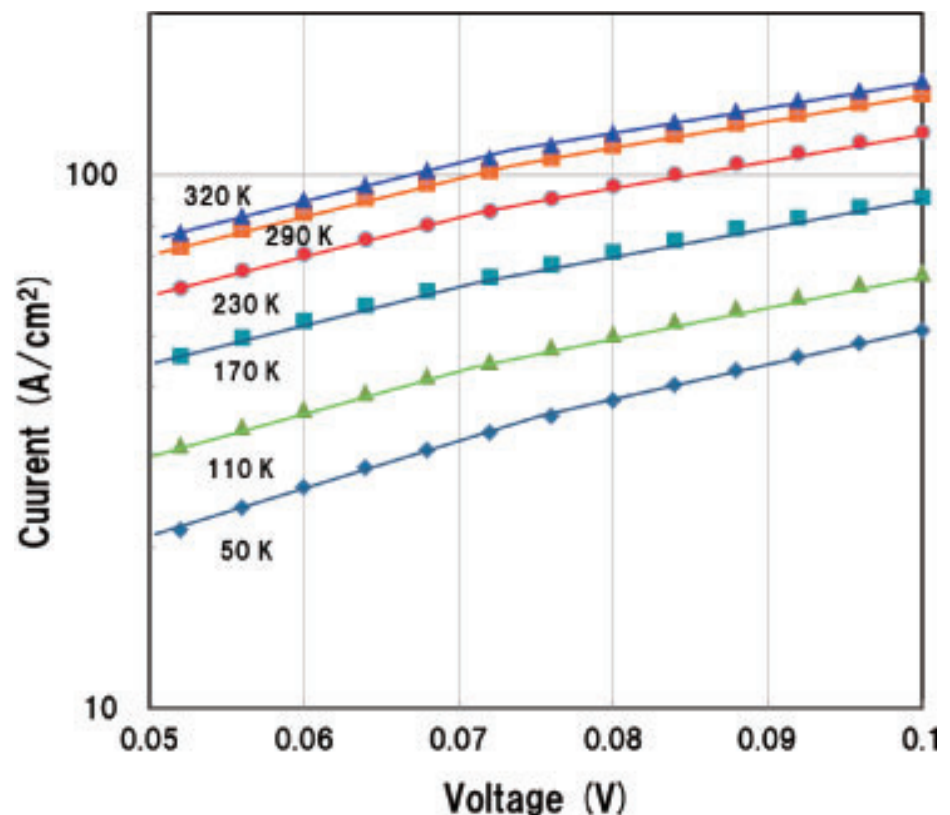
The researchers also produced bonds with thin interlayers of titanium between the p<sup>+</sup>-GaAs and n-InP wafers. The resistance across the bond was ohmic ( $1.5 \times 10^{-3} \Omega$  for p<sup>+</sup>-GaAs/2.0nm Ti/2.0nmTi/n-InP), but higher than for chips without titanium interlayers. ■

<http://dx.doi.org/10.7567/APEX.7.112301>

Author: Mike Cooke



(a)



(b)

# Double metal waveguide yields mid-IR quantum cascade laser with 24.4 $\mu\text{m}$ wavelength

**A double metal waveguide structure reduces optical losses, enabling longer-wavelength mid-infrared radiation.**

**E**TH Zurich has produced a quantum cascade laser (QCL) that is claimed to have the longest mid-infrared (MIR) wavelength so far [K. Ohtani et al, Appl. Phys. Lett., vol105, p121115, 2014].

The device operated near the troublesome 'reststrahlen' band of the compound semiconductors used. Light within a reststrahlen band is unable to propagate because of strong coupling/resonance with lattice vibrations (phonons).

A double metal waveguide structure (Figure 1) was used to avoid reststrahlen arising from the usual indium phosphide

substrate used to create MIR QCLs. The researchers also carefully optimized the dielectric constant of the QCL heterostructure using simulations.

The QCL structure (Figure 2) used a bound-to-continuum scheme. Diagonal transitions between states centered in different wells were used to increase the upper-state lifetime (0.4ps calculated). The lower-state lifetime was simulated at 0.26ps, allowing population inversion to be achieved.

The researchers grew lattice-matched laser structures with  $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$  wells and  $\text{In}_{0.52}\text{Al}_{0.48}\text{As}$

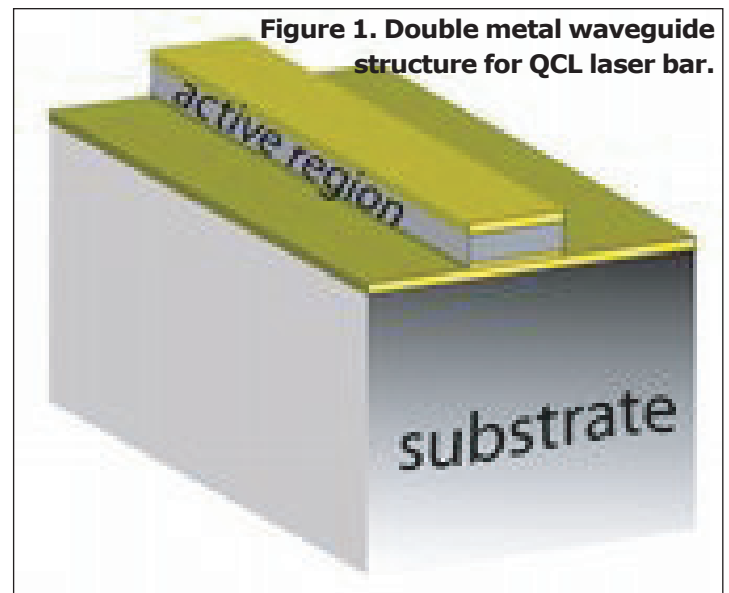


Figure 1. Double metal waveguide structure for QCL laser bar.

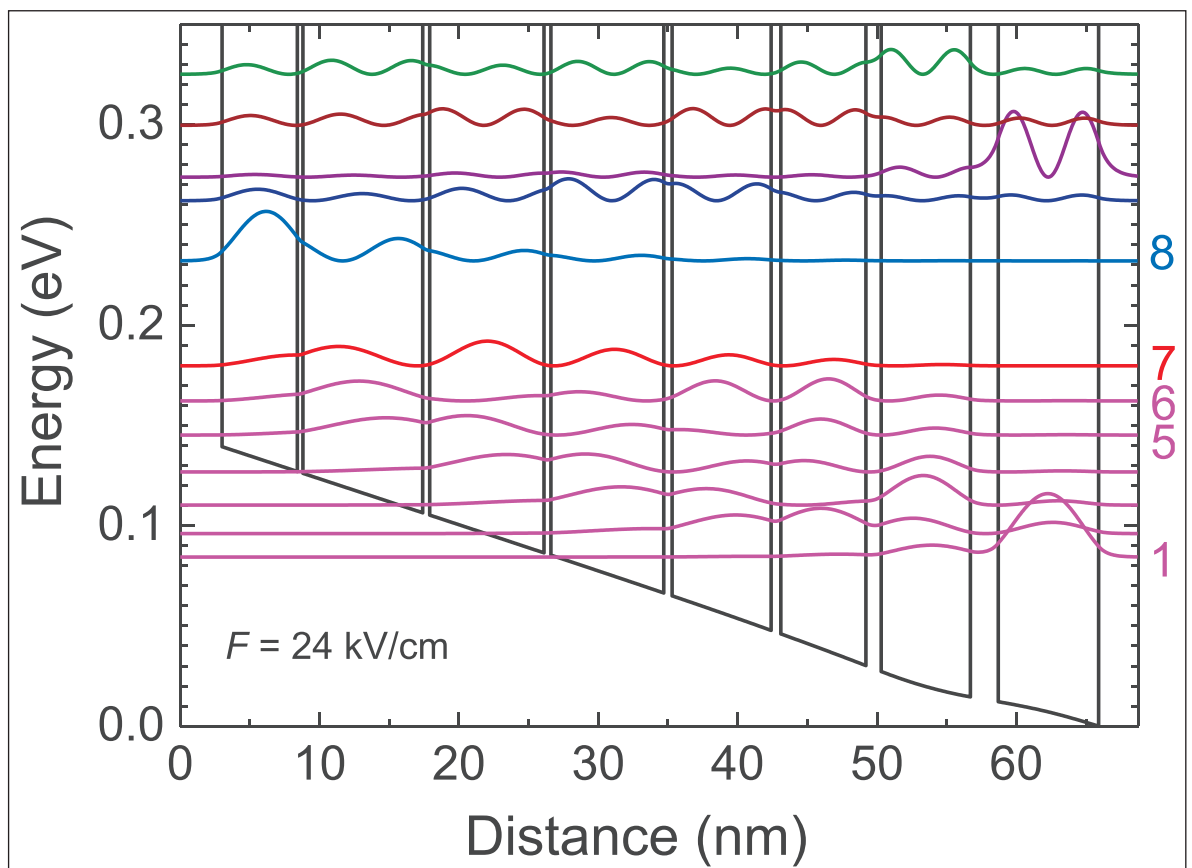


Figure 2. Calculated conduction band diagram and relevant wave functions of one period of active/injection layers with applied electric field of 24kV/cm. Diagonal laser transition with dipole matrix element of 5.6nm occurs between states 7 and 8.



barriers on lightly doped indium phosphide (InP) using solid-source molecular beam epitaxy. The laser diode structure included 40nm silicon-doped InGaAs bottom contact, 60 repeats of the InGaAs/InAlAs injection/active QCL structure, and a 40nm n-InGaAs top contact.

Ridge laser structures with double metal waveguide were produced. Thermocompression was used for gold-gold wafer bonding and transfer to a handling substrate. The InP growth substrate was removed using chemical mechanical polishing (CMP) and selective etching. The (originally) bottom InGaAs contact was etched away to reduce waveguide losses. The ridge width was 30 $\mu$ m. The material was cleaved into 0.5–3.0mm-long cavities.

A 1mm-long device with 24.1 $\mu$ m center wavelength had a threshold current density of 5.7kA/cm<sup>2</sup> at 50K. The peak output power averaged 0.6mW. Laser operation was seen at up to 240K, a significant increase on the 140–170K previously achieved in the same wavelength range. The emission wavelength shifted from 24.1 $\mu$ m to 23.5 $\mu$ m between 50K and 240K, respectively, due to the Stark effect.

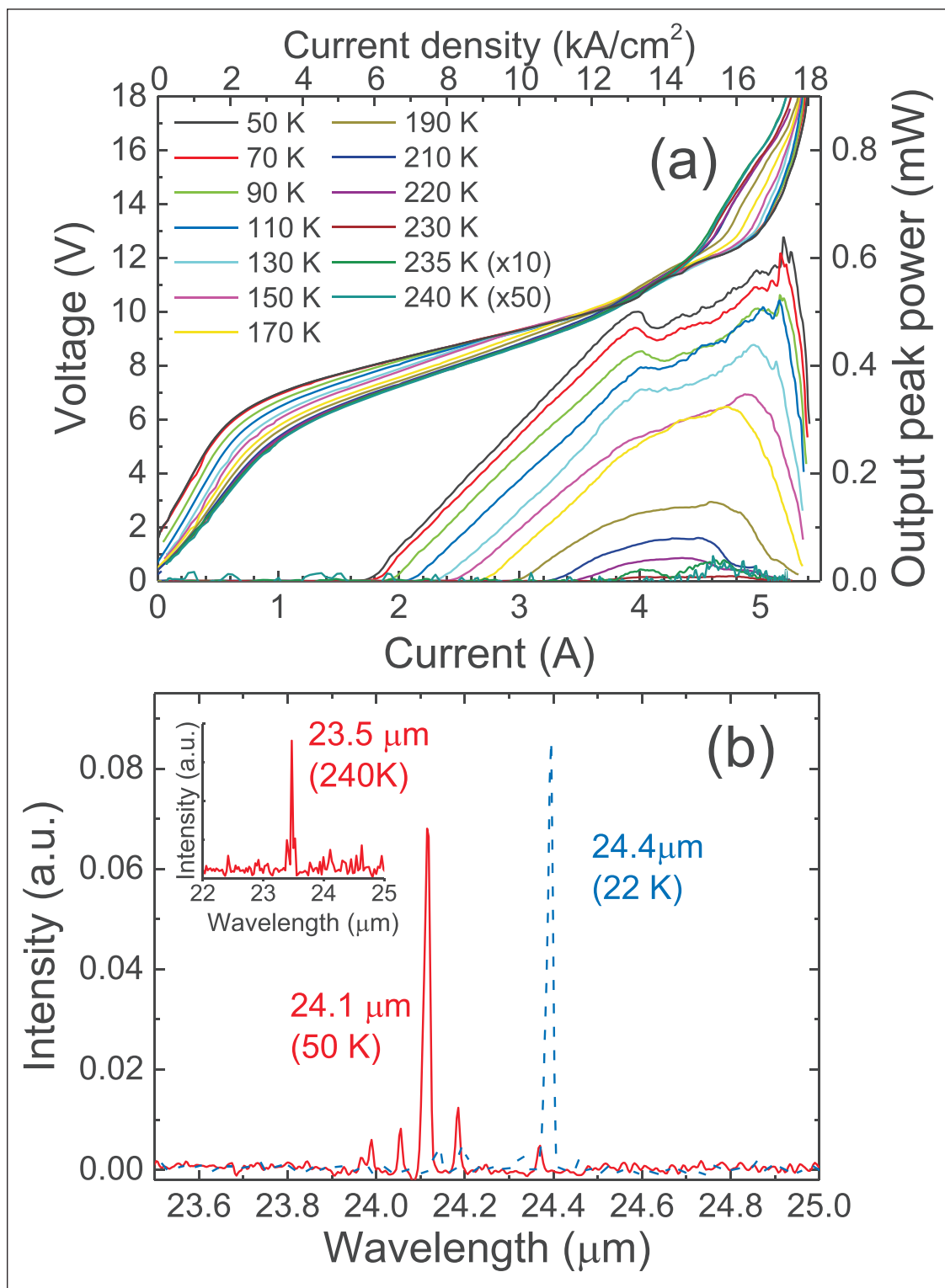
The improvement in thermal performance was attributed to a high dynamic range of the current density of 2.2 ((18–5.7)/5.7), based on a maximum current density of 18kA/cm<sup>2</sup> at 50K. The characteristic temperature,  $T_0$ , for the threshold current was 217K.

Another device with 3% thicker InGaAs wells

achieved a 24.4 $\mu$ m center wavelength at 22K — “the longest wavelength in MIR QCLs so far reported,” according to the researchers. A 24 $\mu$ m wavelength device was achieved in 2002. ■

<http://dx.doi.org/10.1063/1.4896542>

Author: Mike Cooke



**Figure 3. (a) Temperature dependence of light output-current-voltage characteristics. Current pulses of 100ns duration at frequency of 490Hz were used. (b) Laser emission spectra taken by a rapid-scan Fourier infrared spectrometer of resolution 0.125/cm. Inset shows spectrum at maximum operation temperature, 240K. Blue dotted line is spectrum at 22K for QCL having 3% thicker InGaAs wells.**

# Reducing threshold current in 3 $\mu$ m laser diodes

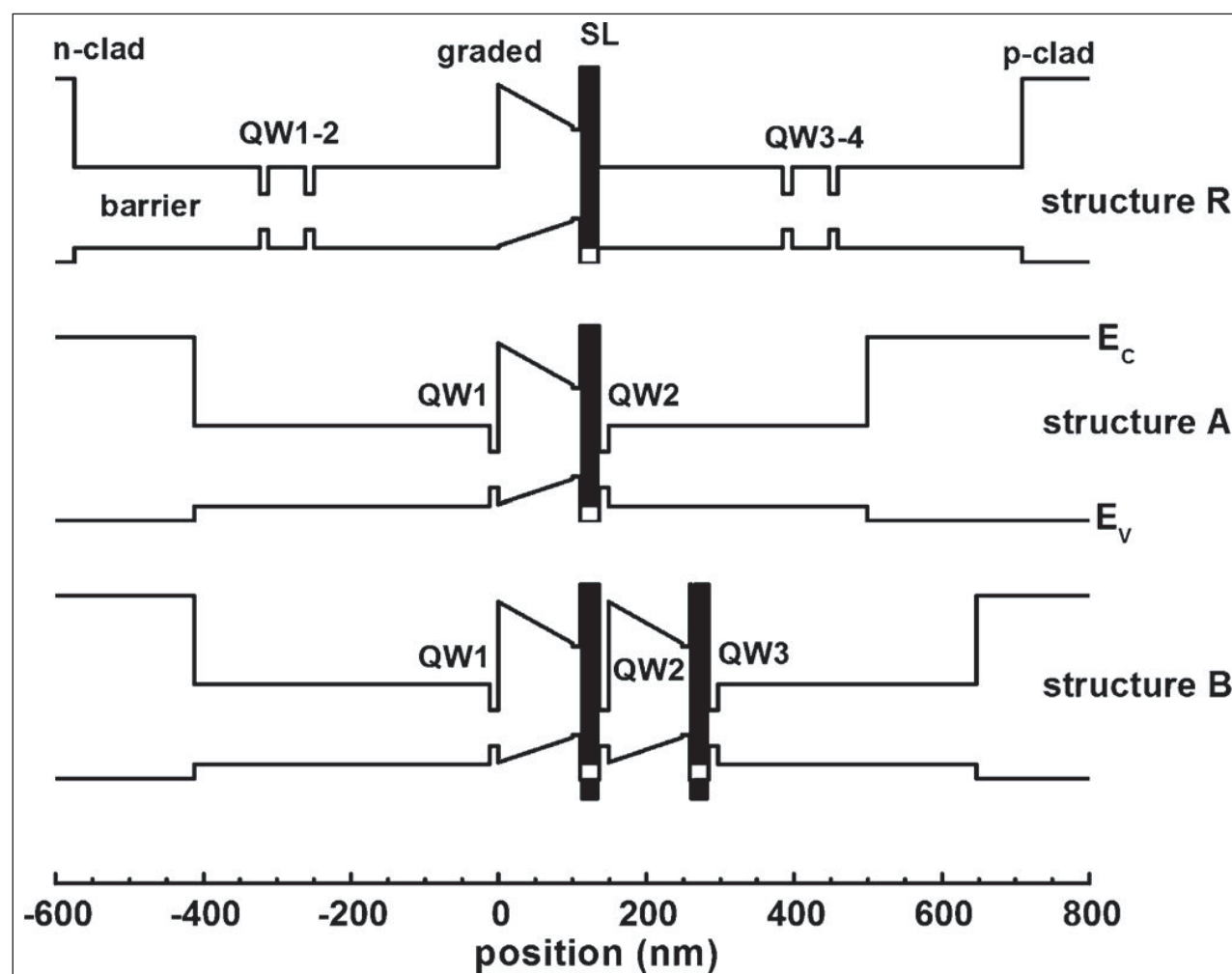
**Researchers claim a two-fold improvement in threshold current over the previous world record for 3 $\mu$ m lasers on gallium antimonide.**

**R**esearchers in USA have reduced the threshold current for 3 $\mu$ m laser diodes on gallium antimonide (GaSb), claiming a two-fold improvement over the previous world record [Leon Shterengas et al, Appl. Phys. Lett., vol105, p161112, 2014].

The devices were developed by State University of New York at Stony Brook (SUNY) and Army Research Laboratory (ARL) based on previous work at Stony Brook, which combined two laser diode structures with a 'cascade pumping scheme' between the stages. The new work eliminated the spacing between the interme-

diates pumping region and the quantum wells (where photons are generated) to improve optical confinement.

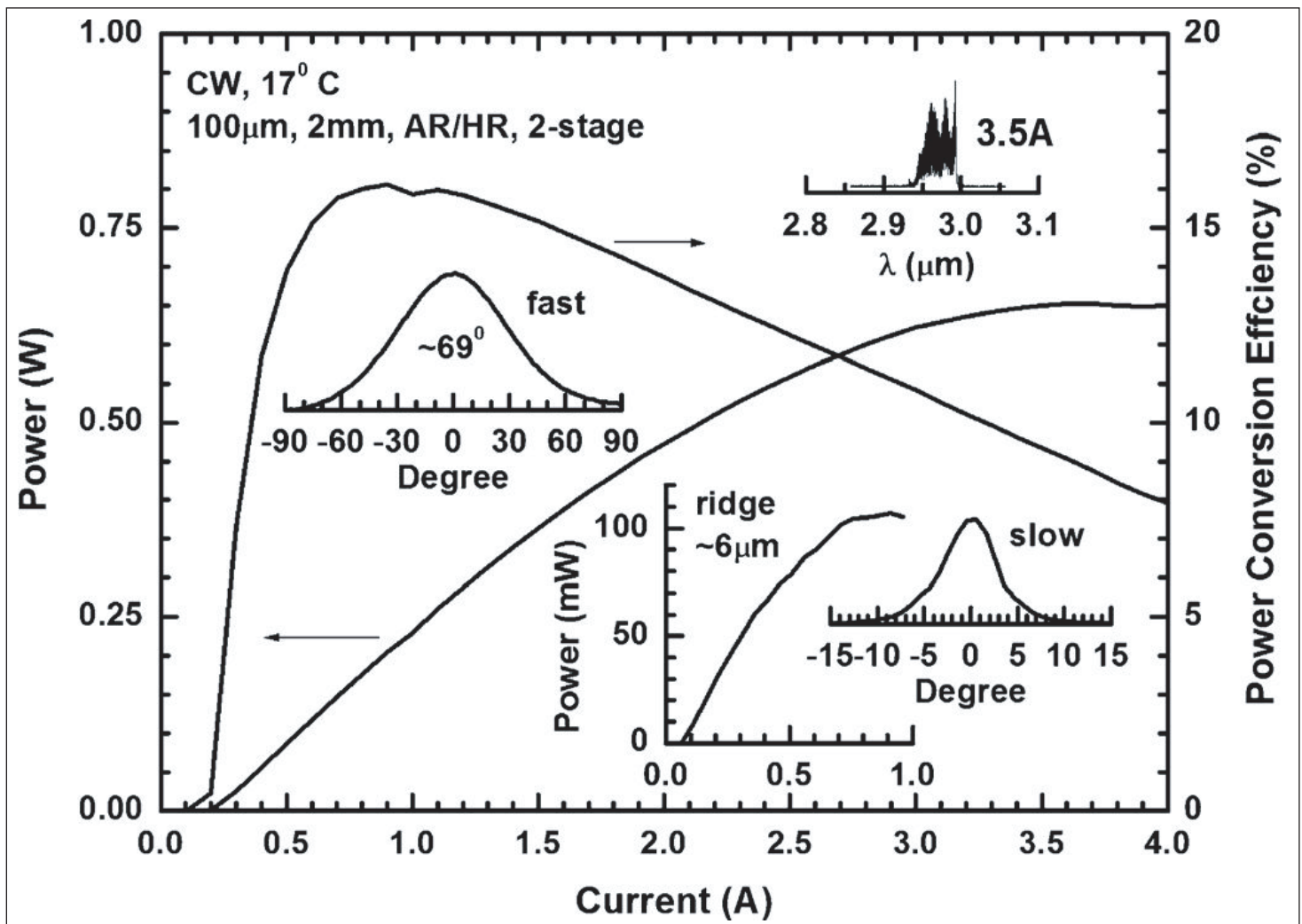
The device materials were created by using solid-source molecular beam epitaxy (SS-MBE) on GaSb substrates. The structures (see Figure 1) used aluminium gallium arsenide antimonide ( $\text{Al}_{0.80}\text{Ga}_{0.20}\text{As}_{0.07}\text{Sb}_{0.93}$ ) doped with tellurium and beryllium for n- and p-type cladding regions, respectively. The barrier and waveguide core layers consisted of unintentionally doped aluminium gallium indium arsenide antimonide ( $\text{Al}_{0.20}\text{Ga}_{0.55}\text{In}_{0.25}\text{As}_{0.23}\text{Sb}_{0.77}$ ).



**Figure 1. Schematic band diagrams of laser heterostructures under flat band condition. Structure R corresponds to Stony Brook's previous cascaded laser diodes. Structures A and B correspond to two- and three-stage cascaded lasers designed for improved optical confinement and minimized threshold current density.**

The quantum wells were 12nm layers of GaInAsSb with ~50% indium. The wells were compressively strained by 1.5%, compared with the rest of the heterostructure.

The cascade pump regions consisted of 100nm graded layers of AlGaAsSb with the aluminium fraction varying from 50% down to 5%, followed by tunnel junctions and electron injectors of



**Figure 2.** CW light-current-power conversion characteristics measured at 17°C for 100μm-wide, 2mm-long AR/HR coated two-stage cascade lasers. Insets show laser spectra at maximum power level, fast-axis far-field pattern as well as CW light-current characteristics of 2mm-long, AR/HR coated narrow (6μm) ridges with corresponding slow-axis far-field pattern.

10nm GaSb, 2.5nm AlSb and 6-period chirped superlattice (SL) of tellurium-doped InAs/AlSb.

The materials were fabricated into 100μm- and 6μm-wide ridge laser diodes.

Three structures were studied — a reference device (structure R) from the previous work, a two-stage cascade diode with increased optical confinement (structure A), and a three-stage cascade design aimed at high efficiency, low threshold current and reduced voltage drop (structure B).

A 100μm×2mm anti-reflection and high-reflection (AR/HR) coated laser diode based on structure A achieved in continuous wave (CW) operation at 17°C a threshold current density of 100A/cm<sup>2</sup>, maximum power of 650W, and peak power conversion efficiency of 16% (Figure 2). The efficiency “remained well above 10% for output powers above ~600mW”, the researchers write, adding: “All of these characteristics surpassed those of the previous state-of-the-art 3μm lasers (i.e. reference structure R)”. In particular, the threshold was a factor of two smaller than that of the

reference device. A 6μm-wide device demonstrated CW emission power above 100mW and power conversion efficiency ~10%.

Diodes with a 100μm×2mm ridge based on structure B with AR/HR coating were tested at 17°C and 70°C. The CW output power at 17°C reached 830mW (100mW at 70°C). Lengthening the ridge to 3mm increased the output power to 960mW. The increase is attributed to an improved thermal footprint. The hoped-for reduction in threshold current was not realized.

The researchers comment: “We hypothesize that this results from the barrier energy asymmetries pushing the electron envelope wave-functions in QW2 of Structure B toward the SL side and thereby intensifying adverse interface interactions”. Growth-to-growth variation effects on carrier localization and lifetimes could also have contributed to the higher-than-desired threshold current. ■

<http://dx.doi.org/10.1063/1.4900506>

Author: Mike Cooke



# Non-polar AlN growth for enhancing deep UV optoelectronics

**Researchers explore the best growth conditions, with a view to creating the ideal platform for light-emitting diodes and laser diodes.**

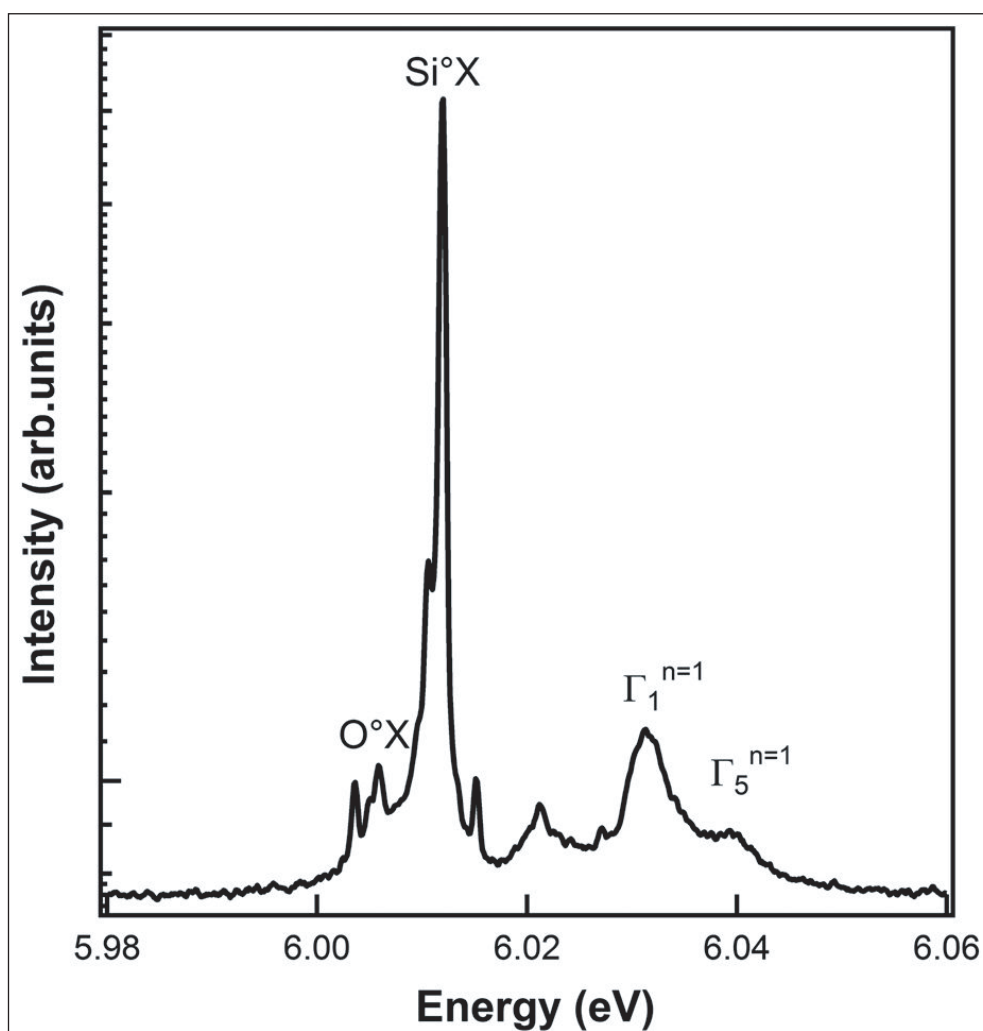
**N**orth Carolina State University (NCSU) has been developing homo-epitaxy of non-polar aluminium nitride (AlN) with a view to deep ultraviolet (DUV, less than 300nm wavelength) optoelectronics [Isaac Bryan et al, J. Appl. Phys., vol116, p133517, 2014].

DUV light emission has been achieved using high-aluminium-content aluminium gallium nitride (AlGaN). However, the efficiencies are generally low due to high defect levels and unwanted electric fields that arise from the polarization of charge in the III-nitride chemical bond.

Defects arise in epitaxial material that has a large lattice-constant mismatch with the growth substrate. The effect of polarization can be reduced by choosing a crystal orientation where the electric fields are in the plane of the surface. Also, the polarization field can be increased by strain from lattice-mismatched hetero-epitaxy.

The NCSU research involved homo-epitaxy to eliminate lattice mismatching and growth on non-polar (1 $\bar{1}$ 00) m-plane substrates. This is in contrast to the conventional route to DUV light-emitting diodes grown in the (0001) c-plane direction on AlN templates on sapphire substrates.

The NCSU says of its work: "The growth of these high-quality non-polar AlN homo-epitaxial films will provide an ideal platform for future deep-UV optoelectronic device structures."



**Figure 1. Low-temperature near-band-edge PL spectrum of a 1.2 $\mu$ m thick (1 $\bar{1}$ 00) homoepitaxial AlN film grown at 1450°C.**

Another potential advantage of m-plane material is that light extraction is expected to be higher compared with c-plane material due to non-propagation of TM-polarized photons along the c-direction (normal to the c-plane).

NCSU used AlN substrates created out of boules grown through physical vapor transport (PVT). The dis-

location density of the boules was less than  $10^3/\text{cm}^3$ . A diamond wire saw was used to slice m-plane substrates from the c-plane boule. The substrate surface was smoothed using mechanical and chemical-mechanical polishing.

NCSU also implemented a wet etch/ammonia anneal treatment that the researchers have developed to reduce the total oxygen content of the substrate surface by more than 80%. Atomic force microscopy (AFM) of the substrate surface showed atomic-level steps. The root mean square (RMS) roughness of the substrate surface was "consistently" below 100pm for  $5\mu\text{m} \times 5\mu\text{m}$  scan areas.

Epitaxial layers of  $1.2\mu\text{m}$  AlN thickness were produced in a vertical cold-wall metal-organic chemical vapor deposition (MOCVD) reactor. The source gases were trimethyl-aluminium and ammonia in hydrogen carrier. The nitrogen/aluminium ratio was 1000. The growth temperature range and pressure were 1250–1550°C and 20Torr, respectively. Substrates with misorientation of  $0.45^\circ$  off  $[1\bar{1}00]$  toward  $[0001]$  crystal direction were chosen for the epitaxial growth.

The surface of all the epitaxial layers "appeared smooth and featureless without cracking through optical differential interference contrast microscopy imaging," according to the research team.

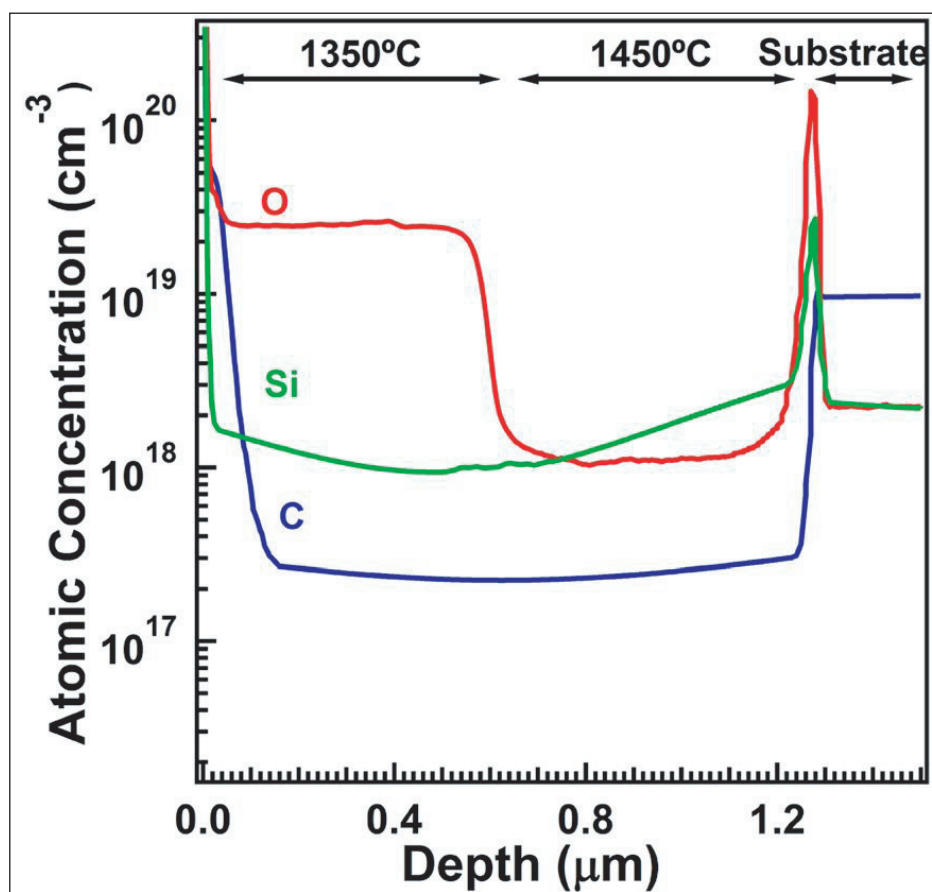
X-ray analysis gave rocking curve full-width at half maximum (FWHM) values between 18 and 25arcsec for the  $(10\bar{1}0)$  peak along the  $[0001]$  direction.

The researchers comment: "These FWHM values are comparable to that of the substrates themselves, demonstrating that the epitaxial layers are of at least the same quality as the substrates. This demonstrates one advantage of using a high-quality native substrate."

The symmetry of the x-ray peaks suggested the absence of strain between the epitaxial layer and substrate. Interference fringes in the curves from difference in carrier density (Pendellösung) suggested an abrupt change in free electron density between the substrate and epitaxial layer.

An epitaxial layer grown below 1350°C showed rough surfaces with RMS values of 8–13nm over  $5\mu\text{m} \times 5\mu\text{m}$  areas. The surfaces also showed preferential faceting in the  $\pm[0001]$  direction. Above 1350°C the surface became atomically smooth, with RMS roughness of less than 0.4nm.

Photoluminescence on 1450°C material showed



**Figure 2.** Calibrated SIMS depth profile for O, Si, and C in a two layer  $1.2\mu\text{m}$  thick  $(1\bar{1}00)$  homo-epitaxial AlN film with 600nm grown at 1450°C followed by 600nm grown at 1350°C.

peaks from donor-bound ( $\text{Si}^0\text{X}$ , 6.012eV) and free ( $\Gamma_1$ , 6.032eV,  $\Gamma_5$ , 6.040eV) excitons (Figure 1). There were also peaks from an oxygen bound exciton ( $\text{O}^0\text{X}$ , 6.006eV), and two unidentified structures at 6.010eV and 6.003eV. The unidentified peaks are not typically seen in  $(0001)$  c-plane epitaxial films.

A two-step process with growth of 600nm at 1450°C followed by 600nm at 1350°C was used to study the impurity content through secondary-ion mass spectrometry (SIMS, Figure 2). The main effect of the higher growth temperature was to reduce the oxygen content by more than an order of magnitude. It was also found that the epitaxial layers had reduced silicon and carbon impurities compared with the substrate.

The researchers compared the oxygen incorporation with 200nm  $(1\bar{1}00)$  m-plane and  $(0001)$  c-plane films grown at 1250°C. The m-plane material had oxygen concentration of  $4 \times 10^{20}/\text{cm}^3$ , compared with just  $3 \times 10^{17}/\text{cm}^2$  for c-plane films.

The researchers comment: "It is clear from this SIMS analysis that  $(1\bar{1}00)$  AlN homo-epitaxial growth at higher temperatures as compared to  $(0001)$  growth is necessary for high-purity epitaxial films, as the impurity incorporation depends on surface morphology." ■

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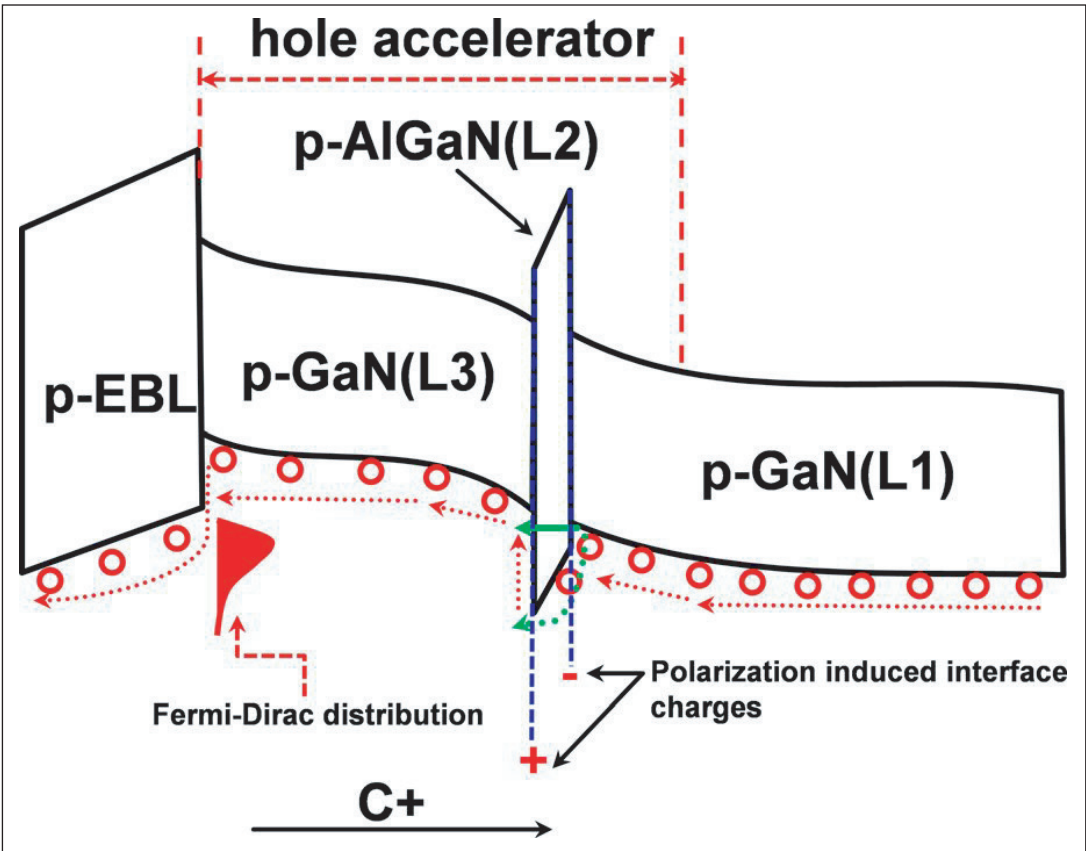
Author: Mike Cooke

# Hot holes for improved injection into nitride LEDs

A new hole accelerator structure aims to boost hole injection over the electron-blocking layer, giving 15% better output power at 100A/cm<sup>2</sup>.

Researchers based in Singapore and Turkey have been developing a hole accelerator structure with a view to improving the performance of indium gallium nitride (InGaN) semiconductor light-emitting diodes (LEDs) [Zi-Hui Zhang et al, Appl. Phys. Lett., vol105, p153503, 2014]. The team was based at Nanyang Technological and Bilkent universities.

The aim of the hole acceleration structure was to improve hole injection over aluminium gallium nitride (AlGaN) electron-blocking layers (EBLs). The purpose of EBLs is to avoid electrons from overshooting the active multiple quantum well (MQW) light-emitting regions. Overshooting electrons end up recombining in the p-type hole injection layers,



**Figure 1. Schematic energy diagram of hole accelerator. Solid green and dashed green arrows illustrate the hole transport through intra-band tunneling and thermionic emission, respectively.**

Hole injector	p-GaN	120nm
Hole accelerator	p-Al <sub>0.25</sub> Ga <sub>0.75</sub> N	3nm
Hole accelerator	p-GaN	80nm
Electron blocking	p-Al <sub>0.20</sub> Ga <sub>0.80</sub> N	25nm
Multiple quantum well	5x(In <sub>0.15</sub> Ga <sub>0.85</sub> N/GaN)	5x(3nm/12nm)
Electron injector	n-GaN (silicon doping)	2µm
Buffer	n-GaN (unintentional doping)	4µm
Buffer	GaN	20nm
Substrate	Sapphire	

**Figure 2. Epitaxial structure for LED B with hole acceleration structure.**



generally non-radiatively, reducing output power and efficiency.

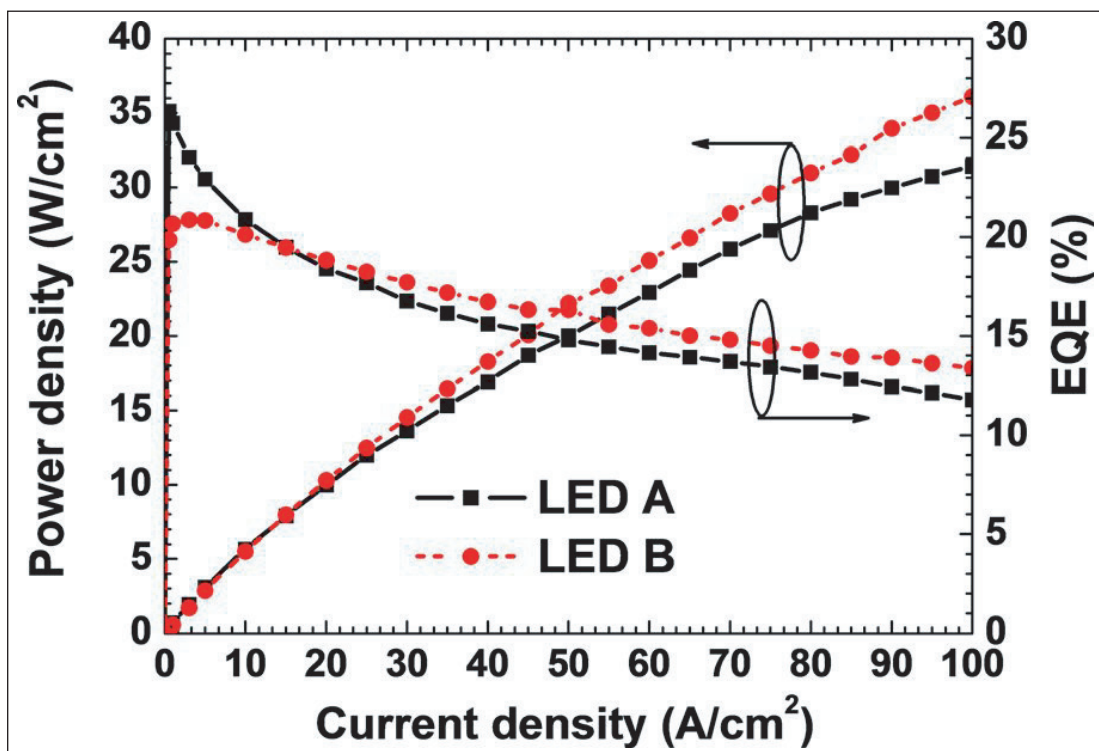
However, EBLs also inhibit hole injection into the MQW, particularly since hole transport and density levels are lower than for electrons. The mobility for holes in p-GaN is typically less than  $10\text{cm}^2/\text{V}\cdot\text{s}$ . By contrast, electron mobility in GaN is around  $440\text{cm}^2/\text{V}\cdot\text{s}$ .

The team therefore designed a structure (Figure 1) that would accelerate holes and allow more to cross the EBL and reach the MQW. The p-type GaN hole injection region was divided in two by a thin layer of p-AlGaN. The AlGaN divider had to be thin to avoid hole blocking.

Polarization-induced AlGaN/GaN interface charges created an electric field in the region up to the EBL that accelerated holes over the barrier and into the MQW. The researchers worked with both simulations and actual LED structures.

The epitaxial structures were grown on c-plane sapphire through metal-organic chemical vapor deposition (MOCVD) — see Figure 2. LED structures with (LED B) and without (LED A) hole accelerator layers were grown after the electron-blocking p-type aluminium gallium nitride (AlGaN) layer (EBL). The device without hole acceleration had 200nm p-GaN after the AlGaN EBL. Bis(cyclopentadienyl)magnesium ( $\text{Cp}_2\text{Mg}$ ) was used as the precursor for the magnesium doping for the p-type layers.

The output power (Figure 3) of the LED B with hole acceleration had 15% higher output power density



**Figure 3. Experimentally measured optical output power density and EQE as function of injection current density for LEDs A and B.**

( $36.1\text{W}/\text{cm}^2$ ) at  $100\text{A}/\text{cm}^2$  current density, compared with LED A ( $31.4\text{W}/\text{cm}^2$ ). The droop at  $100\text{A}/\text{cm}^2$  from maximum external quantum efficiency (EQE) was 54.2% for LED A and 35.9% for LED B. As is usual in such cases, the improvement in efficiency droop from the hole acceleration structure is not as dramatic as these figures suggest — the peak EQE of LED A is somewhat higher than that of LED B. A crossover in EQE occurs at around  $20\text{A}/\text{cm}^2$ .

The researchers comment: "The unimproved optical performance for LED B at the low current injection levels ( $<10\text{A}/\text{cm}^2$ ) is most likely due to the blocking effect by the  $\text{p-Al}_{0.25}\text{Ga}_{0.75}\text{N}$  layer in the hole accelerator region." ■

<http://scitation.aip.org/content/aip/journal/apl/105/15/10.1063/1.4898588>

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# LED makers to raise technology entry level and find new applications to boost profitability in 2015

China rose from 27% to 36% of global LED chip production in 2014, says [LEDinside](#).

**F**or many LED makers, 2014 has been a challenging year, with performance in the first and second halves of the year very polarized for many, notes Roger Chu, research director of LEDinside (a research division of TrendForce). Lighting market demand was stronger than expected in first-half 2014, leading to a period of LED supply shortages, he adds.

Despite the positive development, the industry was impacted by clients double booking plus distributors rising inventory levels during second-half 2014. Many manufacturers were impacted by the market's cooling demand, and consequently price competition. Also, the emergence of Chinese LED makers has led to sliding LED product prices. Hence, LED makers will raise technology entry levels and find new applications in the hope of boosting profitability in 2015, expects Chu.

LEDinside highlights the top five industry trends to watch out for in 2015 as follows.

## 1. Market shares of Chinese LED makers grow; big manufacturers become even larger

LEDinside estimates that 239 new MOCVD systems were installed worldwide in 2014. Some local governments will continue to issue subsidies in China throughout 2015, so more than 170 new MOCVD systems are expected to be installed in China. Overall, LED makers' expansion projects depend on local governments subsidies, hence LED chip manufacturers will grow.

As Chinese LED chip makers improve their technology and scale up production capacity, China's LED chip production has increased from 27% in 2013 to 36% of the global LED chip market in 2014. In the past, Chinese LED backlight and lighting applications have largely relied on Taiwanese or international LED manufacturing, but this is no longer the case. Due to Chinese package manufacturers increasing their usage of domestic LED chips, prices are becoming increasingly competitive, leading to Chinese manufacturers growing their market share in the global LED industry.

## 2. LED lighting clients continue to seek low-cost solutions

Spurred by falling product prices, great LED lighting market demand has emerged. LED bulbs remain the main growth drivers for LED lighting products in 2015, including LED bulbs, tubes and other light source products, says Chu. Therefore, LEDs retail price and costs are often the main factors taken into consideration.

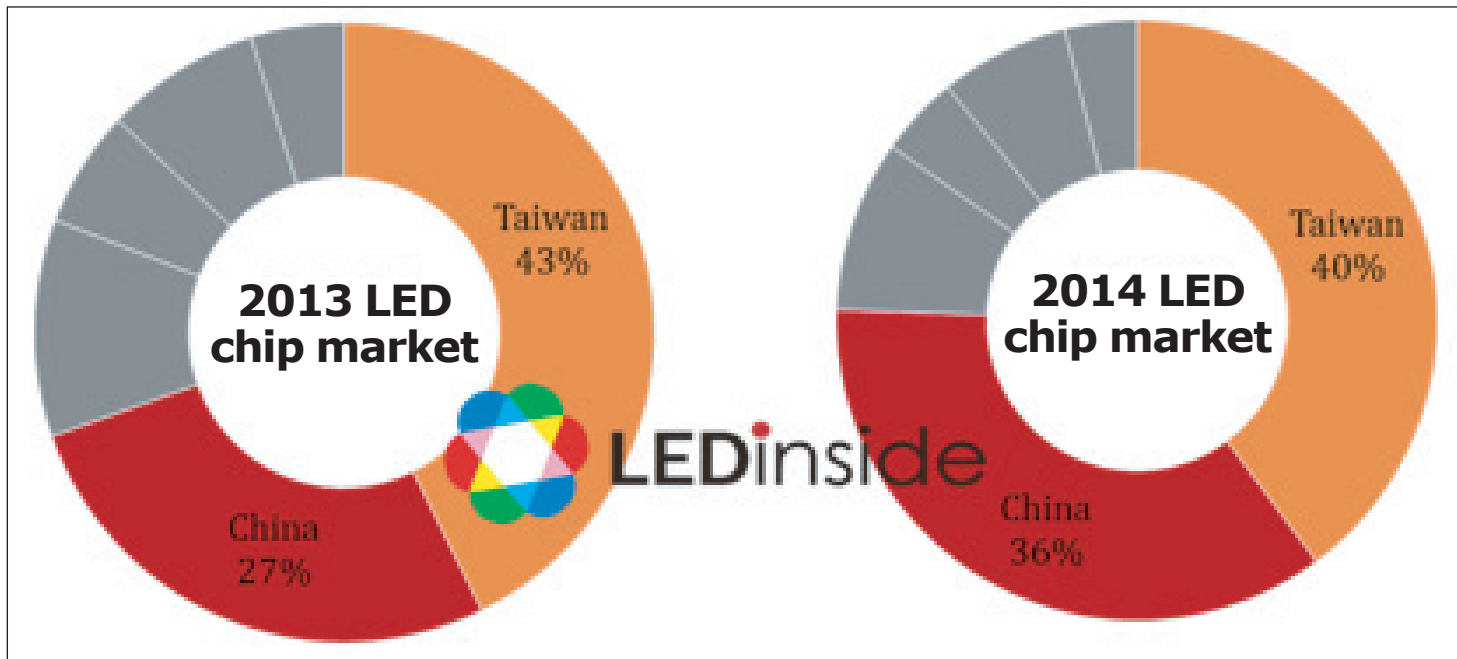
Standard- and mid-power LEDs with a good C/P (cost-to-performance) ratio often meet these LED lighting products' lower price demands — for example, 3030 and 2835 LEDs have become mainstream on the market.

Future LED makers will continue to find better heat dissipation materials, and use high driving currents to reduce the number of LEDs, says Chu. Even chip-on-board (COB) LEDs have gradually attracted attention from lighting manufacturers. Besides lower LED prices, LED lighting manufacturers have also turned their focus to drivers and other components, in the hope of designing total solutions in order to reduce costs.

## 3. Finding special niche applications to raise profitability

Due to intense LED price competition, LED makers hope to find new applications to raise profitability. For example, invisible LED lights including ultraviolet (UV) or infrared (IR) LEDs are gradually becoming valued by LED makers. However, invisible LED lighting remains a niche market, and cannot compare with LED lighting or backlighting application volumes, says LEDinside.

Due to technical difficulties, customized demand and close cooperation with system manufacturers, the market sector has a much higher entry level. Gross margin for invisible LED products is therefore markedly better than that for white LED.



Shares of global LED chip production for Taiwan and China in 2013 and 2014.

#### 4. Growing automotive LED market value; exterior automotive lighting market showing highest growth

The automotive LED market has grown steadily, with daylight running lamps (DRL) and high/low beam lights showing the most significant growth. This is mainly due to automotive LEDs — driven by advances in LED technology and the drop in LED prices — gradually shifting from high-end to mid-class models of car. This will spur automotive lighting demand over the next few years, reckons LEDinside. Additionally, car panels remain the largest LED backlight application in cars. Also, accompanying the spread of multimedia and image sensors, traditional panels have all been changed to LCD panels, spurring demand for automotive backlight.

#### 5. Mobile phones become thinner; smart-phone backlight LED specs turn towards 0.4t

Many manufacturers are trying to upgrade backlight LED specs to counteract price competition. In the case of handheld devices, high-end smart-phones are becoming thinner, with increasingly higher panel reso-

lutions. This challenges LED makers to make thinner and brighter LEDs in 2015. Currently, high-end smart-phones are using 0.4t LEDs as major backlight specs, with a brightness of 2500–2700mcd. In the 4.7" iPhone 6 smart-phone, 10–12 LEDs are used in the backlight modules, since 0.4t and 0.6t LEDs have become thinner, and are now the slimmest LEDs in the mass-production backlight market. On the other hand, package technology has a much higher technology entry level. Korean and Japanese LED makers, such as Nichia, have been the main suppliers for this technology. Furthermore, the 0.4t LED has been introduced into the iPhone 6 backlight, which will even shift towards the thinner 0.3t LED in the future.

As for TV LED backlight specs, raising LED brightness to satisfy the demands of 4K2K panels — and the introduction of the NTSC 100 high color gamut — will also become a development focus for LED makers, forecasts LEDinside. All in all, LED makers will have to figure out ways to upgrade the entry level to have an upper hand in the price war, the firm concludes.

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# Expanding interest in cubic silicon carbide on silicon substrates

**SiC on Si substrates could reduce costs for power electronics and III-nitride LEDs, reports Mike Cooke.**

**S**ilicon carbide (SiC) is widely developed and promoted as a semiconductor material for high-power and high-temperature electronics. Additional advantages

include high thermal conductivity and fast switching speeds. Further, a close lattice match to gallium nitride (GaN) and high thermal conductivity make SiC an attractive substrate for high-power blue and ultraviolet LEDs. The well known drawback of SiC is the high cost of high-quality substrates.

An alternative route to SiC electronics – epitaxial growth on silicon – has been around since the 1990s. This potentially allows large-scale production on wafers up to 300mm diameter, compared with 150mm for bulk SiC substrates offered by commercial suppliers such as Cree of Durham, NC, USA. MTI Corp of Richmond, CA, USA is one commercial supplier of 3C-SiC on Si wafers with a diameter of up to 8-inch (200mm). In 2013, Queensland Micro and Nanotechnology Facility (QMF) of Griffith University in Australia claimed the first 3C-SiC on 300mm Si wafers.

Developers of 3C-SiC on Si see opportunities beyond electronic devices such as micro-electro-mechanical systems (MEMS) and as substrate/buffer layer for the growth of III-nitride materials and graphene. In fact, Linköping University in Sweden found in 2013 that large-area 50µm<sup>2</sup> graphene sublimated on 3C-SiC demonstrated superior uniformity over graphene on 4H- and 6H-SiC. (Linköping has also developed a 3C-SiC growth technology that uses 6H-SiC substrates.)

However, 3C-SiC on Si has a different crystal structure (polytype) from bulk SiC substrates: respectively, cubic – the ‘3C’ – rather than hexagonal 4H/6H (Table 1). Supporters argue that 3C-SiC has many

**Table 1. Some material characteristics of various polytypes of SiC and of Si from [www.ioffe.ru/SVA/NSM/Semicond/SiC/ebasic.html](http://www.ioffe.ru/SVA/NSM/Semicond/SiC/ebasic.html) and [www.ioffe.ru/SVA/NSM/Semicond/Si/electric.html](http://www.ioffe.ru/SVA/NSM/Semicond/Si/electric.html)**

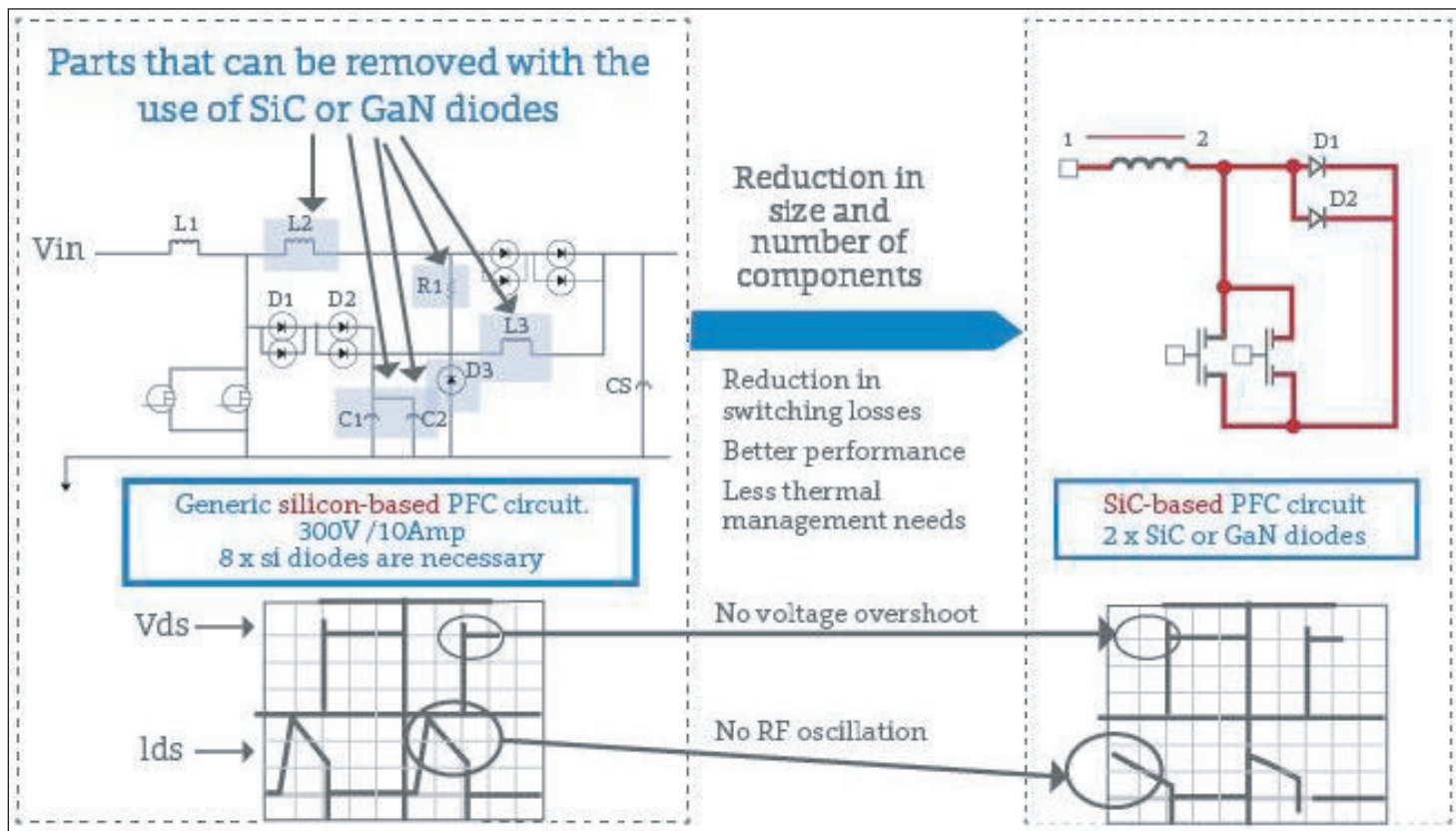
	3C-SiC	4H-SiC	6H-SiC	Si
Breakdown field	10 <sup>6</sup> V/cm	(3–5)×10 <sup>6</sup> V/cm	(3–5)×10 <sup>6</sup> V/cm	3×10 <sup>5</sup> V/cm
Electron mobility	≤800cm <sup>2</sup> /V-s	≤900cm <sup>2</sup> /V-s	≤400cm <sup>2</sup> /V-s	≤1400cm <sup>2</sup> /V-s
Hole mobility	≤320cm <sup>2</sup> /V-s	≤120cm <sup>2</sup> /V-s	≤90cm <sup>2</sup> /V-s	≤450cm <sup>2</sup> /V-s

advantages for MOS device applications due to a smaller energy bandgap, which is associated with higher mobility in general. The electron Hall mobility for 3C-SiC is also not direction dependent (i.e. ‘isotropic’), unlike the mobility in 4H/6H SiC. The narrower bandgap also means a reduced ability to handle high electric fields – a feature not so desirable for power devices.

QMF has been working on low-temperature 3C-SiC/Si for more than 10 years. The facility worked with equipment-making company SPTS Technologies Ltd of Newport, Wales, UK on the reactor for the deposition on 300mm wafers. QMF and SPTS hope that their joint work will lead to a cost-effective buffer for GaN devices on silicon substrates. Cost analyses suggest that the process should add no more than \$35 to the cost of 300mm substrates. QMF claims 1% uniformity in SiC layer thickness across 300mm wafers.

Researchers at QMF and Queensland University of Technology have also explored different ways to reduce surface roughness, such as chemical mechanical polishing (CMP) and plasma etching. In 2014, the team achieved nanometer-scale roughness with CMP removal of 200nm of the 3C-SiC layer. Hydrogen chloride plasma gave a 30% improvement in roughness, sacrificing only 50nm of the 3C-SiC. QMF has also researched potential MEMS and III-nitride applications.

Processing of 3C-SiC needs lower temperatures than for 4H/6H materials. This should allow the use of more standard silicon-like device fabrication, such as room-temperature ion implantation. At the same time, 3C-SiC has an improved critical electric field over silicon,



**Figure 1. Anvil case study — use of 3C-SiC in power factor correctors.**

so that expensive and challenging 'super-junction' processes are not needed.

There are challenges, of course. Standard growth of 3C-SiC on Si through low-pressure chemical vapor deposition (LPCVD) needs substrate temperatures around 1350°C or higher — close to silicon's melting point. High temperature also redistributes dopants and accumulates thermal mismatch stress.

Anvil Semiconductors Ltd of Coventry, UK claims 'unique technology' for growing 3C-SiC on silicon that reduces SiC wafer costs by a factor of 20. The epitaxial process includes patented stress control techniques to overcome lattice and thermal expansion mismatches between 3C-SiC and silicon.

The Anvil technique uses a polycrystalline SiC grid to divide the wafer into squares, reducing the effect of lattice mismatch and thermal expansion. The square crystal SiC regions are still large enough for complex devices. The company has demonstrated thick epitaxial layers up to around 10µm on 100mm-diameter wafers. When stress accumulates in epitaxial processes the wafers tend to bend/bow — Anvil reports that its processed wafers are 'without bow'. The company expects that its process can be readily migrated to 150mm Si wafers and beyond.

The company believes that its process will lead to production of silicon carbide (SiC) power switches at a similar cost to devices on conventional silicon. Vertical Schottky barrier diodes (SBDs) and metal-oxide-semiconductor field-effect transistors

(MOSFETs) with 650V and 1200V ratings can be realized with the material, according to Anvil. Such devices could lead to a reduction in the number and size of components needed in power systems (Figure 1).

Anvil was established in August 2010 based on technology and personnel from Warwick University. In 2013, Anvil secured £1m in funding from a number of investors to accelerate development and commercialization of the technology. The investors were led by the part-EU-funded Low Carbon Innovation Fund (LCIF); other backers were Ntensive, Cambridge Capital Group, Midven and Minerva Business Angels, along with several individuals.

This funding was followed up in 2014 with a grant from the UK Technology Strategy Board (now Innovate UK) to evaluate the feasibility of using Anvil's 3C-SiC/Si technology to enable the production of low-cost, high-brightness LEDs on large-diameter silicon substrates.

Although attempts have been made to grow GaN LEDs directly on silicon, the poor matching of the lattices and thermal expansion coefficients make it difficult to achieve the high-quality material needed for efficient LEDs. Silicon carbide has a better lattice and thermal expansion match with GaN.

Anvil hopes its SiC/Si process will lead to better-quality GaN layers on silicon at low cost. Further, the research team wanted to explore the possibility of producing non-polar cubic (zinc blende) GaN. Normal hexagonal wurtzite GaN has strong spontaneous and strain-dependent (piezoelectric) polarization due to the

partially ionic character of the chemical bond. The polarization can lead to strong electric fields in the III-nitride heterostructures used to make LEDs. These electric fields reduce the recombination of electrons and holes into photons, adversely affecting LED efficiency.

In fact, successful production of cubic GaN on 3C-SiC was announced in December 2014. Anvil and University of Cambridge's Center for GaN report that single-phase GaN was produced on 3C-SiC/Si using metal-organic chemical vapor deposition (MOCVD). "The layers, characterized by XRD, TEM, photoluminescence and AFM, show promise for LED applications," according to Anvil.

Like 3C-SiC, cubic GaN has a narrower bandgap than its hexagonal counterpart (about 0.2eV less, according to [www.ioffe.ru/SVA/NSM/Semicond/GaN/bandstr.html](http://www.ioffe.ru/SVA/NSM/Semicond/GaN/bandstr.html)). Also, holes have improved transport properties in cubic GaN. Poor hole transport has been one of the road-blocks to more efficient GaN LEDs.

University of Cambridge professor Sir Colin Humphreys commented: "This is a very promising development and fits well with our current research activities to develop state-of-the-art LEDs. It has the potential to overcome many of the challenges currently seen for green devices and could contribute significantly to the ongoing solid-state lighting revolution."

Anvil has made a production source agreement with commercial SiC wafer and epitaxy supplier Norstel AB. It announced in September 2014 that its 3C-SiC/Si process had been successfully transferred onto production reactors at Norstel's facilities in Norrköping, Sweden. The move enables the technology to progress to 150mm (6-inch) wafers.

Anvil has also been contributing to a Raytheon-led project developing robust, high-temperature driver circuits for power transistors using low-cost 3C on Si. Part of the funding also comes from the UK Technology Strategy Board. The work has been ongoing from October 2012 to September 2015 at Raytheon's facility in Glenrothes, Scotland, UK. The research is particularly focused on driver circuits for energy-efficient power transistors operating at high temperature that could find application in oil and gas exploration, energy generation and electric vehicles.

Universität Paderborn in Germany has used 3C-SiC on Si substrates for plasma-assisted molecular beam epitaxy (PAMBE) of cubic GaN, AlN and AlGaIn alloys [Donat J. As and Christian Mietze, *Phys. Status Solidi A* 210, p474, 2013]. The researchers developed quantum wells of cubic III-N material with photoluminescence peaks from inter-sub-band transitions in the optical communication 1.3–1.5µm wavelengths. Some of this work used free-standing 3C-SiC substrates (i.e. material with the Si growth substrate removed).

The researchers see the growth of non-polar cubic GaN/AlN multi quantum well (MQW) structures on (001)-oriented substrates that eliminate the detrimental strong spontaneous polarization fields as possibly allowing easier design of complex structures such as for quantum cascade lasers (QCLs).

Italy's Institute for Microelectronics and Microsystems (IMM-CNR) and Catania Epitaxial Technology Center, along with University of Florida in the USA, have tried to improve 3C-SiC quality by surface texturing the silicon growth wafer with inverted square-base pyramids [Francesco La Via, et al, *Journal of Materials Research*, vol28, p94, 2013].

The texturing resulted in stacking faults combining within the first micron of growth, reducing the stacking fault density to  $9.31 \times 10^3/\text{cm}^3$  in 9µm-thick 3C-SiC layers. Lower residual stress in the 3C-SiC samples on textured substrate was attributed to faster stress relaxation during growth.

## Gallium nitride transistors

Researchers in Germany have developed GaN high-electron-mobility transistors (HEMTs) on silicon carbide (SiC) layers on silicon wafers [Wael Jatal et al, *IEEE Electron Device Letters*, published online 11 December 2014]. The ohmic source-drain contacts were gold-free (Au-free) titanium nitride on titanium (TiN/Ti). The researchers came from Technische Universität Ilmenau and Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH (IMMS GmbH).

GaN-based HEMTs are being developed for radio frequency (RF) power amplification, based on high operating frequencies combined with high output power. The best GaN transistors are generally produced on 4H-SiC wafers.

The substrate used by Jatal et al was low-resistivity ( $3\text{m}\Omega\text{-cm}$ ) (111) Si on which 3C-SiC had been deposited. RF applications usually prefer semi-insulating or fully insulating wafers to reduce factors such as substrate leakage and signal cross-talk.

The SiC growth began with 3nm carbonization with ethylene ( $\text{C}_2\text{H}_4$ ) precursor. Further SiC was grown by adding silane ( $\text{SiH}_4$ ) as a silicon chemical vapor deposition (CVD) precursor. MOCVD was then used to apply 100nm aluminium nitride (AlN) as an interlayer, and GaN buffer. The barrier structure consisted of  $\text{Al}_{0.2}\text{Ga}_{0.8}/\text{AlN}$  (design A) or  $\text{Al}_{0.35}\text{Ga}_{0.65}\text{N}$  (design B). The AlGaIn barrier thickness in both cases was 20nm. The AlN spacer between the AlGaIn barrier and GaN buffer of design A was 2nm. The structures were capped with 2nm of GaN.

The epitaxial design A achieved a Hall mobility of  $1760\text{cm}^2/\text{V-s}$ , compared with  $1200\text{cm}^2/\text{V-s}$  for design B. The sheet carrier densities were very similar, at  $7.5 \times 10^{12}/\text{cm}^2$  for design A and  $7.2 \times 10^{12}/\text{cm}^2$  for design B.



The nickel-gold HEMT gate had two fingers of total width  $150\mu\text{m}$ . The gate was centered in the  $2\mu\text{m}$  source-drain gap.

The ohmic contacts for the source-drain regions were applied using magnetron sputtering of titanium. The initial deposition was 20nm of titanium followed by 100nm of titanium nitride. The titanium nitride was formed through reactive magnetron sputtering in an argon/nitrogen atmosphere and annealing at  $850^\circ\text{C}$  in nitrogen.

The specific contact resistance of the Ti/TiN structures was  $\sim 10^{-6}\Omega\text{-cm}^2$ . The contact resistance was  $0.13\Omega\text{-mm}$ . The root-mean-square (rms) roughness was 1.8nm. The researchers claim that their Ti/TiN structure is among the best gold-free structures so far.

The researchers comment:

"We ascribe the low contact resistivity to the conversion of

Ti into TiN causing the formation of nitrogen vacancies in the barrier layer which lead to a high doping level of the AlGaN underneath the contact."

The team carried out a number of characterizations on a 100nm-gate-length device (Table 2). The researchers attribute the improved performance of design A HEMTs to reduced alloy scattering due to the AlN spacer layer.

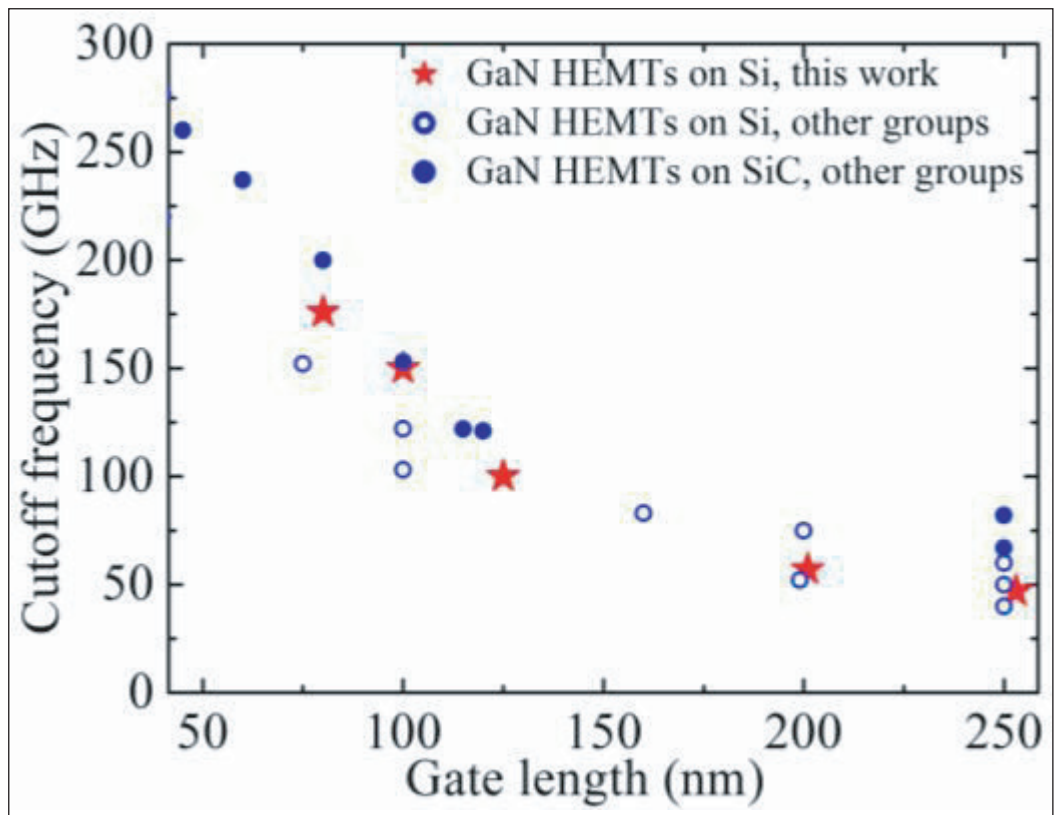
RF measurements were carried out between 0.1GHz and 50GHz. Using extrapolations and de-embedding corrections, the cut-off frequency ( $f_T$ ) for an 80nm-gate HEMT at 20V drain bias and  $-2.75$  gate potential was estimated to be 176GHz. The maximum oscillation frequency ( $f_{\text{max}}$ ) was 70GHz. The low  $f_{\text{max}}$  was blamed on the simple rectangular gates and low-resistance substrate that was used. "Significant improvements of  $f_{\text{max}}$  can be expected by using mushroom gates with

reduced gate resistance and high-resistivity substrates", the team writes.

By contrast, the best 80nm-gate  $\text{Al}_{0.35}\text{Ga}_{0.65}\text{N}/\text{GaN}$  HEMTs demonstrated a poor  $f_T$  of only 115GHz at 20V drain voltage. HEMTs on SiC can achieve  $f_T$  values of 200GHz with a 75nm gate length. The corresponding value for GaN HEMTs on silicon is 152GHz.

Comparing their results with those of others (Figure 1), the researchers comment: "It can be seen that our 80nm-gate HEMT shows competitive  $f_T$  performance compared to GaN HEMTs on Si (with Au-based and Au-free contacts) reported by other groups. Moreover, our GaN HEMTs on Si with barrier design A rival successfully the best reported GaN HEMTs on SiC substrates in the 80–125nm gate length range." ■

Author: Mike Cooke



**Figure 2. Comparison of cutoff frequencies of GaN HEMTs on Si with AlGa barrier design A with best data reported by other groups for GaN HEMTs on Si and on SiC.**

**Table 2. Results of DC and RF characterization of 100nm-gate HEMTs. DC measurements at 10V drain-source voltage ( $V_{\text{DS}}$ ): maximum drain current ( $I_D$ ) and peak transconductance ( $g_m$ ). On resistance ( $R_{\text{on}}$ ) measured at low drain voltage with zero gate potential. Also shown are contact resistance ( $R_c$ ), sheet resistance ( $R_s$ ), specific contact resistance ( $\rho_c$ ), and cut-off frequencies ( $f_T$ ) at 10V and 20V  $V_{\text{DS}}$  ( $-2.75\text{V}$  gate potential).**

Barrier design	$I_D$	$g_m$	$R_{\text{on}}$	$R_c$	$R_s$	$\rho_c$	$f_T$ at 10V	$f_T$ at 20V
A	1.13A/mm	388mS/mm	0.9 $\Omega$ -mm	0.13 $\Omega$ -mm	169 $\Omega$ /sq	$1 \times 10^{-6}\Omega\text{-cm}^2$	115GHz	150GHz
B	0.95A/mm	360mS/mm	1.6 $\Omega$ -mm	0.6 $\Omega$ -mm	365 $\Omega$ /sq	$1 \times 10^{-5}\Omega\text{-cm}^2$	79GHz	107GHz

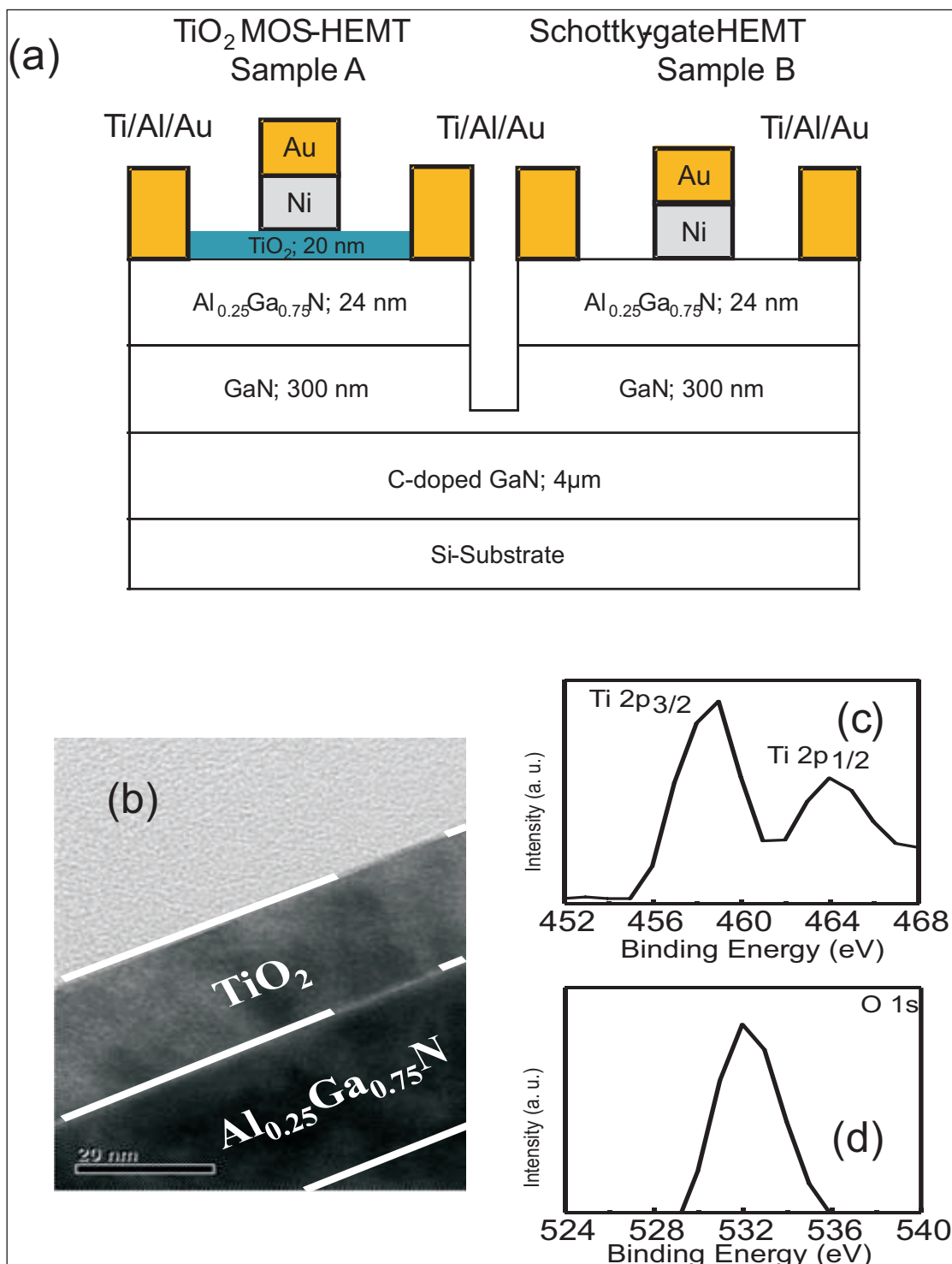
# First application of low-cost deposition of titanium dioxide for GaN MOS-HEMT

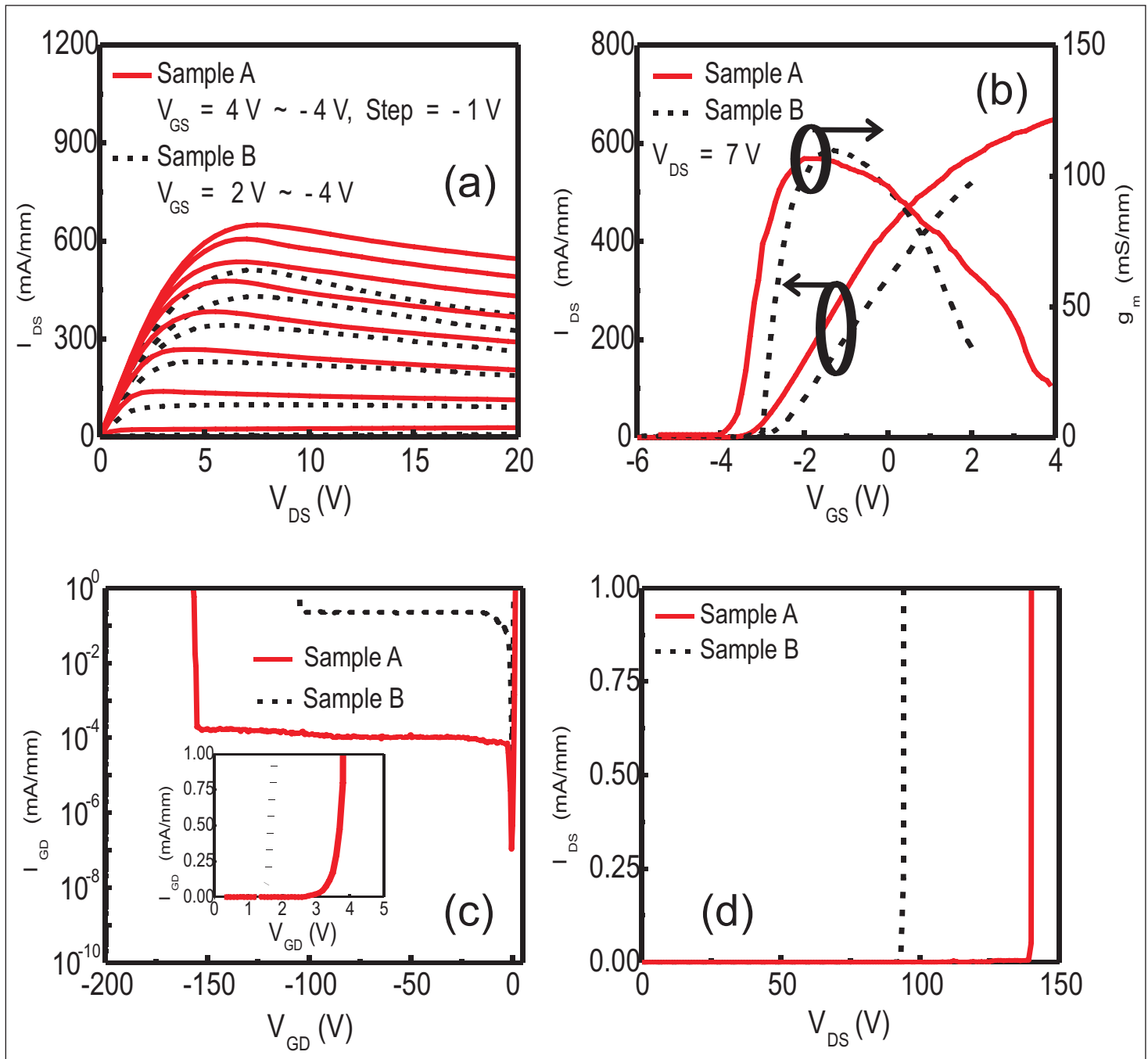
Ultrasonic spray pyrolysis deposition has been used to create devices with promising performance characteristics.

**R**esearchers in Taiwan have used ultrasonic spray pyrolysis deposition (USPD) "for the first time" to apply titanium dioxide ( $\text{TiO}_2$ ) high-k dielectric layers to aluminium gallium nitride ( $\text{Al}_{0.25}\text{Ga}_{0.75}\text{N}/\text{GaN}$ ) metal-oxide-semiconductor high-electron-mobility transistors (MOS-HEMTs) [Bo-Yi Chou et al, IEEE Electron Device Letters, published online 17 September 2014].

The team — from National Cheng Kung University, Feng Chia University, and Industrial Technology Research Institute — sees USPD as an economical deposition method. In particular, the non-vacuum process environment and high deposition rate make USPD suitable for low-cost large-area deposition and other mass-production scenarios.

**Figure 1. (a) Schematic diagram of  $\text{AlGaN}/\text{GaN}$  MOS-HEMT, (b) transmission electron microscope photo of MOS-gate structure, and (c) electron spectroscopy for chemical analysis (ESCA) intensities.**





**Figure 2. (a) Common-source  $I_{DS}$ - $V_{DS}$  curves, (b) transfer  $g_m/I_{DS}$ , (c) two-terminal off-state  $I_{GD}$ - $V_{GD}$ , and (d)  $BV_{DS}$  characteristics at 300K.**

USPD has previously been used to create aluminium oxide dielectric layers for GaN MOS-HEMTs.  $TiO_2$  has a higher dielectric constant of 86–173, compared with  $\sim 10$  for aluminium oxide.

The epitaxial structure was grown using

**The non-vacuum process environment and high deposition rate make USPD suitable for low-cost large-area deposition... USPD has previously been used to create aluminium oxide dielectric layers for GaN MOS-HEMTs.  $TiO_2$  has a higher dielectric constant of 86–173, compared with  $\sim 10$  for aluminium oxide**

low-pressure metal-organic chemical vapor deposition (LP-MOCVD) on silicon (see Figure 1). The MOS-HEMT fabrication involved mesa etching for electrical isolation, titanium/aluminium/gold deposition and annealing for ohmic source-drain contacts, 20nm  $TiO_2$  USPD for gate insulation, exposure of the source-drain electrodes, and nickel/gold deposition for the gate electrode. A reference Schottky-gate device was produced without  $TiO_2$  dielectric.

The gate length and width were  $1\mu m$  and  $100\mu m$ , respectively. The gate-source and gate-drain spacings were both  $2\mu m$ .

Hall measurements before and after  $TiO_2$  USPD gave carrier densities of  $2.08 \times 10^{13}/cm^2$  and  $2.41 \times 10^{13}/cm^2$ ,



Table 1. Comparison of MOS-HEMT and Schottky HEMT.

	MOS-HEMT	Schottky HEMT
Maximum drain current	650mA/mm	511mA/mm
Maximum drain current at 0V gate	384mA/mm	342mA/mm
Peak transconductance	107mS/mm	110mS/mm
Gate voltage swing	2.7V	1.7V
Two-terminal gate-drain breakdown voltage (BV <sub>GD</sub> )	-155V	-105V
On voltage	3.8V	1.8V
On-state breakdown (BV <sub>DS</sub> )	139V	94V
On/off current ratio	4.5x10 <sup>5</sup>	3.5x10 <sup>2</sup>

respectively. The mobility slightly decreased, respectively, from 883cm<sup>2</sup>/V-s to 872cm<sup>2</sup>/V-s. The product of carrier density and mobility was increased from 1.84x10<sup>16</sup>/v-s to 2.1x10<sup>16</sup>/V-s, leading to expectations of increased on-current with TiO<sub>2</sub> gate insulation/passivation.

Capacitance versus voltage (CV) measurement gave an oxide capacitance of 190pF and a dielectric constant (k) of 53.6, lower than the range quoted above. The composition of the USPD 'TiO<sub>2</sub>' was estimated as a Ti/O ratio of 0.47, which is slightly off the 0.5 for exact TiO<sub>2</sub>. The equivalent oxide thickness (EOT) of the 20nm TiO<sub>2</sub> layer was estimated at 1.45nm.

**The threshold voltage of the MOS-HEMT was negative (normally-on, depletion-mode) at -3.9V. At zero gate potential the maximum drain current (I<sub>DSS0</sub>) was 384mA/mm for the MOS-HEMT and 342mA/mm for the Schottky HEMT. The researchers also compared their devices with those produced using different TiO<sub>2</sub> deposition techniques. USPD gave "the best improvement [over Schottky-based devices] of I<sub>DS</sub> at V<sub>GS</sub> = 0V (ΔI<sub>DSS0</sub>) of 12.3%, the highest G<sub>VS</sub> linearity of 2.7V, enhanced gm,max, and superior low I<sub>GD</sub> leakage".**

The electrical performance between the devices was compared, generally showing improved performance of the MOS-HEMT over the Schottky HEMT (see Figure 2 and Table 1). The maximum drain current (I<sub>DS</sub>) of the MOS-HEMT was 650mA/mm. The peak transconductance (g<sub>m,max</sub>) was 107mS/mm. The reference Schottky HEMT had corresponding performance values of 511mA/mm and 110mS/mm. The increased gate-channel separation in the MOS-HEMT device only slightly decreased the peak transconductance due to use of TiO<sub>2</sub> as a high-k dielectric with its 1.45nm EOT.

The gate voltage swing (G<sub>VS</sub>) linearity for transconductance within 90% of the peak value was 2.7V for the MOS-HEMT, compared with 1.7V for the Schottky HEMT.

The threshold voltage of the MOS-HEMT was negative (normally-on, depletion-mode) at -3.9V. At zero gate potential the maximum drain current (I<sub>DSS0</sub>) was 384mA/mm for the MOS-HEMT and 342mA/mm for the Schottky HEMT.

The researchers also compared their devices with those produced using different TiO<sub>2</sub> deposition techniques (Table 2), commenting that USPD gave "the best improvement [over Schottky-based devices] of I<sub>DS</sub> at V<sub>GS</sub> = 0V (ΔI<sub>DSS0</sub>) of 12.3%, the highest G<sub>VS</sub> linearity of 2.7V, enhanced g<sub>m,max</sub>, and superior low I<sub>GD</sub> leakage". ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6901258>

Author: Mike Cooke

Table 2. Comparisons with other TiO<sub>2</sub>-dielectric MOS-HEMTs.

Oxidation technique	USPD	Liquid phase deposition	Molecular beam epitaxy	Evaporation
Gate length	1μm	1μm	0.7μm	0.5μm
Dielectric constant, k	53.6	24.4	70	80
ΔI <sub>DSS0</sub>	12.3%	-7.8%	-6%	-67%
Δg <sub>m,max</sub>	-2.7%	-1%	-20.9%	-50%
g <sub>m,max</sub>	(110mA/mm)	(99mA/mm)	(140mA/mm)	(60mA/mm)
G <sub>VS</sub> (V)	2.7V	2.2V	2V	2.4V
I <sub>GD</sub> @ V <sub>GD</sub> -50V	1x10 <sup>-4</sup> mA/mm	1x10 <sup>-4</sup> mA/mm	8x10 <sup>-3</sup> mA/mm	





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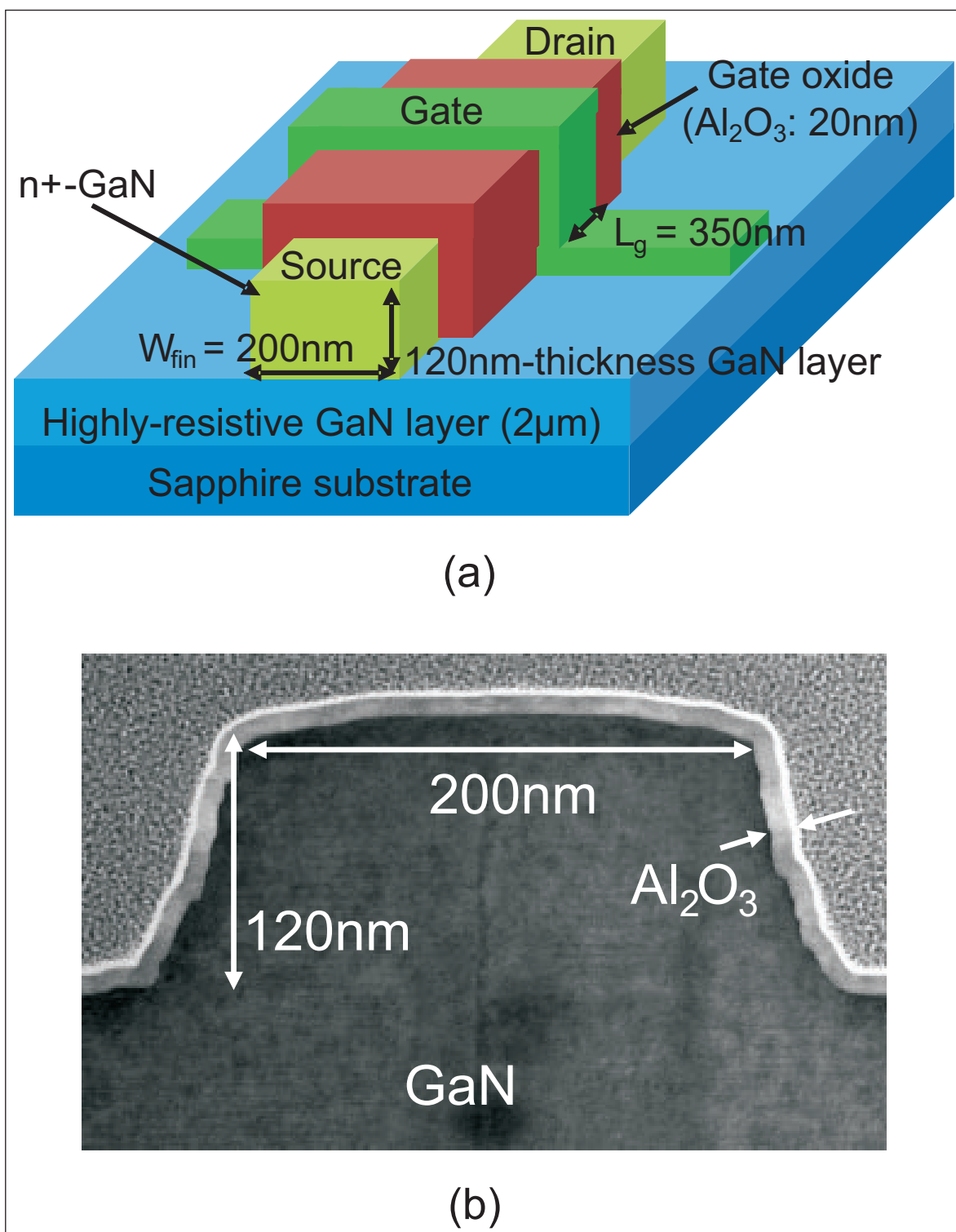
# RF performance of junctionless trigate GaN FETs

**Researchers report the first small-signal model parameter extraction for such devices.**

**R**esearchers based in Korea and France have measured the first high-frequency performance of gallium nitride (GaN) junctionless trigate field-effect transistors (JL TGFETs) [Ki-Sik Im et al, Jpn. J. Appl. Phys., vol53, p118001, 2014]. The work enabled the team from Kyungpook National University, Gachon University, Samsung Electronics Co Ltd and Grenoble Polytechnic Institute to create the first RF models for such devices.

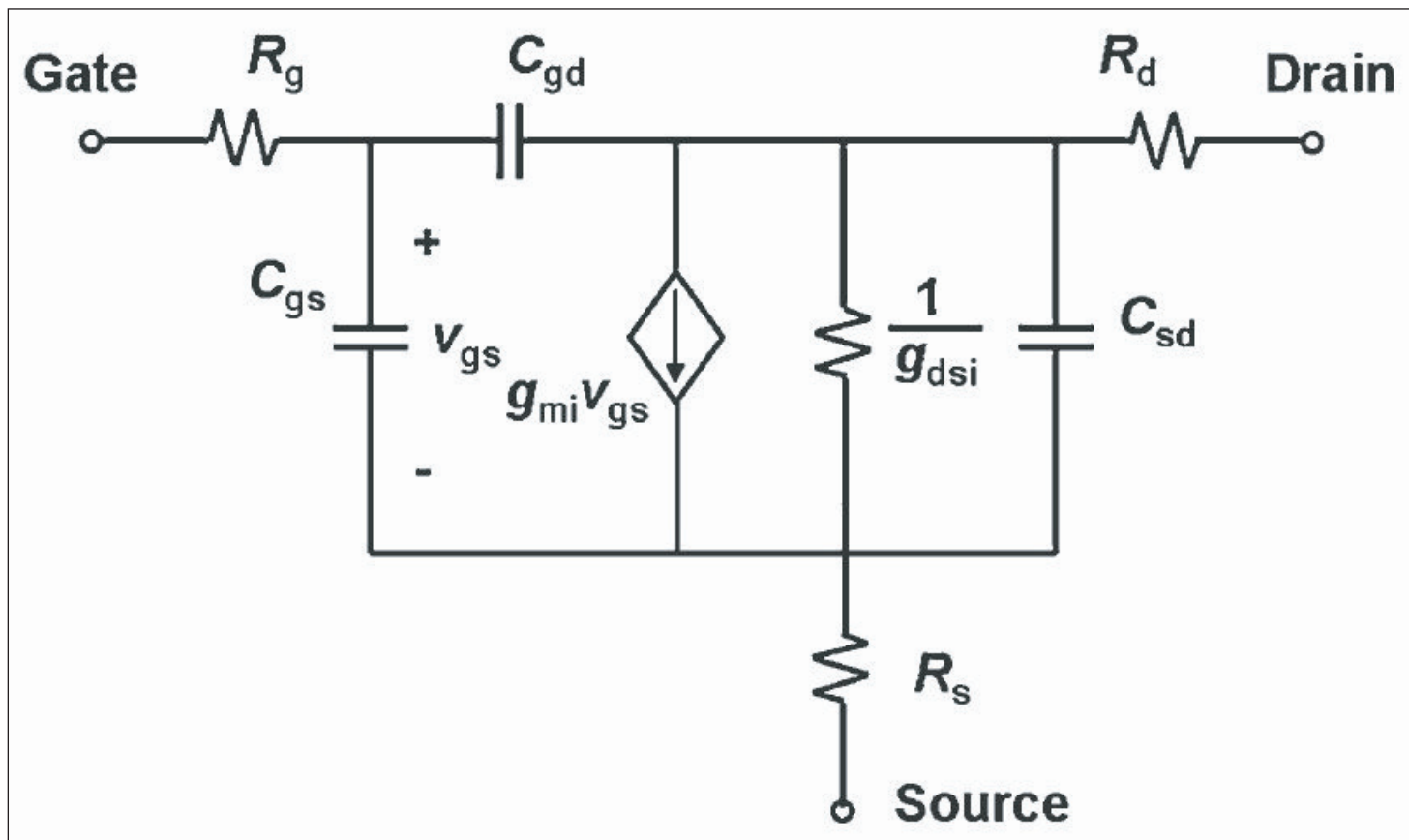
Unlike the usual structure for GaN transistors, the JL TGFETs used only epitaxial GaN rather than a heterostructure of gallium nitride and aluminium gallium nitride.

The junctionless (JL) trigate field-effect transistors (TGFETs) were fabricated on sapphire (Figure 1), based on a design presented and fabricated in 2013. The devices consisted of five fin channels in parallel.



**Figure 1. Device structure. (a) Schematic view. (b) Cross-sectional TEM image of fabricated GaN JL TGFET.**





**Figure 2. Small-signal equivalent circuit for extracting RF parameters from GaN JL TGFET in on-state.**

The maximum transconductance at  $-4.5\text{V}$  gate potential was  $123.6\text{mS/mm}$ . The maximum drain current was  $403\text{mA/mm}$ .

The threshold voltage of the device was  $-5.8\text{V}$ . Although these were depletion-mode normally-on transistors, the researchers believe that the more desirable enhancement-mode normally-off behavior could be achieved with suitable gate metals and device geometry.

With  $-4.5\text{V}$  gate potential and  $10\text{V}$  drain bias, the cut-off ( $f_T$ ) and maximum oscillation ( $f_{\text{max}}$ ) frequencies were  $2.45\text{GHz}$  and  $9.75\text{GHz}$ , respectively. These values are as-measured without de-embedding the effect of parasitic passive components.

The researchers also developed an RF model for the device (Figure 2, Table 1), which suggested that the

**Table 1. Summary of RF parameters extracted for GaN JL TGFET.**

$R_g$	$150.3\Omega$
$R_s$	$102.2\Omega$
$R_d$	$101.6\Omega$
$g_{\text{dsi}}$	$58.5\mu\text{S}$
$g_{\text{mi}}$	$0.292\text{mS}$
$C_{\text{gs}}$	$22.4\text{fF}$

source and drain resistances were about  $100\Omega$ . The team believes that "The model verification results and high-frequency performances of the GaN JL TGFET confirm its strong potential for application to RF ICs." ■

<http://iopscience.iop.org/1347-4065/53/11/118001>

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# Diamond transistor achieves 1530V breakdown voltage

**Researchers in Japan have more than doubled the breakdown voltages previously achieved for diamond-based transistors.**

**J**apan's National Institute of Advanced Industrial Science and Technology (NAIST) has claimed the highest breakdown voltage to date for a diamond metal-semiconductor field-effect transistor (MESFET) [Hitoshi Umezawa et al, IEEE Electron Device Letters, published online 25 September 2014].

In principle, diamond transistors should benefit from high breakdown electric field, high thermal conductivity, low dielectric constant and high bulk carrier mobility. Such material properties could lead to high performance in terms of high-power and low-loss or high-power and high-frequency electronics.

High-temperature operation was also explored with a view to reducing or eliminating the need for complex and expensive thermal management.

The MESFETs were fabricated from microwave plasma-assisted chemical vapor deposition (MWCVD) p-type epitaxial material on semi-insulating Ib (001) synthetic diamond substrate (Figure 1). The carbon source was methane and the light p-type dopant was boron.

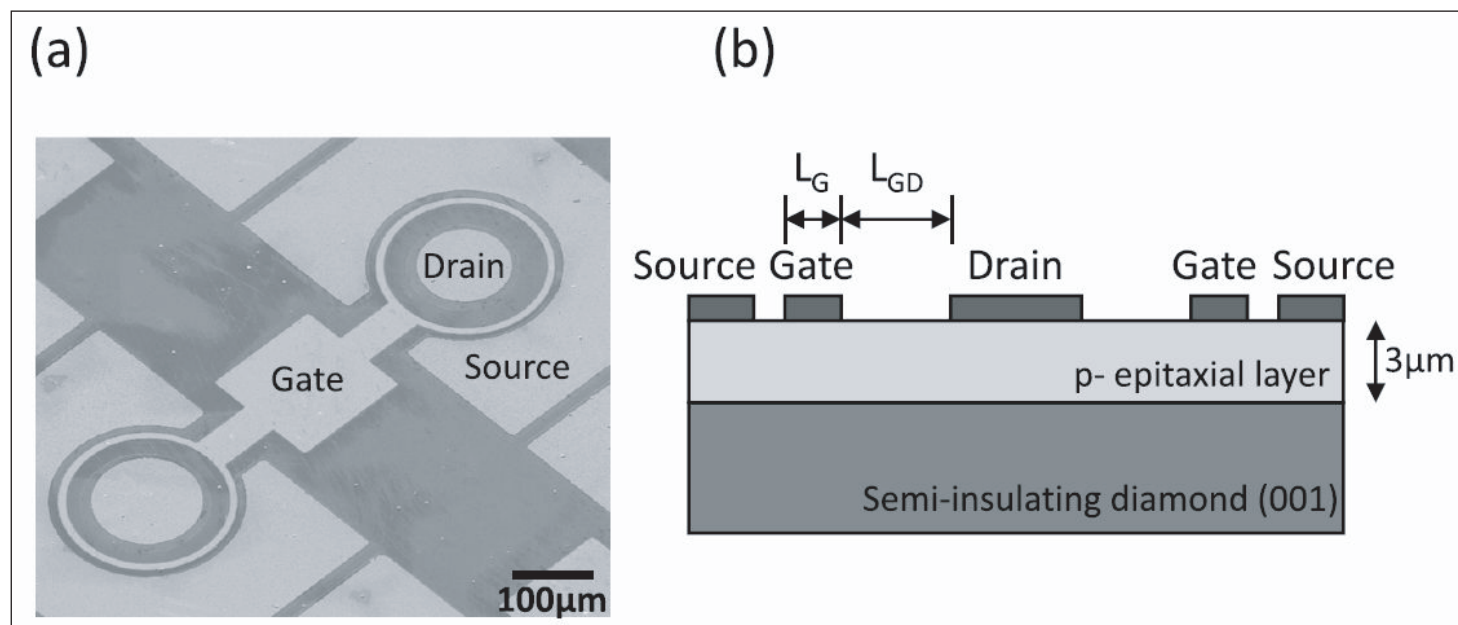
The researchers describe the boron doping as 'unintentional' at the level of  $\sim 10^{15}$  atoms per cubic centimeter. The low doping level was aimed at preventing degradation of film quality and the Schottky contact.

The transistors were formed in circular 'Corbino type' configurations, with the ohmic drain contact in the center, the source contact on the outside, and the Schottky gate as a thin annulus between the source and drain. The ohmic metals were titanium gold.

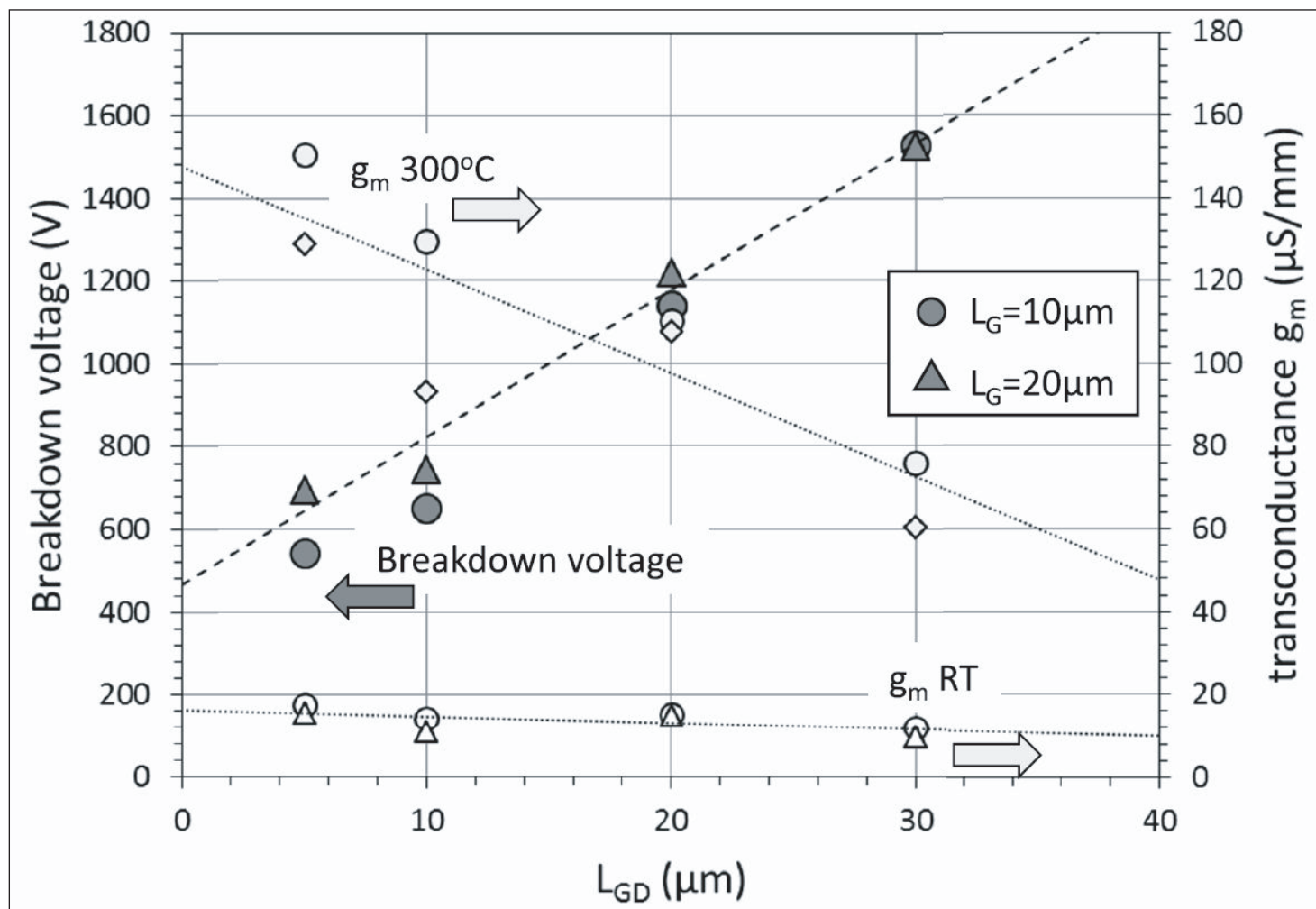
The Schottky gate metal stack consisted of platinum/gold multi-layers. The gate region was exposed to ultraviolet light in ozone before the gate metal deposition. The pre-treatment was designed to give a stable oxygen termination of the surface bonds of the epitaxial layer.

The source-gate distance was fixed at  $5\mu\text{m}$ . The gate length and gate-drain distance were varied to allow optimization of various performance characteristics.

The maximum drain current and peak transconductance of  $20\mu\text{m}$ -gate-length devices (gate-drain  $30\mu\text{m}$ ) both increased as the temperature was raised from room temperature to  $300^\circ\text{C}$ . The drain currents were  $-0.06\text{mA/mm}$  and  $-1.23\text{mA/mm}$ , respectively. The corresponding transconductances were  $9.7\mu\text{S/mm}$  and  $61\mu\text{S/mm}$ . The increase in current is attributed to greater thermal activation of holes from the boron acceptor levels at  $0.36\text{eV}$  ( $360\text{meV} \gg 26\text{meV}$  gives low carrier density at room temperature). Another factor boosting the drive current, suggest the



**Figure 1. (a) Top view showing two linked diamond MESFETs with Corbino geometry and (b) cross-sectional schematic.**



**Figure 2. Breakdown voltage and transconductance of diamond MESFETs as a function of gate-drain distance ( $L_{GD}$ ) for gate lengths ( $L_G$ ) of 10  $\mu\text{m}$  and 20  $\mu\text{m}$ .**

researchers, is lower ohmic contact resistance at high temperature.

Analyzing the parasitic resistances, the researchers extracted intrinsic values for the transconductance of 143  $\mu\text{S/mm}$  at 300°C (4.9x the value of 29  $\mu\text{S/mm}$  at room temperature).

The researchers say that improved current response would require reduced gate lengths, parasitic resistance in the source-gate gap, and ohmic contact resistance.

The threshold voltage of the device was 2.7V. The on/off current ratio was  $\sim 10^7$  at room temperature, reducing to  $\sim 10^3$  at 300°C. The much poorer ratio at 300°C was attributed to increased gate leakage (even under reverse bias) of the Schottky junction.

**The 1530V breakdown voltage is "the highest for a diamond FET reported to date". Previously, breakdown voltages in diamond transistors have been limited to less than 700V. The 1530V breakdown performance is almost comparable to that achieved in GaN-based devices**

The breakdown was assessed with a 50V gate potential to reduce leakage currents. A number of 20  $\mu\text{m}$ -gate-length devices were tested. With a 30  $\mu\text{m}$  gate-drain distance, breakdown occurred at 1530V (2.5x higher than for a device reported in February 2014). The researchers claim that the 1530V breakdown voltage is "the highest for a diamond FET reported to date". Previously, breakdown voltages in diamond transistors have been limited to less than 700V. The 1530V breakdown performance is almost comparable to that achieved in gallium nitride (GaN)-based devices.

After breakdown had occurred once, subsequent testing showed more than 30% degradation in breakdown voltage due to critical damage. Estimates of the critical electric field for breakdown were higher than the critical field for silicon, but were also 5–10x lower than the ideal value for diamond, suggesting room for improvement. One way to improve field profiles — reducing spikes and thus increase breakdown voltages — is to use field plates. ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6910291>

Author: Mike Cooke



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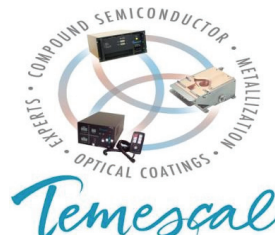


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Programmentwicklungen)**Bregstrasse 90, D-78120  
Furtwangen im Schwarzwald,  
Germany

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)

## 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)

### **Materion Advanced Materials Group**

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**

2700 Augustine Drive, Suite 110,  
Santa Clara, CA 95054,  
USA

Tel: +1 408 748 0100

Fax: +1 408 748 0111

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

## 17 Assembly/packaging foundry

### **Quik-Pak**

10987 Via Frontera,  
San Diego, CA 92127, USA

Tel: +1 858 674 4676

Fax: +1 8586 74 4681

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

## 18 Chip foundry

### **Compound Semiconductor Technologies Ltd**

Block 7, Kelvin Campus,  
West of Scotland, Glasgow,  
Scotland G20 0TH,  
UK

Tel: +44 141 579 3000

Fax: +44 141 579 3040

[www.compoundsemi.co.uk](http://www.compoundsemi.co.uk)

### **United Monolithic Semiconductors**

Route departementale 128,  
BP46, Orsay, 91401,  
France

Tel: +33 1 69 33 04 72

Fax: +33 169 33 02 92

[www.ums-gaas.com](http://www.ums-gaas.com)

## 19 Facility equipment

### **MEI, LLC**

3474 18th Avenue SE,  
Albany, OR 97322-7014,  
USA

Tel: +1 541 917 3626

Fax: +1 541 917 3623

[www.marlerenterprises.net](http://www.marlerenterprises.net)

## 20 Facility consumables

### **W.L. Gore & Associates**

401 Airport Rd, Elkton,  
MD 21921-4236,  
USA

Tel: +1 410 392 4440

Fax: +1 410 506 8749

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

## 21 Computer hardware & software

### **Ansoft Corp**

4 Station Square, Suite 200,  
Pittsburgh, PA 15219, USA

Tel: +1 412 261 3200

Fax: +1 412 471 9427

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

### **Crosslight Software Inc**

121-3989 Henning Dr.,  
Burnaby, BC, V5C 6P8, Canada

Tel: +1 604 320 1704

Fax: +1 604 320 1734

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

**Semiconductor Technology Research Inc**

10404 Patterson Ave., Suite 108,  
Richmond, VA 23238,  
USA

Tel: +1 804 740 8314  
Fax: +1 804 740 3814

[www.semitech.us](http://www.semitech.us)

**22 Used equipment****Class One Equipment Inc**

5302 Snapfinger Woods Drive,  
Decatur, GA 30035, USA

Tel: +1 770 808 8708  
Fax: +1 770 808 8308

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

**23 Services****Henry Butcher International**

Brownlow House, 50-51

High Holborn, London WC1V 6EG,  
UK

Tel: +44 (0)20 7405 8411  
Fax: +44 (0)20 7405 9772

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

**M+W Zander Holding AG**

Lotterbergstrasse 30,  
Stuttgart,  
Germany

Tel: +49 711 8804 1141  
Fax: +49 711 8804 1950

[www.mw-zander.com](http://www.mw-zander.com)

**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****Al Shultz Advertising Marketing for Advanced Technology Companies**

1346 The Alameda,  
7140 San Jose, CA 95126, USA  
Tel: +1 408 289 9555

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

**SEMI Global Headquarters**

3081 Zanker Road,  
San Jose, CA 95134, USA

Tel: +1 408 943 6900  
Fax: +1 408 428 9600

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

**Yole Développement**

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69006 Lyon, France

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**27–29 January 2015**

## **2015 DOE Solid-State Lighting (SSL) R&D Workshop**

San Francisco, CA, USA

**E-mail:** [solidstate@yesevents.com](mailto:solidstate@yesevents.com)

**http://energy.gov/eere/ssl/ssl-rd-workshop**

**28–30 January 2015**

## **Euro - TMCS I (Theory, Modelling and Computational Methods for Semiconductors, European Session)**

University of Granada, Spain

**E-mail:** [info@tmcsuk.org](mailto:info@tmcsuk.org)

**www.tmcsuk.org/conferences/Euro-TMCSI**

**4–6 February 2015**

## **SEMICON Korea 2015**

COEX, Seoul, Korea

**E-mail:** [semiconkorea@semi.org](mailto:semiconkorea@semi.org)

**www.semiconkorea.org**

**7–12 February 2015**

## **SPIE Photonics West 2015**

Moscone Center San Francisco, CA, USA

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)

**http://spie.org/photonics-west.xml**

**24–26 February 2015**

## **Strategies in Light**

Sands Expo & Convention Center, Las Vegas, NV, USA

**E-mail:** [registration@pennwell.com](mailto:registration@pennwell.com)

**www.strategiesinlight.com**

**2–5 March 2015**

## **LED China 2015**

China Import and Export Fair Complex, Area B,  
Pazhou, Guangzhou, China

**E-mail:** [led-trust@ubm.com](mailto:led-trust@ubm.com)

**www.LEDChina-gz.com**

**17–19 March 2015**

## **SEMICON China 2015**

Shanghai New International Expo Centre, China

**E-mail:** [semichina@semi.org](mailto:semichina@semi.org)

**www.semiconchina.org**

**22–26 March 2015**

## **Optical Fiber Communication Conference & Exposition (OFC 2015)**

Los Angeles Convention Center, CA, USA

**E-mail:** [info@ofcconference.org](mailto:info@ofcconference.org)

**www.ofcconference.org**

**31 March – 1 April 2015**

## **Intersolar China 2015**

China International Exhibition Center (CIEC), Beijing,  
China

**E-mail:** [maas@intersolarchina.com](mailto:maas@intersolarchina.com)

**www.intersolarchina.com**

**13–15 April 2015**

## **CPV-11 (11th International Conference on Concentrator Photovoltaics)**

Aix-les-Bains, France

**E-mail:** [info@cpv-11.org](mailto:info@cpv-11.org)

**www.cpv-11.org**

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**13–16 April 2015****SPIE Optics + Optoelectronics 2015**

Clarion Congress Hotel, Prague, Czech Republic

**E-mail:** [info@spieurope.org](mailto:info@spieurope.org)**http://**[spie.org/optics-optoelectronics.xml](http://spie.org/optics-optoelectronics.xml)**20–25 April 2015****SPIE DSS 2015 (SPIE Defense + Security and SPIE Sensing Technology + Applications)**

Baltimore Convention Center, Maryland, USA

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)**http://**[spie.org/defense-security-sensing.xml](http://spie.org/defense-security-sensing.xml)**20–25 April 2015****4<sup>th</sup> Optical Interconnects conference (OI 2015)**

San Diego, CA, USA

**E-mail:** [m.figueroa@ieee.org](mailto:m.figueroa@ieee.org)**www.**[oi-ieee.org](http://www.oieee.org)**22–24 April 2015****SEMICON Southeast Asia 2015**

SPICE Arena, Penang, Malaysia

**E-mail:** [skoh@semi.org](mailto:skoh@semi.org)**www.**[semiconsea.org](http://www.semiconsea.org)**10–15 May 2015****Conference on Lasers and Electro-Optics (CLEO 2015)**

San Jose Convention Center, CA, USA

**E-mail:** [custserv@osa.org](mailto:custserv@osa.org)**www.**[cleoconference.org](http://www.cleoconference.org)**18 May 2015****2015 ROCS: Reliability of Compound Semiconductors Workshop**

Hyatt Regency Scottsdale Resort, AZ, USA

Abstract deadline: 2 March 2015

**E-mail:** [Peter.Ersland@macomtech.com](mailto:Peter.Ersland@macomtech.com)**www.**[jedec.org/home/gaas](http://www.jedec.org/home/gaas)**18–21 May 2015****CS MANTECH 2015: International Conference on Compound Semiconductor Manufacturing Technology**

Hyatt Regency Scottsdale Resort &amp; Spa at Gainey, Scottsdale, AZ, USA

**E-mail:** [conferencechairman@gaasmantech.org](mailto:conferencechairman@gaasmantech.org)**www.**[csmantech.org](http://www.csmantech.org)**7–10 June 2015****16th European Workshop on Metalorganic Vapour Phase Epitaxy (EW MOVPE 2015)**

Lund, Sweden

**E-mail:** [ewmovpe2015@ftf.lth.se](mailto:ewmovpe2015@ftf.lth.se)**www.**[nano.lth.se/ewmovpe2015](http://www.nano.lth.se/ewmovpe2015)**15–19 June 2015****2015 Symposia on VLSI Technology and Circuits**

Rihga Royal Hotel, Kyoto, Japan

**E-mail:** [vlsi@vlsisymposium.org](mailto:vlsi@vlsisymposium.org)**www.**[vlsisymposium.org](http://www.vlsisymposium.org)**16–18 June 2015****SEMICON Russia 2015**

Moscow, Russia

**E-mail:** [eweller@semi.org](mailto:eweller@semi.org)**www.**[semiconrussia.org/en](http://www.semiconrussia.org/en)**8–10 July 2015****SEMICON West 2015**

Moscone Center, San Francisco, CA, USA

**E-mail:** [semiconwest@semi.org](mailto:semiconwest@semi.org)**www.**[semiconwest.org](http://www.semiconwest.org)**13–16 July 2015****Intersolar North America 2015**

Moscone Center West Hall and InterContinental Hotel

San Francisco, CA, USA

**E-mail:** [brade@intersolar.us](mailto:brade@intersolar.us)**www.**[intersolar.us](http://www.intersolar.us)**9–13 August 2015****SPIE Optics + Photonics 2015**

San Diego Convention Center, CA, USA

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)**http://**[spie.org/optics-photonics1](http://spie.org/optics-photonics1)**26–28 August 2015****IEEE Photonics Society's 12th International Conference on Group IV Photonics (GFP-2015)**

Vancouver, British Columbia, Canada

**E-mail:** [m.figueroa@ieee.org](mailto:m.figueroa@ieee.org)**www.**[gfp-ieee.org](http://www.gfp-ieee.org)**2–4 September 2015****SEMICON Taiwan 2015**

Taipei World Trade Center (TWTC), Taipei, Taiwan

**E-mail:** [staiwan2@semi.org](mailto:staiwan2@semi.org)**www.**[semicontaiwan.org](http://www.semicontaiwan.org)**21–24 September 2015****SPIE Remote Sensing 2015**

Centre de Congrès Pierre Baudis, Toulouse, France

**E-mail:** [info@spieurope.org](mailto:info@spieurope.org)**http://**[spie.org/spieremotesensing](http://spie.org/spieremotesensing)**4–8 October 2015****28th IEEE Photonics Conference (IPC 2015)**

Reston, VA, USA

**E-mail:** [c.c.scott@ieee.org](mailto:c.c.scott@ieee.org)**www.**[ipc-ieee.org](http://www.ipc-ieee.org)

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