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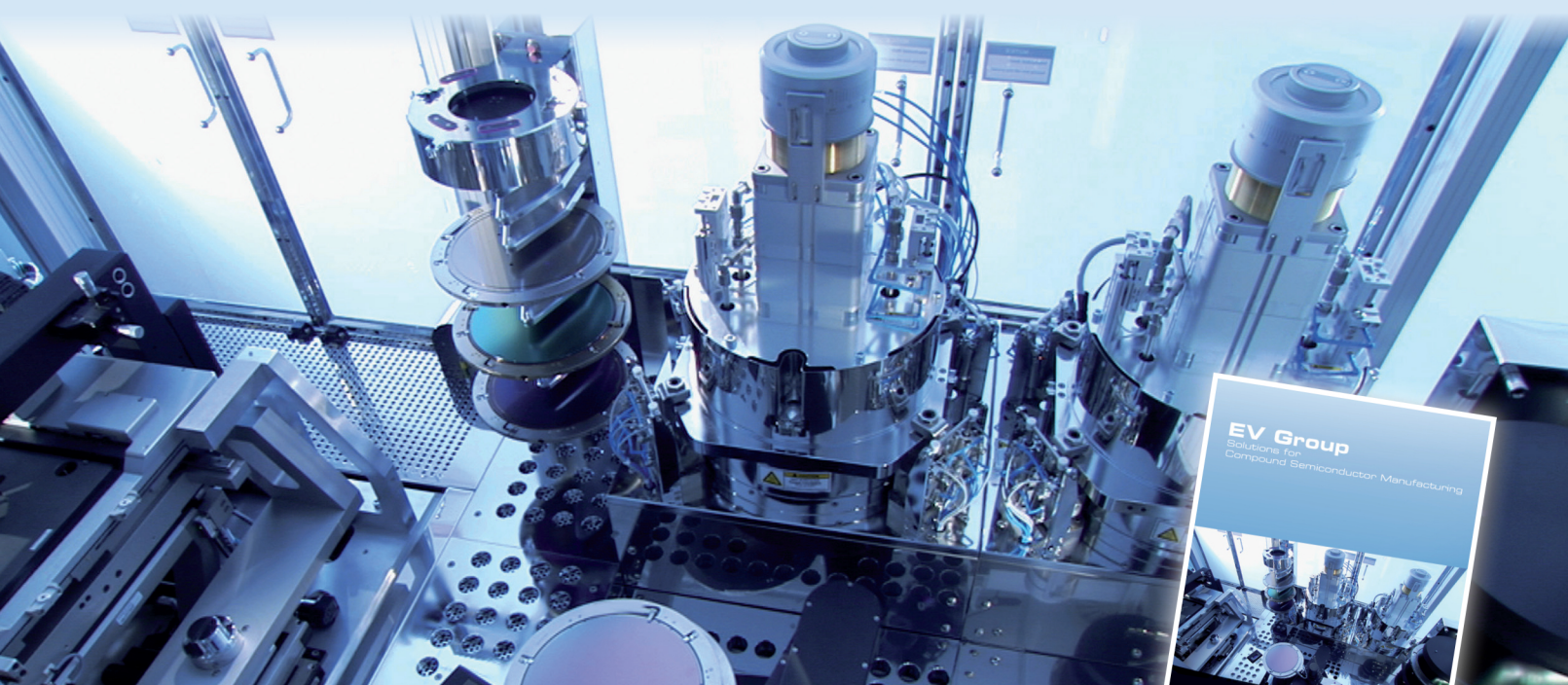
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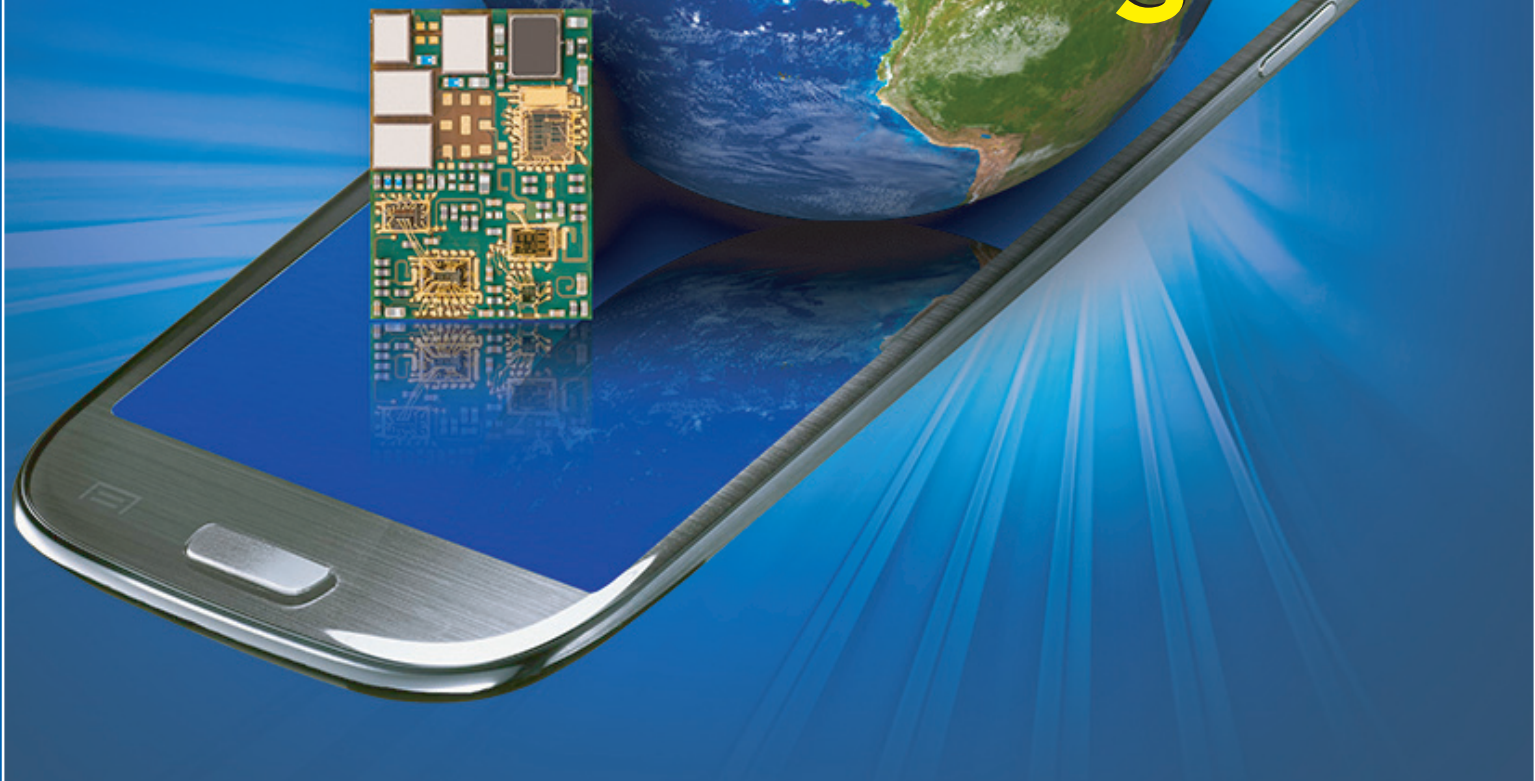
C O M P O U N D S & A D V A N C E D S I L I C O N

Vol. 9 • Issue 2 • March 2014

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## Integrating III-Vs with deep submicron silicon

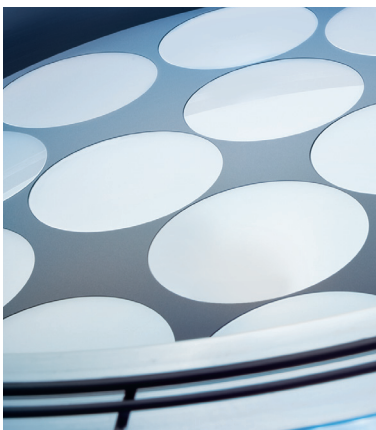
## News from OFC and the Mobile World Congress



Hittite buys Keragis • EpiWorks expands • EVG China founded  
White LEDs reach 300lm/W • First 150mm VCSEL epiwafers

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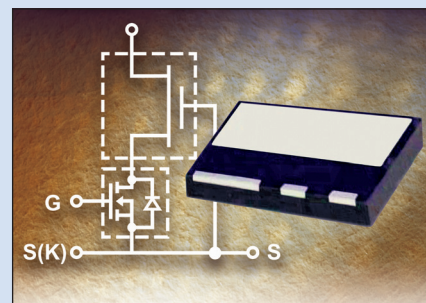
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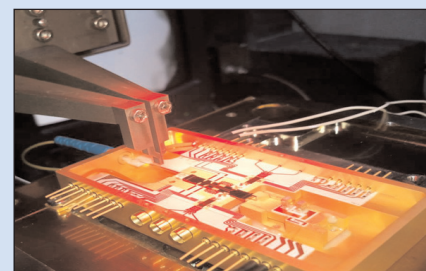
## semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

Vol. 9 • Issue 2 • March 2014



**p24** Transphorm has launched what it claims is the first 600V GaN-based, low-profile PQFN products.



**p69** GigOptix is participating in the EC-funded PANTHER project on multi-flow Terabit transceiver for edge SDN switches & data-centers.



**p89** CIGS PV firm Stion has produced a 23.2%-efficiency thin-film cell based on its proprietary tandem junction technology.



Cover: At Mobile World Congress, Skyworks unveiled its second-generation SkyOne platforms. The new front-ends cover more frequency bands, integrate up to seven duplexers, support carrier aggregation and provide standardized inputs for all leading chipsets that are MIPI RFFE compatible. **p17**

# Compound semiconductors complementary to silicon

Last issue's main feature article (pages 106–111) reported on December's International Electron Devices Meeting (IEDM) in Washington DC, focusing on wide-bandgap semiconductors for power switching applications. Now, in this issue (pages 114–120) part 2 of our IEDM conference report covers the integration of high-electron-mobility III-V materials such as indium gallium arsenide (InGaAs) into the channels of deep-submicron CMOS silicon to create devices with higher performance than is possible using existing silicon-based channels.

While this work focuses on extending the performance of CMOS ICs, other wider-bandgap compound semiconductor materials such as gallium nitride (GaN), grown on silicon substrates, are being adopted commercially for both high-frequency and high-power microelectronic applications and optoelectronic applications such as white LEDs.

For example, on page 7 we report how market analyst firm IHS speculates that some smaller sapphire substrate makers are considering exiting the semiconductor sector, as the penetration of GaN-on-Si wafers into the GaN LED market is forecast to reach 40% by 2020.

On page 9, we report how IDTechEx reckons that the application of both GaN and silicon carbide wide-bandgap (WBG) semiconductors is set to flourish in power electronic devices for electric vehicles (EVs). Indeed, the market analyst firm forecasts that EVs will form the largest WBG application sector by 2020.

Also, as we close for press comes news that epiwafer foundry IQE has delivered the first 200mm GaN-on-Si high-electron-mobility transistor (HEMT) wafers to the Singapore–MIT Alliance for Research and Technology Center's Low Energy Electronic Systems (SMART-LEES) program, which is developing various compound semiconductor on silicon (CSoS) technologies for the monolithic integration of CMOS and compound semiconductor circuits. Further collaboration is expected, combining other compound semiconductor technologies on silicon (for details, see the next issue, and [www.semiconductor-today.com/news\\_items/2014/MAR/IQE\\_310314.shtml](http://www.semiconductor-today.com/news_items/2014/MAR/IQE_310314.shtml)).

IQE has also been active lately in optoelectronics collaborations, including supplying both the engineered germanium/silicon substrates and the III-V MBE template growth to University of California Santa Barbara (UCSB) to help develop 1.3µm-emitting quantum dot (QD) lasers on silicon (page 65). IQE also provided vertical-cavity surface-emitting laser (VCSEL) epiwafers to IBM and Sweden's Chalmers University of Technology, who fabricated 850nm-emitting VCSEL chips that have set a record data transmission speed of 64Gb/s over 57m of multimode optical fiber, using standard non-return-to-zero (NRZ) modulation (see page 64).

These results were presented at the Optical Fiber Communication (OFC) conference in San Francisco in late March, where IQE also announced that it had delivered what it says is the world's first 150mm VCSEL epiwafer process for high-volume, low-cost applications. Between pages 63 and 84 we report other news from OFC, including developments by other firms in VCSELs and the interface of such III-V-based optoelectronic modules with silicon photonics active optical cables (AOCs) for high-speed datacoms.

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

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

## Regular issues contain:

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

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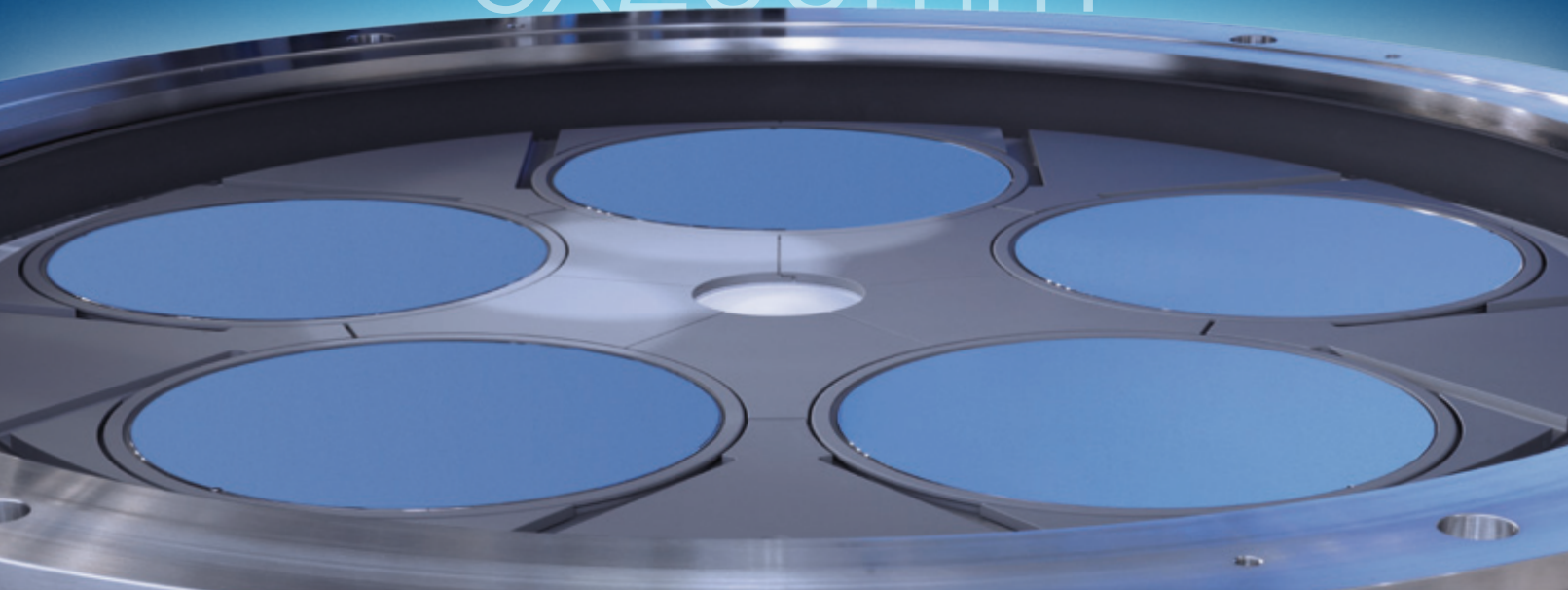
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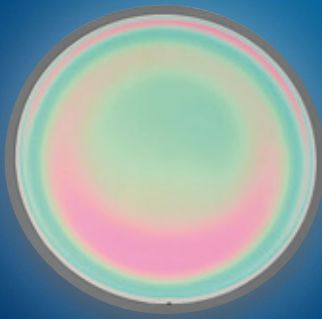
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## HCPV cell efficiency to rise from 40–42% to 45% by 2017, driving system efficiency towards 40%

Consistent improvements in technology and gradually lower costs will drive high-concentration photovoltaic (HCPV) systems to superior efficiencies, making HCPV an increasingly viable rival to conventional solar-generating solutions, according to the report 'CPV on the Edge of Breakthrough' from the solar research service at market analyst firm IHS Technology.

The cell efficiency of HCPV systems, currently at 40–42%, will exceed 45% by 2017, it is forecasted. Used with concentrating optics, such cells will then lead to commercial system efficiencies approaching 40%, compared with typically under 35% currently (see Figure).

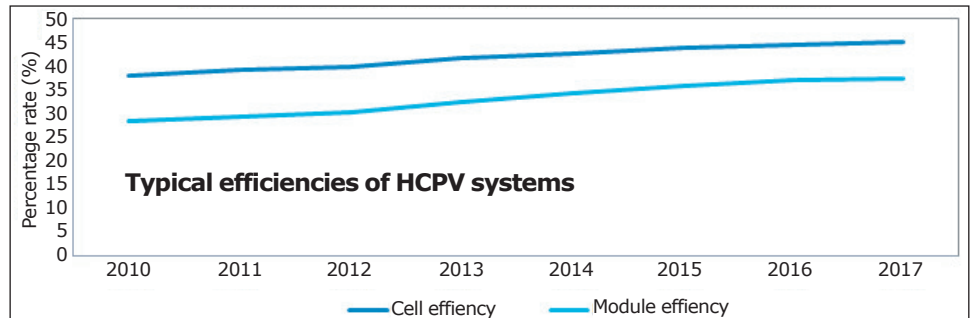
"Efficiency is the most important requirement in CPV technology in order to generate competitive energy costs," says Karl Melkonyan, photovoltaic analyst at IHS. "With the solar industry continuing to be firmly engaged in a quest for ongoing improvements through the development of new technologies, the efficiency of HCPV cells will advance over the years," he adds.

The anticipated improvements in HCPV systems are based on cell efficiencies having reached 44.7% in laboratory conditions, indicating that further advances are possible.

Even so, the gains in efficiency will have to be balanced against the additional manufacturing costs expected to be incurred when implementing the improvements, Melkonyan notes.

### Top HCPV regions in the world

Driven by falling system prices, HCPV is gradually becoming attractive in several regions of the world, notes the report. IHS forecasts that the USA and Central America will install the greatest number of HCPV systems between 2012 and 2017, serving as the world's biggest regional market. Installations for



the region reached 54.1MW in 2012.

In fact, most HCPV suppliers are based in the USA, and their forays into the domestic US market will provide notice to rival conventional PV suppliers, says IHS. Mexico is also forecast to become a large part of this regional market, with plans in place for a 450MW installation.

Meanwhile, enormous growth will occur in South America, where the HCPV market is projected to surge by 560% from the time installations started in 2013 until 2017. The primary driver is Chile, which has the world's highest solar irradiation levels.

But the greatest increase in the HCPV market will take place in the Middle East and Africa region, where installations — excluding South Africa (which is tracked separately because of its more advanced PV market) — will grow from just 1.8MW in 2012 to 155MW in 2017. Morocco and Saudi Arabia will be the main drivers.

China could also emerge as an important player soon as suppliers from the country grow in number, with parts of southwest China shaping up to become prime HCPV locations, reckons IHS.

### Competitive landscape changing turbulently

Unable to keep pace with the dramatic cost and price reductions that conventional PV saw, many CPV pioneers faced financial difficulties in the course of the PV price collapse

that took place in 2011 and 2012, notes the report. Many formerly leading companies — among them SolFocus and GreenVolts in California, as well as Opel Solar in Connecticut — ceased operations or became insolvent.

However, since 2013 the industry has regained stability, and advances in new technologies continue to reduce costs. Just the same, only a few survivors are left from that tumultuous period, and those that remain are the ones with large cash balances and the most cost-efficient technologies, says IHS.

Among the major players, the two biggest CPV manufacturers — Suncore Photovoltaics in China and Soitec Solar in France — will each be expecting HCPV installations of about 50MW by the end of 2014.

Suncore and Soitec — along with top-five suppliers Solaria and SunPower in California, and Magpower SA in Portugal — account for more than 80% of the CPV market at present. Two other manufacturers — Heliotrop in France and North Carolina-based Semprius — could also join the ranks of the top 10 this year, IHS reckons.

The HCPV supplier base will continue to change in the next five years as the current market is still in its early phases of growth, with several newcomers and start-ups expected to liven up the competition, IHS believes.

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# Ramp up of GaN-on-Si LEDs over coming year to drive shift from sapphire to silicon wafers

## Smaller sapphire suppliers looking to exit market?

Last November, market research firm IHS Inc forecast 40% penetration of gallium nitride-on-silicon (GaN-on-Si) into the GaN light-emitting diode market by 2020. But will this affect the sapphire industry, questions Dkins Cho (principal analyst for IHS Technology) in a research note on a new report (examining the impact the transition GaN-on-Si LEDs will have on the sapphire industry)?

There are currently just a few players publicly manufacturing silicon-based LEDs. However, these companies and others joining the market are likely to ramp up production capacity over the coming year at a relatively low price compared with conventional LED chips (grown on sapphire,  $\text{Al}_2\text{O}_3$ ). The result will be a shift from sapphire towards silicon wafers, forecasts IHS.

Since 2011, many sapphire ingot makers have entered the LED market

and have expanded production capacity steadily. However, as competition has intensified, there are rumors in the industry that many of the major suppliers have no more capacity growth and some smaller companies are looking to exit the market, notes IHS.

As a result of the shift to silicon wafers and increased competition, sapphire ingot and wafer suppliers will have to make some hard decisions to remain in business, reckons the research note. One option is to replace their loss in the LED industry by diversifying into other markets such as a protective covers for consumer electronic devices (i.e. smart phones, digital cameras and tablets).

Sapphire possesses the physical properties of a higher dielectric constant and better medium-wave infrared transparency than glass when applied in sensor applications.

Sapphire is also the second hardest material in the world (after diamond).

On 10 September, Apple filed a patent with the US Patent and Trademark Office (USPTO) that revealed its intention to add a sapphire laminate to future devices. This would potentially provide the new iPhone 6, 4th generation iPad and iWatch with a stronger glass that is ultimately scratch resistant, notes IHS. The iPhone 5s already uses sapphire crystal in the home button fingerprint sensor. Other smart phone and tablet manufacturers are likely to follow suit in the future.

IHS concludes that the LED value chain will experience a dynamic industry restructuring over the coming years that will have wider implications in the consumer electronics market.

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# Cumulative CPV installed capacity to rise from 358MW in 2014 to over 1GW by 2020

## CPV market dominated by China and US; market at nascent stage, with technology evolving and efficiency improving

The global concentrated photovoltaic (CPV) market is expected to undergo a major growth spurt in the next five years, with cumulative installed capacity jumping from 357.9MW in 2014 to 1,043.96MW by 2020, forecasts a new report 'Concentrated Photovoltaics (CPV), Update 2014 — Global Market Size, Competitive Landscape and Key Country Analysis to 2020' from research and consulting firm GlobalData.

According to the report, China and the USA dominated the CPV market in 2013, with their cumulative installed capacities reaching shares of 35.4% and 33.3%, respectively. After the USA, Spain stood third

with 12.2% market share, followed by Portugal and Italy, with market shares of 5.1% and 4.3%, respectively.

"The CPV market is at a nascent stage, especially with the technology evolving and achieving new heights of efficiency improvement," notes Swati Singh, GlobalData's analyst covering Alternative Energy. "Companies that have been successful in operating CPV prototype systems in pilot sites are now progressing towards multi-MW CPV projects." Two CPV power plants came online in 2012 and 2013. These were Amonix's 30MW Alamosa in Colorado, USA, and Suncore's 50MW CPV power plant

in Golmud, China (which is the world's largest CPV plant).

However, despite these developments, market growth forecast is conservative, says GlobalData. From 2009, many companies in the CPV industry, both small and large, either had to close down their businesses due to bankruptcy or were acquired by other companies.

"A further concern in the CPV industry is the reliability and performance of the systems, although significant efforts have been made to develop International Electrotechnical Commission standards for CPV system certification," Singh concludes.

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

# China's LED die revenue to grow 36.6% in 2014 to \$1475m

## General lighting to exceed 50% of applications in 2014

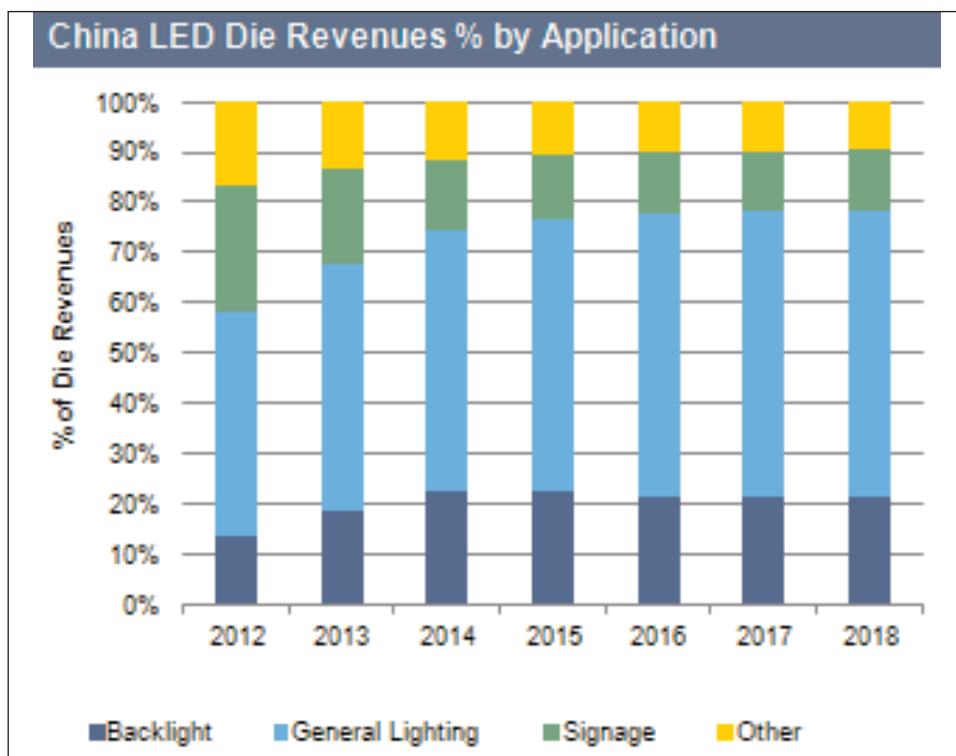
Following the boom in expansion of the Chinese LED market in 2011, many industry insiders and analysts speculated on whether China would be able to sustain the growth, or if many companies simply ordered an excessive amount of metal-organic chemical vapor deposition (MOCVD) reactors just to benefit from government subsidies, states market analyst firm IHS in a new report on the Chinese LED market. The failure of many of the companies was widely predicted. So, what's happening in the China LED industry after three years?

According to the report, China's LED die production revenue will grow 36.6% to \$1475m and packaged LEDs will grow 14.8% to \$4812m in 2014. China's largest LED maker Sanan (with a more than 30% share of die production in China) is actually expanding capacity. Its second-phase project in Wuhu is still going ahead this year, leading to the addition of new tools. Its largest rival Epistar will be directly competing this year to see which will be the world leader for total wafer capacity.

MLS was estimated to be the largest Chinese packaged LED company in 2013, with slightly more than 9% market share among thousands of other Chinese competitors.

General lighting is the major driving force for the China LED market growth from 2013 to 2014 and is forecast to rise from 49.1% share of all applications in 2013 to 51.6% in 2014. The acceptance of LED replacement T-lamps, the falling cost of LED lamps generally, the continued economic growth, and the phasing out of incandescent A-lamps are all factors that are increasing the penetration rate of LED lamps in China, says the report.

The backlight market also grew significantly from 2012 to 2013, by 74% in LED die (from 13.4% share of all applications in 2012 to 18.6%

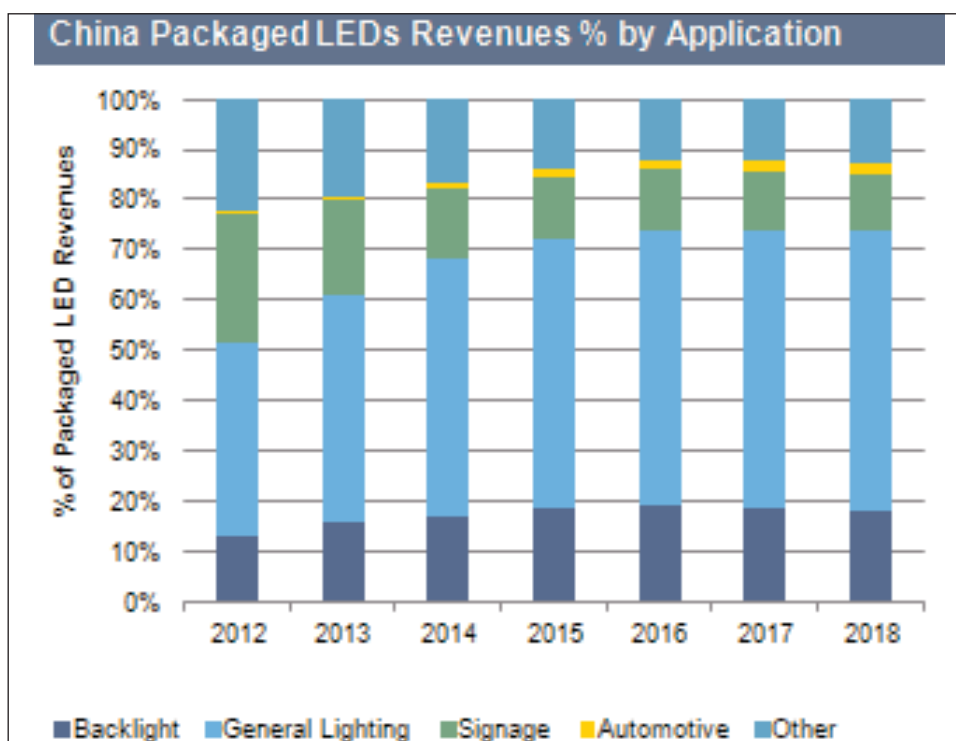


in 2013). High growth is expected to continue in 2014 due to Chinese companies' technology improvements to replace imported products from Taiwan and Korea.

Although the Chinese domestic market is huge, international sales for most Chinese LED companies

remain fairly low, notes the report. However, they are catching up quickly. Larger companies are developing their own brands and IHS expects these suppliers to increase their presence in international markets in the near future.

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## CATV infrastructure amplifier market to reach \$225m GaAs to remain choice for amp building blocks; GaN to grow fastest

With CATV and broadband services becoming integral parts of service providers bundles, network infrastructure is evolving rapidly to keep up with growing demand, notes the Strategy Analytics GaAs and Compound Semiconductor Technology (GaAs) service forecast and data model, which describes trends for semiconductor-based amplifier building blocks used in the evolution of hybrid fiber coax (HFC) and fiber-based networks.

The CATV infrastructure amplifier building block forecast and data model details the market outlook for various amplifier building blocks used in different locations in the network architecture. It also segments shipments by function, process technology and geography.

The report 'CATV Infrastructure Amplifier Market Forecast: 2013–2018' reckons that:

- to keep up with data growth, the number of homes served per node will decrease, so the number of nodes and node amplifiers will increase;
- gallium arsenide (GaAs) will remain the technology of choice for the amplifier building blocks, but gallium nitride (GaN) will see the fastest growth, reaching nearly \$50m in revenue by 2018;
- the size of the population, along with aggressive efforts to deploy CATV and broadband services, will propel the Asia-Pacific region to account for more than 50% of the revenue generated by the amplifier building blocks; and
- the new features allowed by the DOCSIS 3.1 specification will enable HFC networks to evolve to meet the growing data and services demand.

"Driving fiber deeper into networks stands as a competitive threat for semiconductor-based amplifier

building blocks," notes Eric Higham, director of the Strategy Analytics' GaAs service. "Recent ratification of the DOCSIS 3.1 specification — which allows more bandwidth, different upstream and downstream frequency splits, and more efficient data transmission — will ensure that the HFC network architecture keeps pace with consumer demands," he adds.

"This segment was one of the first commercial markets to adopt GaN technology," says Asif Anwar, director for ADS. "While GaAs will still figure prominently, the performance advantages of GaN will make this the fastest-growing technology for the amplifier building blocks."

Strategy Analytics forecasts the market for semiconductor-based amplifier building blocks used in CATV infrastructure will grow to nearly \$225m in 2018.

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

## Electric vehicle to be largest application of wide-bandgap power semiconductors by 2020

In the last century, silicon-based power electronics (which control or convert electrical energy into usable power) transformed the computing, communication, electric vehicle and energy industries and gave consumers and businesses more powerful laptops, cell phones and motors, but over the coming decade that era will begin to come to an end, according to the IDTechEx report 'Power Electronics for Electric Vehicles 2014–2024', which spans inverters to battery management systems.

Wide-bandgap (WBG) semiconductors now offer new opportunities to achieve unprecedented performance while using less electricity. In particular, WBG semiconductors such as silicon carbide (SiC) and gallium nitride (GaN) can operate at higher temperatures, have greater durability and reliability at

higher voltages and frequencies, and be smaller, more efficient and cost less, notes the report. A WBG-based inverter (switching electricity from direct current to alternating current) can be four times more powerful, half the cost, and a quarter the size and weight of a traditional inverter, it is reckoned.

Indeed, WBG adoption is already happening, notably in photovoltaic power generation, followed by more general power grid applications, says IDTechEx. Next, WBG power semiconductors are expected to transform the plug-in electric vehicle (EV) industry, making it easier and cheaper to own an EV and/or give it longer range — they can reduce the size of a vehicle cooling system by about 60% and cut the size of a fast DC charging station (e.g. 60kW) to the size of a kitchen microwave.

The power conversion in future EVs

will encompass things such as converting high DC voltages to lower DC voltages in fast charging, converting AC to DC in other charging, converting low voltage DC to higher voltage DC in photovoltaic and thermoelectric energy conversion in the vehicle, and in photovoltaic roadside chargers, for example. The cost of the electronics and electrics in an EV will rise sharply as a consequence of this, as well as the electrics and electronics replacing mechanics (as when clutches and differentials are eliminated). In due course, the electrics/electronics will become equally important as a component of cost and performance in an electrical vehicle, reckons the report. Although EVs have tougher requirements on cost, size, weight and performance, they should be the largest WBG application by 2020, it concludes.

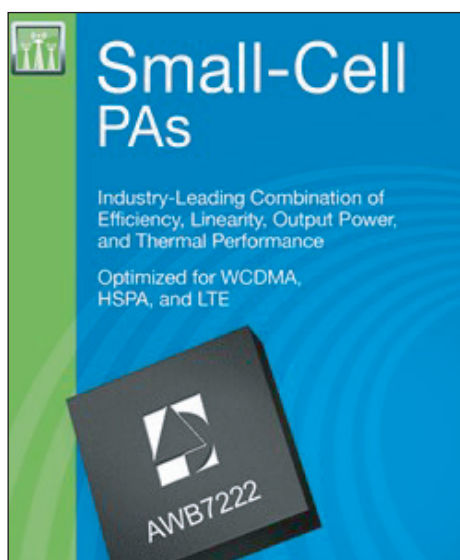
[www.idtechex.com/power](http://www.idtechex.com/power)

# Anadigics launches ½-Watt 1805–1880MHz power amp for WCDMA, HSPA and LTE small-cell applications

Broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has introduced the AWB7222 power amplifier (PA) optimized for WCDMA, HSPA and LTE small-cell base-station applications.

The AWB7222 operates in the 1805–1880MHz frequency band, delivering a combination of output power, linearity, power-added efficiency and thermal characteristics. This level of performance, combined with its integration, enables manufacturers to develop compact wireless infrastructure solutions that consume less power and provide higher throughput with greater coverage, says the firm.

"We continue to expand our small-cell power amplifier family with targeted solutions optimized for the most widely used 3G and 4G frequency bands," says Glenn Eswein, director of product marketing for Infrastructure Products. "As manufacturers develop small-cell products to help carriers address rapidly increasing wireless data consumption, Anadigics' power



**Anadigics' new AWB7222 small-cell power amplifier.**

amplifiers stand out as critical enablers," he claims. "Our small-cell product family delivers the highest output power, linearity, and efficiency in its class, enabling compact, high-throughput devices that provide an economical path to expand broadband network coverage."

Anadigics' family of small-cell wireless infrastructure power amplifiers

leverages the firm's InGaP-Plus technology and design architectures. The AWB7222 offers +27dBm of linear output power for ½-Watt small-cell applications, including picocells, enterprise-class femtocells, and high-performance customer premises equipment (CPE). With linearity of -47dBc ACPR (adjacent channel power ratio) at +27dBm output power and 31dB of RF gain, the AWB7222 enables higher data rates with a greater coverage area. The power amplifier also provides 13% efficiency to minimize power consumption and offer greater flexibility in the choice of network power sources.

The complete family of small-cell power amplifiers is available in compact, low-profile 7mm x 7mm x 1.3mm surface-mount packages with integrated RF matching (optimized for output power, efficiency and linearity in a 50Ω system) to reduce PCB space requirements.

Pre-production samples of the AWB7222 are available now for qualified programs.

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

## Huawei selects Anadigics' front-end ICs to provide WiFi connectivity in new Ascend P6S smartphone

Broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA says that its AWL9281 front-end integrated circuit (FEIC) is enabling WiFi connectivity in Huawei's new Ascend P6S smartphone.

"Our 802.11n and 802.11ac WiFi solutions continue to raise the bar in performance and integration, enabling higher data rates, longer battery life and improved manufacturability," claims Jonathan Griffith, vice president of WiFi Products at Anadigics. "We look forward to working closely with Huawei to bring these

advantages to future WiFi-enabled devices."

Anadigics' family of WiFi FEICs leverages the firm's patented InGaP-Plus technology and uniquely designed architectures to combine a high-performance power amplifier (PA), low-noise amplifier (LNA) with bypass option, and SP3T Tx/Rx RF switch with Bluetooth on a single die, simplifying RF design and reducing time-to-market. The compact 2.5mm x 2.5mm x 0.4mm QFN package also incorporates a high-accuracy, integrated power detector and RF ports internally matched to 50 Ohms. This level of

integration improves manufacturability and reliability, while reducing PCB space requirements, says Anadigics. What is claimed to be best-in-class power efficiency improves thermal characteristics to support MIMO applications. The AWL9281 also delivers low current consumption, extending battery-life in mobile applications.

Anadigics claims that the AWL9281 provides outstanding error vector magnitude (EVM) and noise figure performance in the toughest modulation formats, enabling ultra-high data throughput.

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

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# Combined TriQuint–RFMD to command 36% of GaAs and GaN supply into defense sector

## Merger to consolidate TriQuint’s lead in defense

On 24 February, RF Micro Devices and TriQuint Semiconductor announced a definitive merger agreement under which the firms will combine in an all-stock transaction. The merger will create a company surpassing current market leader Skywork in size. The new entity aims to leverage the strengths of the two firms as suppliers to high-volume markets such as mobile devices as well as network infrastructure and the defense sector.

Market research firm Strategy Analytics’ Advanced Defense Systems (ADS) service report ‘TriQuint-RFMD Merger Solidifies Semiconductor Market Share Lead in Defense Sector’ provides analysis on this deal and outlines the market share that the new company will command.

Both companies have an extensive portfolio of capabilities in semiconductor process technologies

such as gallium arsenide (GaAs) and gallium nitride (GaN). The combination will collate these complementary capabilities, enabling the new firm to pursue defense market opportunities.

“In the area of Defense, TriQuint has been a leading supplier of semiconductor technologies, for example, military radar systems used on fast-jets including the F-15, F-22 and F-35,” notes Eric Higham, North American director for ADS. “The company also holds US DoD Trusted Source accreditation,” he adds. Combination with RFMD will solidify this lead, as the new entity offers an expanded portfolio of capabilities spanning both GaAs and GaN with operational efficiencies as well as manufacturing scale. “RFMD has ongoing activity in the aerospace and defense sectors with products targeting radar, communications and electronic warfare applications,” he

adds. Strategy Analytics estimates that the TriQuint-RFMD operation will command over 36% of the global market for GaAs and GaN supply into the defense sector.

“The combined infrastructure and defense unit can achieve potential revenues of around \$500m. Strategy Analytics’ own estimates indicate that the new company’s defense revenues will account for up to 25% of this unit revenue,” notes Asif Anwar, director of the ADS service. “As a GaAs and GaN semiconductor technologies supplier, we believe TriQuint holds the number one position in the defense space, and the combined TriQuint–RFMD entity will cement this position, extending a lead over contemporaries in this area such as Cree, Hittite and MACOM Technologies,” he adds.

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

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

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

## TriQuint launches high-performance filters for LTE

TriQuint has announced several new premium filters for next-generation smartphones and other mobile devices. The high-performance filters use the firm’s acoustic wave filtering technologies to address what are described as some of the industry’s toughest LTE interference problems.

The number of cellular and Wi-Fi bands packed inside compact high-end smartphones is rocketing to support 2G/3G/4G voice and data services, as well as global roaming, says TriQuint. Advanced filter technology is required to mitigate the resulting interference issues. A global spectrum crunch adds to the growing interference problems as governments around the world squeeze new 4G bands with higher performance requirements next to existing bands,

often with minimal band guards, the firm adds.

“TriQuint’s expanding line of advanced filters solves challenging LTE interference issues for mobile device manufacturers and can provide higher data rates over longer distances for end-users,” says Sean Riley, VP of Mobile Products. “Our specialty quadplexer also enables carrier aggregation techniques for operators eager to boost spectrum efficiency within their overburdened networks,” he adds. “These filters leverage our proprietary acoustic wave technologies to accelerate the next generation of wireless communications.”

TriQuint says its specialty filters are capturing numerous design wins in high-volume 4G smartphones from multiple manufacturers, as well as sockets on reference

designs from leading chipset suppliers.

The new filters include what is said to be the first diplexer for LTE Bands 38 & 40 (the 1.7mm x 1.3mm 885043), which is more than 30% smaller than discrete solutions. The firm has also unveiled the first carrier aggregation module for Bands 2/25 & 4 (the 3.6mm x 2.0mm TQQ2504), an integrated quadplexer that is half the size of discrete architectures. TriQuint’s new Band 7 LTE diplexer (the 2.0mm x 1.6mm TQM976027) and its Band 41 LTE receive filter (the 2.0mm x 2.0mm TQQ0041) both achieve low insertion loss to help maximize the incoming signal strength, resulting in higher data throughput over longer reach.

[www.triquint.com/applications/mobile-devices/advanced-filters](http://www.triquint.com/applications/mobile-devices/advanced-filters)

## RFMD launches RF Fusion complete RF front-end for 4G world phones and tablets, for availability in 2014

RF Micro Devices Inc of Greensboro, NC, USA has introduced RF Fusion — a complete RF front-end (RFFE) solution for global 4G world phones and tablets that integrates all major transmit and receive RF functionality, from the transceiver to the antenna. The first-generation RF Fusion (the RF7503) is designed for best-in-class performance and supports full global coverage of all major cellular networks, from 2G to 4G, in a miniature, highly integrated placement. RFMD says it is in the advanced stages of supporting lead customer design activity and expects commercial availability this year.

Leading smartphone makers using RF Fusion can fulfill the promise of global world phone coverage without sacrificing performance at the RF component level, while also significantly reducing board space and accelerating implementation, versus competing complete RF front-end solutions, RFMD claims.

"Smartphone manufacturers now have the flexibility to design a sin-

gle, scalable platform across all major global modes and bands without sacrificing performance, space, or time," says Eric Creviston, president of RFMD's Cellular Products Group. RF Fusion draws heavily on RFMD's system-level expertise, advanced packaging and assembly capabilities, he adds, as well as performance across all major RF functionality, including power amplification, cellular switching, filtering, antenna tuning and control, and advanced power management.

RF Fusion leverages average power tracking (APT)- and envelope tracking (ET)-enabled power amplifiers (PAs), cellular switching, and highly optimized filtering and duplexing (BAW and SAW) to deliver what is claimed to be superior system-level performance, all in the what is reckoned to be industry's smallest form factor, simplifying and accelerating the implementation of multi-mode, multi-band (MMMB) global world phones and tablets.

The market for 4G smartphones, tablets, and other data-centric mobile devices is expected to expand rapidly as 4G LTE connections proliferate. The number of 4G LTE connections is forecast to rise at a compound annual growth rate (CAGR) of 43% from 238 million in 2013 to 2 billion in 2018, according to industry analyst firm Strategy Analytics.

RF Fusion complete RFFE solutions will be available in multiple geography-specific SKUs (stock keeping units) and will be compatible with additional RFMD RF solutions to support all major regional cellular modes and bands, providing smartphone makers with a single scalable source for the entire cellular front-end.

RFMD presented its expanding portfolio of RF solutions for smartphones, tablets, and other broadband mobile devices at the 2014 GSMA Mobile World Congress in Barcelona, Spain (24–27 February).

<http://rfmd.com/rf-fusion>

## RFMD enables rapidly growing TD-LTE smart-phone market

RF Micro Devices Inc says it is achieving design success with an expanding portfolio of new power amplifiers (PAs), antenna switch modules and antenna control solutions for the rapidly growing global TD-LTE mobile phone market. Working in collaboration with leading TD-LTE baseband makers, RFMD is expanding its portfolio of TD-LTE RF solutions to include multimode, multiband (MMMB) and single-band satellite PAs, transmit modules, antenna switch modules, antenna tuners and impedance tuners.

Industry analyst firm IDC predicts that shipments of global TD-LTE mobile phones will exceed 220 million units in 2017. It expects that shipments of TD-LTE mobile phones will account

for nearly a quarter of the world's 4G mobile phones shipped in 2017.

"Our strong market position in China and close collaboration with the world's leading TD-LTE chipset manufacturers are contributing to RFMD's product and technology leadership in TD-LTE," said Eric Creviston, president of RFMD's Cellular Products Group. "RFMD is well positioned to target the rapid growth in TD-LTE as we launch new RF solutions with higher levels of integration, expand our content in next-generation devices, and help our customers to launch their TD-LTE devices quickly and cost-effectively."

RFMD's TD-LTE portfolio includes RF solutions for advanced

5-mode TD-LTE smartphones (including WCDMA, FDD-LTE, TD-SCDMA, and EDGE) and lower cost 3-mode TD-LTE smartphones (including TD-SCDMA and EDGE). The TD-LTE offering includes its RF79XX family of satellite power amplifiers, RF982x multimode, multiband transmit modules, and RF7378 and RF811x multiband PA modules as well as antenna switch modules, diversity switches, antenna tuners and impedance tuners.

RF Micro Devices presented its expanding portfolio of RF solutions for smartphones, tablets, and other broadband mobile devices at the 2014 GSMA Mobile World Congress in Barcelona, Spain (24–27 February).

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

## RFMD adds antenna control solutions for 4G LTE smartphones and tablets

At the 2014 GSMA Mobile World Congress (MWC) in Barcelona, Spain (24–27 February), RF Micro Devices Inc of Greensboro, NC, USA announced the addition of multiple new products to its expanding portfolio of antenna control solutions (ACS).

The new products further expand the firm's family of routing switches, antenna tuners and impedance tuners to support the newest 4G LTE smartphones and tablets. RFMD's ACS products maximize power transfer to the antenna and optimize radiated efficiency at the antenna, enhancing smartphones by improving battery life, increasing data throughput and extending talk time.

Key new additions to RFMD's ACS family include the RF1149 routing switch, the RF1141A and RF1107/8/9 antenna tuners, and the RF1155 impedance tuner. The RF1149 is a low on-resistance single-pole quadruple-throw (SP4T) routing switch that helps to improve link quality and data throughput. The RF1141A is a rugged, low-loss single-pole double-throw (SPDT) antenna tuner, and the RF1107/8/9 is a family of programmable tuners optimized for radiated efficiency of all active bands in multi-band LTE mobile devices. The RF1155 is the successor to RFMD's recently announced RF1105 first-generation impedance tuner. Both the RF1105 and RF1155 optimize power trans-

fer to the antenna, while the RF1155 adds advanced carrier aggregation capabilities.

As frequency bands proliferate, cellular antennas are required to operate over wider bandwidths, greatly increasing demand for ACS solutions, RFMD's says. According to industry analyst firm Strategy Analytics, the proliferation of multi-band LTE devices is expected to drive phenomenal growth in shipments of antenna tuning components, reaching 1.8 billion units per year by 2018. RFMD says that it has already secured key design wins for its new antenna control solutions in the leading flagship smartphones anticipated in 2014.

## RF Micro Device's envelope tracking solutions to feature in leading 4G reference designs and 4G smartphones

At the Mobile World Congress, RFMD announced that multiple upcoming 4G reference designs and 4G smartphones will feature its envelope tracking (ET) power amplifiers (PAs) and power management integrated circuits (PMICs). The ET-capable RF solutions enable next-generation 4G smartphones and tablets to achieve significantly enhanced power efficiency, resulting in enhanced battery life across modes and bands, increased network coverage, and higher data throughput.

The upcoming 4G baseband reference designs featuring RFMD's ET-capable RF solutions will support global multi-mode, multi-band (MMMB) coverage and feature advanced multi-core processing capabilities. The upcoming 4G smartphones will incorporate multiple RFMD ET-capable RF solutions, including MMMB and discrete satellite PAs and ET PMICs. The firm estimates that its ET-capable RF solutions will support the leading ET-capable LTE devices scheduled

to ramp in 2014, e.g. in an upcoming ET-capable flagship Android smartphone, RFMD's content will include an ET MMMB PA (covering bands 1–5, 8, 18 and 26), three ET satellite PAs (for bands 7, 17 and 20), a PA module for TD-LTE (band 41), and 3G/4G antenna diversity switches.

"RFMD is uniquely positioned to expand our content in the world's leading 4G devices throughout 2014, as major new programs are introduced and ramp to volume production," reckons Eric Creviston, president of the Cellular Products Group. "By combining our deep systems-level expertise with the breadth of our PA product portfolio and our leadership in RF power management, cellular switching, and antenna control, we are designing, manufacturing and delivering the broadest portfolio of scalable, end-to-end RF solutions, and we are helping the world's leading smartphone manufacturers to progress quickly and efficiently from design and layout through to mass production," he claims.

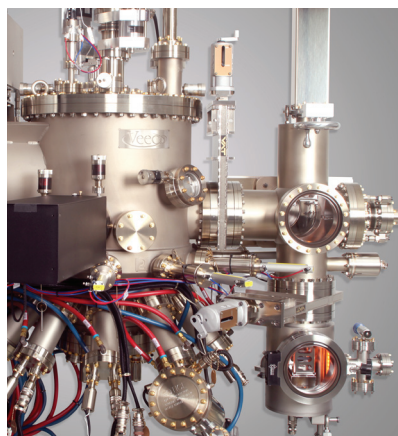
Unlike traditional PAs designed to operate with a constant supply voltage, the supply voltage applied to RFMD's ET-enabled PAs is continuously adjusted so that the amplifier operates at maximum power efficiency. The result is much lower battery power consumption, particularly in LTE platforms. RFMD's growing ET product portfolio is tailored for today's leading LTE chipsets and provides full ET-compatible coverage of all FD-LTE and TD-LTE bands (1–14, 17–21, 25–28, 38, 39, 40, 41, and 44).

RFMD claims it provides customers and reference design channel partners the broadest coverage of cellular modes and bands across all major RF functions, including ET- and average power tracking-(APT)-capable MMMB and discrete (single-band) PAs, APT and ET PMICs, cellular switches, antenna tuners, impedance tuners, routing switches, low-noise amplifiers (LNAs), antenna switch modules, switch filter modules, and duplexer modules.

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

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# Skyworks introduces flip-chip packaged switch/LNA front-ends to shrink footprint in smartphones and tablets

Analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA has unveiled several wireless networking products incorporating flip-chip packaging, augmenting its existing mobile connectivity portfolio.

Skyworks says that its newest devices leverage proprietary manufacturing techniques that allow smartphone and tablet OEMs to incorporate smaller, thinner solutions for 802.11ac system-in-package (SiP) modules. As high-end mobile devices deliver ever-increasing functionality and ubiquitous connectivity, reducing the front-end circuit board footprint is critical as system providers seek high-performance, highly flexible solutions for next-generation platforms.

“Unique flip-chip packaging capabilities are enabling us to offer unprecedented form factors in

support of flagship smartphones and tablets,” says Bill Vaillancourt, VP & general manager of mobile connectivity solutions. “Our newest wireless networking devices are highly integrated and solve our customers’ analog and RF complexity challenges so consumers can enjoy mobile platforms with fast, reliable anytime, anywhere data access,” he adds.

As a surface-mountable technology, flip-chip packaging reduces footprint and thickness (compared to conventional packaging), weighs less, is easy to assemble, lowers production costs and improves electrical and thermal performance, says Skyworks. Flip-chip solutions combine the strengths of various packaging techniques, such as the size and performance advantage of bare die assembly with the reliability of encapsulated devices that can

also be fully RF tested at die level. Their size and weight reductions makes them usable in a variety of mobile devices including smartphones and tablets, adds the firm.

Skyworks’ new connectivity solutions include the following devices:

- SKY85202-11 — a single-pole, triple-throw (SP3T) switch with an integrated low-noise amplifier (LNA) for 2.4GHz, 802.11ac modules;
- SKY85606-11 — a single-pole, double-throw (SP2T) switch with an integrated LNA for 5GHz, 802.11ac modules.

Both devices are highly integrated and feature an LNA with bypass mode, low-loss RF switch and DC blocking capacitors in a single, compact flip-chip package.

Additional products in this portfolio will be released later this year.

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

## Skyworks launches scalable antenna switch solutions supporting LTE, LTE-Advanced and next-generation carrier aggregation

At the Mobile World Congress in Barcelona, Spain (24–27 February), Skyworks unveiled a set of antenna switch solutions supporting LTE, LTE-Advanced and next-generation carrier aggregation architectures. The portfolio includes highly integrated antenna switch modules (ASM) as well as transmit and receive diversity switches. The dual-mode MIPI RFFE-compliant modules are modem-agnostic, making them compatible with every leading chipset provider.

Carrier aggregation allows mobile service providers to combine spectrum and increase data rate throughput by utilizing two or more bands simultaneously instead of the single-band method used currently, providing consumers an enriched data experience regardless of location.

“With the addition of these high-performance modules and analog

control ICs, Skyworks now offers smartphone providers the broadest and most scalable solutions to meet demanding carrier aggregation requirements,” claims David Stasey, VP & general manager of analog solutions. “OEMs can quickly modify their RF front-ends and adapt to multiple band configurations, providing a high level of design flexibility to support differing regional band requirements.”

Designed specifically for carrier aggregation, the SKY13530 (dual-pole 10-throw), SKY13532 (dual-pole 14-throw) and SKY13535 (dual-pole 21-throw) ASM portfolio has independent programmable registers for low-band and mid-high-band switch banks, allowing for multiple carrier aggregation band combinations. This flexibility provides rapid regional customization for smartphone and modem manufacturers, says Skyworks.

In addition, the low-band switch banks are optimized for improved harmonic suppression.

In conjunction with its carrier aggregation LTE portfolio, Skyworks is releasing single-output ASMs to support non-carrier aggregation implementations of the LTE rollout. The SKY13491-21 (single-pole 14-throw), SKY13492 (single-pole 16-throw), SKY13488 (single-pole 12-throw) and SKY13498 (single-pole 10-throw) provide scalability in non-carrier aggregation stock keeping units (SKUs).

Both carrier aggregation and non-carrier aggregation antenna switches feature an integrated dual-mode MIPI RFFE controller. Common truth tables and common footprint philosophy allow system scalability and programming code reuse to expedite front-end modifications at customer design centers.

# Skyworks launches second-generation SkyOne front-ends supporting carrier aggregation and more frequency bands

At the 2014 Mobile World Congress in Barcelona, Spain (24–27 February), analog semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA has unveiled its second-generation SkyOne platforms.

Launched in mid-2012, SkyOne is a family of fully optimized, scalable devices that integrate all of the high-performance RF and analog content between the transceiver and antenna into what is claimed to be the industry's smallest footprint. The devices also provide what is claimed to be the world's best linearity and power-added efficiency for smart RF integration. The newest front-ends cover more frequency bands, integrate up to seven duplexers, support carrier aggregation and provide standardized inputs for all leading chipsets that are MIPI RFFE compatible.

"Skyworks is pushing the integration envelope and meeting demands for smartphones, tablets and datacards requiring wider bandwidths being enabled by carrier aggregation," says Joel King, VP & general manager of advanced market solutions. "By utilizing our SkyOne solutions, mobile device OEMs no longer have to choose between size and time-to-market," he adds. "These devices deliver



best-in-class performance, are highly customizable and scalable as well as compatible with all leading chipsets."

Skyworks has incorporated RF switching technology in its newest devices that are enabling early adopters to implement carrier aggregation solutions. Carrier aggregation allows mobile service providers to combine spectrum and increase data rate throughput by using two or more bands simultaneously instead of the single-band method used currently, giving consumers an enriched data experience regardless of location.

SkyOne devices also support standardized inputs to industry-leading basebands (MIPI RFFE compatible) and address both transmit (Tx) and receive (Rx) switching paths.

Skyworks' carrier aggregation switching solutions, which are compliant to tier-one, carrier-driven specifications, are based on silicon-on-insulator (SOI) wafer process technologies and available in many different configurations.

SkyOne is an 8mm x 9mm x 0.95mm module with up to seven duplexers and a dual-pole, 19-throw antenna switch module (ASM) for models supporting carrier aggregation (CA) and single-pole, 16-throw ASMs for models without a CA requirement.

The SKY78021 is a hybrid, multi-mode, multiband (MMMB) front-end module (FEM) that supports 2.5G, 3G/4G and CDMA handsets and all standard carrier aggregation frequency band combinations through its integrated dual-pole 19-throw switch. The module operates efficiently in EDGE, GPRS, GSM, HSPA, LTE and WCDMA modes.

The SKY78022, SKY78025 and SKY78026 are MMMB FEMs supporting 2.5G, 3G/4G, CDMA and TDD-LTE handsets and operate efficiently in EDGE, GPRS, GSM, HSPA, LTE, TDD-LTE and WCDMA modes. These modules integrate single-pole, 16-throw switches with internal IEC protection.

## Front-ends for low-cost smartphones in emerging TD-LTE markets

At the Mobile World Congress, Skyworks introduced a suite of products targeting low-cost smartphones for emerging, high-growth markets.

Skyworks' portfolio of scalable and flexible front-ends includes multi-band power amplifiers, antenna switches and diversity modules for low- to high-end TD-LTE platforms. The highly efficient solutions deliver enhanced functionality, support multiple modulation schemes and enable handset makers to reduce the number of

discrete components. GTI (the industry association for the Global TDD Initiative) recently presented Skyworks with the 2014 GTI Innovation Award for developing products that address the performance, cost and size challenges of the TD-LTE market.

Skyworks is capitalizing on the enormous LTE upgrade cycle and demand for low-cost smartphones across emerging markets, says Reza Kasnavi, VP & general manager of open market platforms at Skyworks. "Our high-performance

products provide customers with a complete system solution as well as a broad range of architectural implementation options."

According to a Credit Suisse report 'Five Takeaways for Wireless' in January, LTE handsets will double in terms of volumes in 2014 to 537 million, and grow at a compound annual growth rate (CAGR) of 33% long term. In addition, emerging markets will rise from 71% of volume to 80% long term, driving a CAGR of 20%.

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

## IN BRIEF

### MACOM launches wideband, high-dynamic-range frequency doubler for point-to-point radios and cellular backhaul

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) has launched a wideband frequency doubler for point-to-point radios and cellular backhaul applications.

The MAFC-004403 is a frequency doubler for those needing a multiplier with excellent input and output return loss and isolation. Operating over the 16-24GHz bandwidth, the device is packaged in a 4mm x 4mm QFN that is RoHS compliant and compatible with reflow temperatures to 260°C. Unlike the competition, it is claimed, the frequency doubler exhibits input power level ranges from -5dBm to +5dBm, delivering typical output power of 17dBm. Input and output return losses are both 12dB. The device also demonstrates high 1xFIN and 3xFIN isolations (of -25dBm and -15dBm, respectively). Supply current (ID) is 130mA.

"The doubler provides microwave radio designers with a solution for generating the required LO frequencies aimed at the 18-42GHz bands," says product line director David Richardson. "When combined with the chipsets and VCOs that MACOM already offers for these bands, it provides a complete high-performance solution."

Production quantities and samples of MAFC-004403 are available from stock.

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

## Peregrine demonstrates UltraCMOS Global 1 power amplifier at Mobile World Congress

At the 2014 GSMA Mobile World Congress (MWC) in Barcelona, Spain (24-27 February), Peregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-sapphire (SOS) and silicon-on-insulator (SOI), hosted the first public demonstrations of its UltraCMOS Global 1 power amplifier (PA), which was launched at the beginning of February.

The UltraCMOS Global 1 is claimed to be the first LTE CMOS PA to deliver the performance level of gallium arsenide (GaAs) PAs, as well as offering the unique benefit of being integrated onto a single chip with Peregrine's Global 1 system, the first reconfigurable RF front end (RFFE). Only with an integrated reconfigurable RFFE can 4G LTE platform providers and OEMs create a single-SKU (stock keeping unit) handset design for global markets, the company adds.

To support over 40 frequency bands and a more than 5000-fold increase in the number of possible operating states, a truly reconfigurable RFFE is now a requirement,

says Peregrine. This level of reconfigurability is only feasible with a CMOS process, reckons the firm.

The entire UltraCMOS Global 1 system — multimode, multiband (MMMB) power amplifier (PA); post-PA switch; antenna switch; and antenna tuner — is based on Peregrine's UltraCMOS 10 technology platform (launched last November), which leverages 25 years of RF expertise with proven performance demonstrated by more than 2 billion RF SOI units shipped.

Peregrine says that, before now, no vendor has been able to deliver GaAs-level PA performance in a CMOS PA, which prevented CMOS PAs from competing in the performance-driven LTE handset market. The demonstration showed how the UltraCMOS Global 1 PA has what is claimed to be the same raw performance as the leading GaAs PAs, as well as a 33% increase in efficiency over other CMOS PAs, without enhancements from envelope tracking or digital pre-distortion (which is often used when benchmarking CMOS PAs with GaAs PAs).

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

## MACOM showcasing portfolio of S- and L-band power devices for radar

At the World ATM Congress 2014 in Madrid, Spain (4-6 March 2014), M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) showcased its portfolio of new gallium nitride (GaN) power products and high-power limiters for next-generation radar applications.

These included the following:

- what are claimed to be the highest-power GaN in plastic-packaged power transistors;
- integrated GaN power modules for L- and S-frequency bands;
- industry-first, highly integrated plastic-packaged control MMICs for commercial radar applications; and
- efficient, rugged and integrated high-power limiters that enable next-generation L- through X-band radar applications.

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

# InterDigital and Imec to co-develop 60GHz mmW and phased-array technology for 5G-ready small-cell backhaul

Wireless R&D firm InterDigital Inc and nano-electronics research center Imec have agreed to develop 60GHz millimeter-wave (mmW) radio and phased-array technology for small-cell backhaul and 5G wireless communications. The technology will enable easier deployments for small cell mobile backhaul resulting in lower cost solutions for high-speed data delivery.

Imec will work with InterDigital's 5G research team to develop a high-gain, wideband radio and phased-array antenna with fast electrical steering in azimuth and elevation. This fourth generation of Imec's phased-array antenna technology will be combined with InterDigital's directional mesh backhaul and 5G access link technologies on InterDigital's mmW Hotspot Demonstration Platform, which is being designed for gigabit per second rates across small-cell backhaul radio links.

Existing mmW solutions for backhaul are fixed point-to-point, resulting in costly installation expenses for installers to align links as well as capital expenditure for additional radios for each connection. InterDigital and Imec will provide radio and phased-array technologies to combine the high gain needed to close mmW links with the rapid beam steering that enables reliable and cost-effective mesh network small cell backhaul solutions.

"Phased-array antennas are a cornerstone to mmW wireless evolution," says Doug Castor, principal engineer, InterDigital Labs. "Imec's mmW technology, and the expertise of their researchers, will be a great complement to InterDigital's 5G development projects," he adds.

"Imec's R&D on 60GHz phased-array radios has resulted in small CMOS-based solutions with record low power consumption for 802.11ad/WiGiG," says Liesbet

Van der Perre, program director, wireless communication at Imec. "Together, we aim at leveraging our expertise for outdoor backhaul solutions," he adds. "This collaboration is a reinforcement of our strategy to bring attractive implementations for 5G terminals and networks to the industry."

InterDigital and Imec completed a millimeter-wave backhaul feasibility

study in 2013. The new agreement represents InterDigital's continuing collaboration in 5G with industry and university partners.

Imec exhibited at the Mobile World Conference (MWC 2014) in Barcelona, Spain (24–28 February), where InterDigital also had a pavilion.

[www.interdigital.com](http://www.interdigital.com)  
[www.imec.be](http://www.imec.be)

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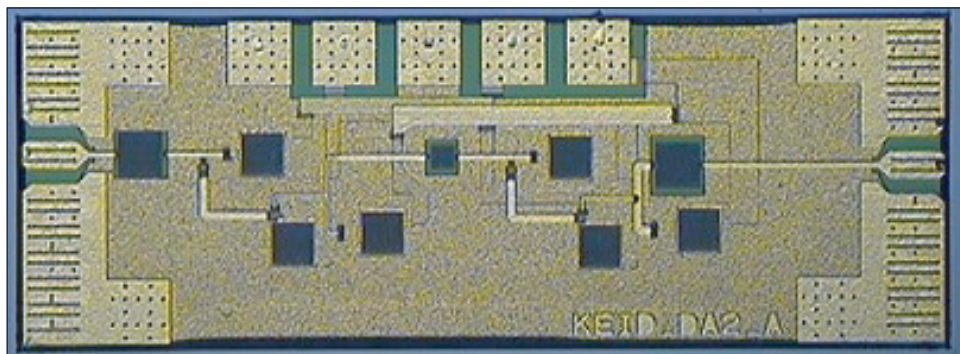


# UCL and Chalmers report widest-band amplifier at 235GHz, opening door to ultrafast broadband

A research collaboration between the University College London (UCL) in the UK and Chalmers University of Technology in Gothenburg, Sweden has resulted in the design and testing of what is reckoned to be the widest-band amplifier circuit ever reported.

The work was led by professor Herbert Zirath (head of the Microwave Electronics Laboratory at the Department of Microtechnology and Nanoscience at Chalmers) and professor Izzat Darwazeh (head of the Communications and Information Systems Group in UCL's Department of Electronic and Electrical Engineering).

Zirath and Darwazeh started on the joint project in summer 2012, aiming to design circuits suitable for communication at frequencies approaching the terahertz (THz) region. A set of amplifier circuits was designed by PhD student Klas Eriksson, manufactured by Teledyne in the USA, and measured at Chalmers a few months ago. However, the circuit builds on previous research and design work reported by Zirath and Darwazeh over the past two decades.



**Microphotograph of two-stage 235GHz amplifier MMIC (1.12mm x 0.48mm).**

The new monolithic microwave integrated circuit (MMIC) amplifiers achieved results close to design predictions: exceptionally wide broadband operation (from low GHz frequencies to frequencies exceeding 235GHz) and gain exceeding 15dB translate to a gain bandwidth product of about 1.5THz. The design team believes this amplifier is at least twice as fast (in terms of bandwidth) as the fastest amplifier reported to-date.

"This achievement was possible both because of excellent technological advances in nanotechnology and state-of-the-art design processes and techniques," says Darwazeh. "This technology will help make ultrafast broadband possible for

widespread use not only for communication systems but also for different scientific and test & measurement instrumentation," he adds.

"This result is of considerable interest for the development of new products within the area of communication and instrumentation such as fast oscilloscopes, pulse amplifiers and fast fiber-optic receivers," reckons Zirath.

Details of the work will be reported at the IEEE Microwave Theory and Techniques Society's (MTT-S) 2014 International Microwave Symposium (IMS) in Tampa Bay, FL, USA in June.

[www.chalmers.se/en](http://www.chalmers.se/en)

[www.ee.ucl.ac.uk/research/comminfosys](http://www.ee.ucl.ac.uk/research/comminfosys)

## Hittite to buy assets of Keragis

### Acquisition to enable Hittite to provide high-power wideband amplifiers

Hittite Microwave Corp of Chelmsford, MA, USA (which designs and supplies analog, digital and mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation) has entered into a definitive agreement to buy substantially all the assets of Keragis Corp of San Diego, CA.

Founded in 1993 and privately owned by Robert and Maria Rector, Keragis provides high-power, wideband amplifier modules (operating at 0.5–32GHz) that utilize both

gallium arsenide (GaAs) and gallium nitride (GaN). The high-performance military-grade and rugged commercial products have applications in RF and microwave systems, including radar subsystems, rack-mounted instruments, phased arrays and tow decoys.

The acquisition expands Hittite's power amplifier portfolio, combining Hittite's capabilities in designing and manufacturing ICs, modules and subsystems with Keragis' patented wideband high-power amplifier module products.

"Keragis' power amplifiers, in combination with Hittite's semiconductor technologies, synthesizer and up/downconverter module portfolio, will allow Hittite to expand its system content in both military and commercial applications that include electronic warfare, radar, communications, and test equipment," says Hittite's president & CEO Rick Hess.

The transaction is expected to close within the next 90 days.

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

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

## TowerJazz's Asia Pacific VP presents at SEMICON China 'More than Moore Technology Forum'

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) says that, at SEMICON China 2014 in Shanghai (19 March), its VP of sales for the Asia Pacific region, Dani Ashkenazi, presented at the 'More than Moore Technology Forum', which focused on 'Internet-of-Things Application driven MtM innovation'. The forum provided a platform for engineers, researchers and other industry peers to discuss advanced engineering and scientist information, ideas and solutions in the industry. Topics included: MEMS/sensor technologies, RF/mmWave technologies, CMOS image sensors, high voltage, high power, LED drivers, and the IP needed in the 'More than Moore' world.

TowerJazz's presentation discussed the role of the specialty foundry in the fast-growing China market and highlighted the firm's technology, including silicon germanium (SiGe), silicon-on-insulator (SOI) and its power platform (bipolar-CMOS-DMOS process and 700V technology). TowerJazz claims to be the market leader among foundries for SiGe processes. In China, customers are using this technology for wireless applications such as base stations, GPS, and walkie-talkies. In addition, they are using the firm's SOI switch for cell-phones and its power platform for notebooks, mobile applications and LED lighting.

TowerJazz has engaged nearly 20 China customers for its SOI switch technology. The firm reckons that, by collaborating with them, its market share will rise for Chinese-made mobile phones. In addition, at least 10 China customers are already

engaged in using TowerJazz's 700V technology for LED lighting and for AC-DC converters. Both 1.0µm 6" and 0.18µm 8" nodes offer a complete solution for LED lighting, says TowerJazz. According to market research firm IHS, the industrial LED market in the Asia-Pacific region is expected to increase at a compound annual growth rate (CAGR) of 10.8% from \$1.5bn in 2013 to \$2.3bn in 2017.

"We continue to place a strong focus on China as it consumes almost 50% of the world's ICs and internal China fabs can only cover 10% of the need," says Ashkenazi. "We are growing our customer base in China and are committed to meeting the rising demands of this region. We increased our revenue growth in China by 50% from 2012 to 2013 and we expect to maintain this growth rate in 2014 and beyond."

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

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# ST unveils 1200V SiC power MOSFETs with 200°C rating

STMicroelectronics of Geneva, Switzerland has unveiled a family of high-voltage silicon carbide (SiC) power MOSFET products, enabling power supply designers to drive up energy efficiency in applications such as solar inverters and electric vehicles, enterprise computing and industrial motor drives.

ST claims to be among the first firms to produce high-voltage SiC power MOSFETs, and has achieved what is said to be the industry's highest temperature rating of 200°C. SiC's properties help to save at least 50% of the energy normally wasted passing through conventional silicon power transistors, it is reckoned. The devices can also be physically smaller for a high breakdown voltage. The technology is seen as essential for continued improvement in system energy efficiency, miniaturization and cost.

In computer rooms and data centers, high energy costs are driving power and efficiency to the top of many IT directors' concerns, ST says. Replacing ordinary silicon switches with SiC devices in bulk power supplies helps to increase power usage effectiveness (PUE, a standard metric for determining data-center energy efficiency). The Climate Savers Computing Initiative (CSCI) claims that more

energy-efficient networking systems and devices can help to save more than \$5bn and offset 38 million tons of CO<sub>2</sub> by 2015.

SiC MOSFETs are also used in solar inverters, as an alternative for conventional high-voltage silicon insulated-gate bipolar transistors (IGBTs), to convert the DC output from the panel into high-voltage AC feeding into the mains supply with no special drive circuitry required. In addition, by operating at higher frequencies than IGBTs, SiC MOSFETs allow designers to miniaturize other components in the power supply, reducing the cost and size as well as enhancing energy efficiency.

In electric vehicles, SiC is expected to help to significantly increase the energy efficiency and reduce the size of traction systems. The US DRIVE Electrical & Electronics Technical Team (a partnership between industry and the US government's Department of Energy) is calling for energy losses to be approximately halved by 2020 while also reducing size by more than 20%. Its roadmap specifies wide-bandgap semiconductors (such as SiC) as a focus for R&D to increase power-converter efficiency and make the device tolerate higher operating temperatures more safely. ST claims that the increased temperature capability of

its SiC devices (200°C), compared with ordinary silicon and competitors' SiC MOSFETs, will help to simplify vehicle cooling system design.

ST's new SCT30N120 1200V SiC power MOSFET is currently sampling and will enter volume production by September.

As well as the 200°C maximum operating temperature (reducing pc-board size, simplifies thermal management), features include:

- typical on-state resistance ( $R_{DS(ON)}$ ) of 80mΩ at 25°C, and ≤100mΩ over the entire temperature range to 200°C;
- low turn-off energy and gate charge (ensuring efficient, high-speed switching);
- leakage current lower than 10μA typical (enhancing system energy efficiency and reliability, compared with other structures based on the same material);
- fast intrinsic and robust body diode (saving external freewheeling diode for cost/size reduction); and
- simplified gate drive circuitry (reducing costs of network driving).

The SCT30N120 is available in the firm's proprietary HiP247 package, which has an industry-standard outline and is optimized for high thermal performance. The guide price is \$35 in 1000-unit quantities.

[www.st.com/sicmos](http://www.st.com/sicmos)

## Mitsubishi develops EV motor drive system with built-in SiC inverter

Tokyo-based Mitsubishi Electric Corp has developed a prototype electric vehicle (EV) motor drive system with a built-in silicon-carbide (SiC) inverter.

Reckoned to be the smallest of its kind, the EV motor drive system is intended to enable manufacturers to develop EVs offering more passenger space and greater energy efficiency.

Global demand for EVs and hybrid EVs (HEVs) has been growing in recent years, reflecting increasingly strict regulations for fuel efficiency and growing public interest in saving energy resources and reducing CO<sub>2</sub> emissions, notes Mitsubishi Electric. As EVs and HEVs require relatively

large spaces to accommodate their robust battery systems, there is a strong need to reduce the size and weight of motor systems and other equipment to ensure sufficient passenger space, the firm adds.

Mitsubishi Electric says that, with an integrated all-SiC inverter, its new prototype EV motor drive system has been downsized further (to 14.1L, for 60kW) due to having a smaller motor, resulting from improved thermal resistance between the motor drive system and cooling system. The system is equal to existing EV motors in power and volume, enabling replacement.

Mitsubishi Electric also highlights improved motor cooling performance, since the cooling system for both the motor and inverter are integrated due to the cylindrical shape of the power module accommodating parallel cooling ducts for motor and inverter. This ensures stable cooling with even a low-power pump.

Mitsubishi Electric plans to commercialize its new EV motor system after finalizing technologies for motor/inverter cooling, as well as downsizing the dimensions further and increasing efficiency.

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

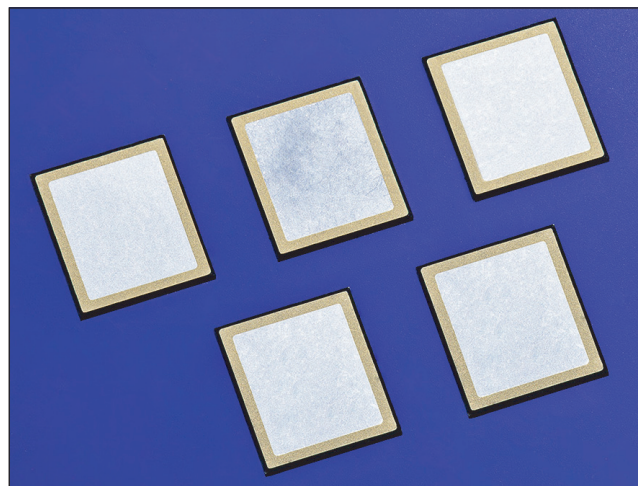
## Cree launches first 50A silicon carbide rectifiers

Cree Inc of Durham, NC, USA has launched the CPW5 Z-Rec high-power silicon-carbide (SiC) Schottky diodes — claimed to be the first commercially available family of 50 Amp SiC rectifiers.

Designed to deliver the cost reduction, high efficiency, system simplicity and improved reliability of SiC technology to high-power systems from 50kW to over 1MW, the new diodes address demanding applications including solar/PV inverters, industrial power supplies, induction heating, battery charging stations, wind turbine converters and traction inverters.

Developed to facilitate the direct matching of 50A diodes to 50A metal-oxide-semiconductor field-effect transistors (MOSFETs) or insulated-gate bipolar transistors (IGBTs), the CPW5 Schottky diodes reduce system complexity and cost by enabling the replacement of multiple low-voltage, low-current SiC Schottky diodes, or silicon PiN diodes, with a single CPW5 rectifier, says Cree. Additional cost savings can be achieved through reduced maximum voltage ratings and the elimination of snubber circuitry due to the diminished voltage overshoot during switching in silicon carbide.

"Cree's CPW5 family of SiC Schottky diodes are a critical component in our high-performance power modules and power electronic systems," comments Ty McNutt, director of business development at Arkansas Power Electronics International Inc (APEI) of Fayetteville,



**Cree's CPW5 Z-Rec 1700V 50A SiC Schottky diodes.**

AR, USA, a developer of technology for power electronics systems.

"The low forward voltage drop, fast switching speed and extended temperature capability allow us to push power density and efficiency across many applications, such as high-power motor drives and solar inverters."

**Developed to facilitate the direct matching of 50A diodes to 50A MOSFETs or IGBTs, the CPW5 Schottky diodes reduce system complexity and cost by enabling the replacement of multiple low-voltage, low-current SiC Schottky diodes, or silicon PiN diodes, with a single CPW5 rectifier**

Cree says that the CPW5 diodes enable a new generation of high-current Si/SiC IGBT modules. Hybrid Si/SiC IGBT modules can deliver up to a 43% reduction in switching losses over conventional modules, while also reducing voltage- and current-overshoot, switching dead time and cooling requirements.

As an added benefit, design engineers can use the same gate

driver design and circuits used with conventional modules, allowing easy and immediate implementation, says the firm. The CPW5 diodes also provide a peak forward surge resistance greater than 500A repetitive and 2000A non-repetitive, delivering increased reliability under the harshest electrical conditions.

"As the sole distributor of Cree SiC-based power products in wafer and die form, SemiDice is excited to offer the CPW5 family of Z-Rec Schottky diodes," says Dan Cormack, CEO of SemiDice Inc. "We are seeing increased customer demand for 50 Amp Schottky diodes," he adds.

The CPW5 family of Z-Rec Schottky diodes includes 1700V/50A, 1200V/50A, 650V/50A and 650V/30A combinations. The new CPW5 diodes are available immediately in bare die form from SemiDice.

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

[www.semidice.com/OurPartners/](http://www.semidice.com/OurPartners/)

## Cree presents at APEC on silicon carbide MOSFETs

At the Applied Power Electronics Conference and Exposition (APEC 2014) in Fort Worth, Texas (16–20 March), Cree Inc of Durham, NC, USA exhibited as well as delivering three presentations.

Cree provided information about its new CPW5 Z-Rec high-power Schottky diodes (claimed to be the first commercially available family

of 50A SiC rectifiers).

Cree also conducted an exhibitor seminar about its second-generation SiC MOSFETs, which are said to enable smaller, higher-efficiency solutions at cost parity with silicon-based technologies. The firm also participated in two technical sessions: T30-Semiconductor Devices; Track: Devices and Components,

'Dynamic and Static Behavior of Packaged Silicon Carbide MOSFETs in Paralleled Applications'; D08-Higher Power Device Switching; Track: Devices and Components, '1000V Wide Input Auxiliary Power Supply Design with 1700V Silicon Carbide (SiC) MOSFET for Three-Phase Applications'.

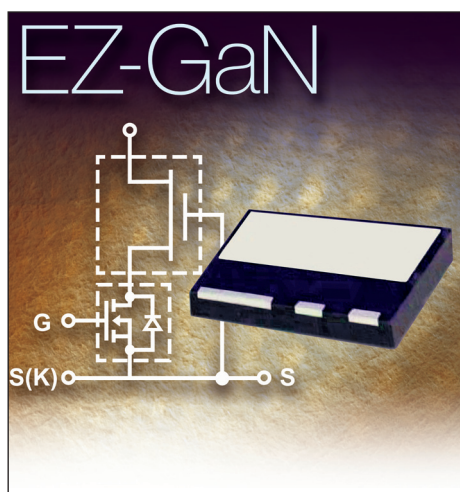
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# Transphorm adds first 600V GaN PQFN-packaged products to JEDEC-qualified GaN-on-Si family

At the IEEE Applied Power Electronics Conference & Exposition (APEC 2014) in Fort Worth, TX, USA (16–20 March), Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and delivers power conversion devices and modules) has announced what it claims is the industry's first 600V gallium nitride (GaN)-based, low-profile PQFN products and the expansion of its product portfolio in industry-standard TO220 packages.

This follows the introduction of the firm's GaN-on-Si transistor family at APEC 2013 as the industry's first JEDEC-qualified 600V GaN device platform. Transphorm's 600V GaN high-electron-mobility transistors (HEMTs) use the firm's patented EZ-GaN technology, which combines low switching and conduction losses, reducing overall system energy dissipation by up to 50% compared with using conventional silicon-based power conversion designs, it is reckoned.

The new TPH3002LD and TPH3002LS PQFN products are offered in widely used, low-profile PQFN88 packages and feature 290mΩ  $R_{DS(on)}$ , 29nC  $Q_{rr}$  and low inductance for what is claimed to be superior high-frequency switching



**Transphorm's 600V GaN HEM in a PQFN package.**

capability. The PQFN88-packaged LD devices also feature a kelvin connection to better isolate the gate circuit from the high-current output circuit to further reduce electromagnetic interference (EMI).

In addition, the TPH3002PD and TPH3002PS TO220-packaged 600V GaN HEMTs have been released for use in smaller, lower-power applications such as adapters and all-in-one computer power supplies. These devices also feature 290mΩ  $R_{DS(on)}$ , 29nC  $Q_{rr}$  and high-frequency switching capability.

"Every year since 2011 we have announced new advancements of our GaN technology at this major tradeshow," notes president Primit Parikh. "Now, by introducing the industry's first qualified 600V GaN PQFN-packaged products, we have increased the types of applications where GaN can enable dramatically more efficient, compact and low-cost solutions," he adds. "This dispels the widespread misconception that GaN isn't ready for prime-time. Once again we've shown GaN products are available today and are actually being used in a multitude of real-world applications."

The TO220-packaged TPH3002PD and TPH3002PS and the PQFN-packaged TPH3002LD and TPH3002LS are available for sale to qualified customers worldwide, directly or through Transphorm's distribution channels.

Additionally, evaluation boards are available with the 600V TO220 GaN HEMT devices in configurations for LLC DC–DC converter, totem-pole PFC (power factor correction) and all-in-one power supply.

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

[www.apec-conf.org](http://www.apec-conf.org)

[/conference/industry-sessions](http://conference/industry-sessions)

## Transphorm gives presentations on GaN in APEC's Industry Sessions

At last year's IEEE Applied Power Electronics Conference & Exposition (APEC), Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and delivers power conversion devices and modules) introduced the first — and only — 600V JEDEC-qualified GaN-on-silicon high-electron-mobility transistors (HEMTs). This year, at APEC 2014 in Fort Worth, TX, USA (16–20 March), Transphorm gave two presentations providing an update on growing industry acceptance of gallium nitride (GaN), along with the advantages of using the technol-

ogy for power conversion designs in actual implementations.

To offer an update on energy-efficient and compact power conversion technology, one presentation addressed long-term reliability of GaN devices, while the other deals with the impact of high-frequency switching on magnetic devices:

- 'Moving Beyond Qualification to Verify the Long-Term Reliability of GaN Devices', authored by Dr Kurt Smith and Dr YiFeng Wu, in the Industry Session IS2-4-2 on 'Wide Band Gap Devices';

- 'A GaN Speaker, What He Needs', by YiFeng Wu, in Industry Session IS2-5-3 on 'How are Magnetics Catching up to SiC & GaN'.

APEC's Industry Session presentations are solicited from leaders in the power electronics industry and are geared to address topics of current interest — particularly the impact of emerging technologies on today's designs. Unlike APEC's General Session papers, presentations in Industry Sessions are not published in the conference proceedings and were only available to session attendees.

# RFMD awarded \$9.7m Air Force contract to produce first 6" mm-wave GaN-on-SiC ICs

## AFRL's 0.14 $\mu$ m MMIC technology to be transferred to RFMD's 6" line

RF Micro Devices Inc of Greensboro, NC, USA has signed a \$9.7m agreement with the Manufacturing and Industrial Technologies Directorate within the US Air Force Research Laboratory (AFRL) to transfer and produce a 0.14 $\mu$ m gallium nitride (GaN) monolithic microwave integrated circuit (MMIC) technology. The technology will be scaled to 6"-diameter wafers using RFMD's 6" GaN-on-silicon carbide (SiC) manufacturing line.

"Through this Air Force contract we have the opportunity to establish the industry's first 6-inch millimeter-wave GaN-on-SiC process technology, allowing RFMD to expand our technology capabilities beyond 100GHz," says Gorden Cook, general manager of RFMD Power Broadband. "We expect this new technology will not only enable a new class of affordable power MMICs for defense applications such as radar and military communications, but also commercial

applications including cable TV networking, microwave backhaul and cellular infrastructure."

According to industry analyst firm Strategy Analytics, the GaN microelectronics market is expected to

more than triple to \$334m by 2017, representing a compound annual growth rate (CAGR) of 28%, driven by both military (radar, electronic warfare, communications) and commercial (power management,

**Through this Air Force contract we have the opportunity to establish the industry's first 6-inch millimeter-wave GaN-on-SiC process technology, allowing RFMD to expand our technology capabilities**

cellular, CATV, land mobile radios) applications.

"AFRL has a distinguished history of developing high-performance technologies with an understanding of underlying physics that drive reliability," says Cook. "RFMD plans to leverage AFRL's experience to offer reliable, 0.14 $\mu$ m-gate GaN power technology for mass production in our US-based, open foundry."

GaN technology supports broad frequency bandwidths and high breakdown voltages in a small area. RFMD's 6" GaN wafer offers 2.5 times more usable area over competing 4" GaN wafer platforms currently available, resulting in 2.5 times more RF power devices per wafer. Millimeter-wave GaN enables the best trade-off between key performance parameters such as power gain, bandwidth and efficiency for applications in the range of DC to over 100GHz, says RFMD.

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

## RFMD's gallium nitride amplifiers for DOCSIS 3.1 cable TV win CableFAX Tech Award for Green Technology

RF Micro Devices Inc of Greensboro, NC, USA says that its gallium nitride (GaN) amplifier family for the new DOCSIS 3.1 CATV networking standard has won the CableFAX Tech Award for Green Technology, which recognizes technology that helps cable companies and program distributors to cut energy consumption in equipment installed at the head-end and/or in equipment distributed to residential and business customers. RFMD was recognized during the CableFAX Digital and Tech Awards ceremony at the Yale Club in New York City.

RFMD claims that its GaN-based amplifier products improve the power efficiency of existing CATV

systems supporting DOCSIS 3.1, reducing current consumption by as much as 20% compared with competing gallium arsenide (GaAs)- and silicon-based amplifiers. Beyond power savings, use of the firm's GaN technology reduces material waste and the energy needed to produce line amplifiers made from either GaAs or silicon: a single GaN amplifier replaces 16 silicon-based amplifiers or two GaAs amplifiers.

"This award is a tribute to RFMD's CATV hybrid amplifier team and to the power and space savings offered by the new GaN amplifier family they developed, which is helping customers upgrade equipment for the next generation

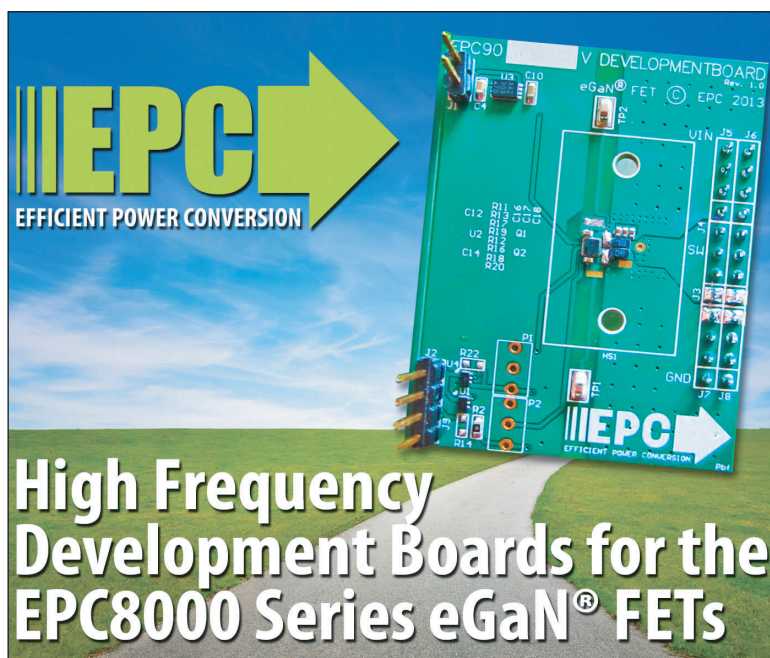
of cable networking," says Norm Hilgendorf, president of RFMD's Multi-Market Products Group.

RFMD's GaN family for DOCSIS 3.1 includes the RFCM4363 push-pull amplifier, RFCM3316 power doubler amplifier, and RFPD2580 hybrid power doubler amplifier. Compared with DOCSIS 3.0, the DOCSIS 3.1 standard increases effective downstream data rates from 160Mb/s to 10Gb/s, and upstream data rates from 120Mb/s to 1Gb/s. DOCSIS 3.1 extends CATV frequencies from 1GHz to 1.2GHz, enabling higher data speeds as well as additional high-definition television (HDTV) and video on demand (VOD) services.

# EPC introduces development boards for EPC8000 family of eGaN FETs

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 introduced a family of development boards — the EPC9022 through EPC9030 — to simplify evaluation of its EPC8000 family of ultra-high-frequency eGaN power transistors.

The EPC8000 family of high-frequency eGaN FETs has switching transition speeds in the sub-nanosecond range, making them capable of hard-switching applications above 10MHz — blurring the line between power and RF transistors. Even beyond the 10MHz for which they were designed, they exhibit good small-signal RF performance with high gain well into the low-GHz range, making them a competitive choice for RF applications, says the firm. The eGaN FETs are suitable for applications such as wireless power and 65V and 100V devices for envelope tracking, where extremely fast power transistor



2" x 1.5" and contain two eGaN FETs in a half-bridge configuration with a minimum switching frequency of 500kHz. The boards contain all critical components and layout for optimal high-frequency switching performance.

switching is required.

Products in the EPC8000 family are available with on-resistance values from 125mΩ through 530mΩ, and three blocking voltage capabilities: 40V, 65V and 100V.

To simplify the evaluation of the family of eGaN FETs, EPC is offering a development board for each device in the new product family.

The development boards are

There are various probe points to facilitate simple waveform measurement and efficiency calculation.

Evaluation units of the EPC8000 family of devices are available in 2- and 10-piece packs, starting at \$23, through Digi-Key Corp. EPC9022 through EPC9030 development boards are priced at \$150 each.

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

## EPC presents GaN technology for high-frequency resonant and envelope tracking power supplies at APEC

At 29th annual IEEE Applied Power Electronics Conference & Exposition (APEC 2014) in Fort Worth, TX, USA (16–20 March), 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, gave three application-focused technical presentations about high-frequency resonant converter, and high-frequency, hard-switched power converter design.

Technical presentations featuring GaN FETs by EPC experts were as follows:

- 'Evaluation of Gallium Nitride Transistors in High Frequency Resonant and Soft-Switching DC-DC Converters' by David Reusch and Johan Strydom (TO9-Wide Bandgap Devices in DC-DC Converters);
  - 'GaN: Raising the Bar for Power Conversion Performance' by David Reusch (IS2-4-3, Wide Band Gap Devices); and
  - 'Design and Evaluation of a 10 MHz Gallium Nitride Based 42 V DC-DC Converter' by Johan Strydom and David Reusch (T30-Semiconductor Devices, Track: Devices and Components).
- Focusing on practical and applied

aspects of the power electronics business, APEC addresses the use, design, manufacture and marketing of all kinds of power electronics components and equipment.

"We are honored that the technical review committee of APEC 2014 has selected EPC experts to give technical papers focusing on GaN technology at their annual conference," says EPC's co-founder & CEO Alex Lidow. "This selection supports our belief that the superior performance of GaN technology has gained the interest and acceptance of power system design engineers."

[www.apec-conf.org](http://www.apec-conf.org)

## EPC demonstrates how eGaN FETs boost efficiency by 20% in wireless power 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, is giving technical presentations at three power electronics conferences in Asia.

At two conferences in Shanghai, China on 18 March, EPC presented how GaN power devices have emerged as higher-efficiency replacements for aging silicon (Si) power MOSFETs, specifically due to increases in performance offered by eGaN FETs in wireless power transfer (WiPo) applications. Examples include a new power conversion design that delivers up to 20% improvement in efficiency and a second design delivering power of up to 30W operating with loosely

coupled coils in the 6.78MHz ISM (industrial, scientific & medical) band.

On 18 March at Electronica China 2014, 'Improving Wireless Energy Transfer Performance with eGaN FET-based Converter' was presented by Dr Michael de Rooij (executive director of Application Engineering) and Peter Cheng (director of FAE for Asia).

On 18 March at the IIC-China 2014 Spring Conference (Power Management and Semiconductor), 'Improving Wireless Energy Transfer Performance with eGaN FET-based Converter' was presented by Dr Michael de Rooij (executive director of Application Engineering) and Peter Cheng (director of FAE for Asia).

On 10 April, at the International Workshop on Wide-Band-Gap Power Electronics (IWWPE 2014) at

ITRI, Taiwan, 'Crushing Silicon with GaN' will be presented by EPC's CEO & co-founder Dr Alex Lidow, who will highlight key new applications, latest products on the market, latest roadmaps into the future, and the relative competitive position of GaN with the power MOSFET and silicon carbide (SiC).

"These three key Asian industry conferences provide EPC an opportunity to meet with practicing power system design engineers and share the attributes of GaN technology and how eGaN FETs can increase performance and efficiencies in their power system designs," says Lidow.

[www.electronicachina.com.cn](http://www.electronicachina.com.cn)  
[www.fair.iic-china.com/iicc/CONVISTR/2014spring-power.HTM](http://www.fair.iic-china.com/iicc/CONVISTR/2014spring-power.HTM)  
<http://wpec.org.tw/Industry>  
[www.epc-co.com](http://www.epc-co.com)

## Raytheon outlines continuing maturing of GaN technology through DARPA's WBGS program

Raytheon Company of Waltham, MA, USA says that, under the US Defense Advanced Research Projects Agency (DARPA) Microsystems Technology Office (MTO) Wide Bandgap Semiconductor (WBGS) program, it has systematically matured gallium nitride (GaN) from basic material to transistors, monolithic microwave integrated circuits (MMICs), transmit/receive (T/R) modules and finally transmit/receive integrated multichannel modules (TRIMMs), enabling what is reckoned to be game-changing system performance for the Department of Defense (DOD).

This is the latest milestone for Raytheon's GaN technology, which last June was honored by the Office of the Secretary of Defense (OSD) for successful completion of a Defense Production Act (DPA) Title III GaN production improvement program, a result of more

than a decade of Government and Raytheon investment in GaN RF circuit technology (in which GaN yield was improved by more than 300% and cost was reduced more than 75% for MMICs).

GaN technology extends warfighting capabilities, providing radar, electronic warfare, navigation and communication systems with more affordable solutions and increased capability.

"Through our partnership with DARPA we continue to explore new ways to leverage GaN's limitless capabilities to drive performance and reliability of defense systems," comments Joe Biondi, vice president of Advanced Technology for Raytheon's Integrated Defense Systems (IDS) business in Tewksbury, MA.

As part of the DARPA MTO Wide Bandgap Semiconductor Program, Raytheon — with the support of a

Navy, Air Force and Army technology team — has achieved several first-of-their-kind milestones:

- demonstrated record X-band GaN power amplifier MMIC performance — higher efficiency and power enables more affordable systems with higher capability;
- completed first X-band GaN T/R module demonstrations, involving extensive, successful design verification testing over a range of relevant operating conditions (demonstrating the maturity of the GaN technology); and
- completed the first X-band GaN TRIMM demonstration, involving extensive testing in a relevant array environment (including a 1000 hour operating test in a laboratory pilot array and an insertion validation in a production radar), proving that the TRIMM is ready for transition to production.

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

# TriQuint launches 130W Spatium GaN-based solid-state power amplifier for Ka-band SatComs

RF front-end component maker TriQuint Semiconductor Inc of Hillsboro, OR, USA says that its Spatium technology achieves unprecedented levels of Ka-band solid-state power, bandwidth and efficiency, providing greater broadband capacity and opening up new satellite possibilities, as it launched a 130W Spatium solid-state power amplifier for Ka-band SatComs at the Satellite 2014 event in Washington DC (11–13 March).

TriQuint's patented Spatium technology enables satellite communications for commercial and defense use of the recently deployed Ka-band spectrum. Its high-frequency broadband connectivity can be used for media-rich and high-bandwidth communications such as airborne wireless access; defense communications; and video for UAV unmanned aerial vehicles or systems. Spatium combines multiple gallium nitride (GaN) monolithic microwave integrated circuits (MMICs), enabling cost effective and reliable solid-state broadband power amplification (SSPA), the firm says.



duces linear output power of 60W with more than 15% efficiency, operating at only 20V.

TriQuint claims that Spatium's ease of integration, small form factor and integral parallel redundancy ensure

cation (SSPA), the firm says.

"With Spatium, TriQuint is advancing the use of GaN technology in a broad range of radar, electronic warfare and communication applications," says vice president James Klein, TriQuint Infrastructure and Defense Products. "TriQuint's Spatium technology has eclipsed historical industry performance levels by a significant margin, providing exactly what the rapidly growing Ka-band satellite market needs," he claims.

Spatium produces average saturated power of more than 130W over the entire 27–31GHz band. It also pro-

vides a reliable alternative to travelling-wave tube amplifiers (TWTAs). Spatium's high power and bandwidth capability provide a solid-state alternative to TWTAs, which operate at high voltage and require complex and expensive external optimization networks to improve efficiency and linearity, the firm adds.

Spatium amplifiers are available in a wide variety of both off-the-shelf and custom configurations operating at frequencies up to 40GHz and power levels up to multiple kilowatts.

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

# MACOM adds 10W GaN in Plastic power transistor for radar and communications system

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) has added to its GaN in Plastic series with a wideband packaged gallium nitride (GaN) power transistor suitable for high-performance civilian and military radar and communications systems.

The MAGX-000035-01000P is a 10W GaN-on-SiC unmatched power transistor that offers broad RF frequency capability, reliable high-voltage operation, and what is claimed to be the smallest footprint in plastic-packaging technology. The SMT surface-mount technology enables faster time-to-market through the use of high-volume

commercial, surface-mount assembly methods, says the firm.

Packaged in miniature 3mm x 6mm DFN and 14-lead DFN package, the MAGX-000035-01000P operates from DC–3.5GHz and leverages thermal management techniques to ensure reliability in true surface-mount applications. The device also operates at 50V drain bias, resulting in what is claimed to be outstanding power density performance, higher efficiency, and smaller impedance-matching circuits due to improved device parasitics. Power-added efficiency (PAE) at 1GHz is 58%. Power gain is 15dB. The high-voltage operation also benefits overall system design, with smaller energy storage capacitors and lower

current draw. The device can operate in pulsed and CW modes and maintains a calculated mean-time-to-failure (MTTF) at 200°C of about 600 years.

"MACOM's 10W GaN in Plastic power transistor offers both pulsed and CW modes of operation, making it a highly versatile driver or final power stage for multiple applications," says product manager Paul Beasley. "Furthermore, the device has been thermally designed to operate with standard surface-mount assembly, which significantly simplifies the design and implementation into higher level systems."

GaN in Plastic test fixtures are available upon request.

[www.macom.com/gan](http://www.macom.com/gan)

# GaN Systems appoints power electronics exec as CEO

GaN Systems Inc of Ottawa, Ontario, Canada, a fabless developer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, has appointed Jim Witham as CEO.

GaN Systems' power conversion devices, based on its proprietary Island Technology, are being commercialized in 2014 and the firm is expanding globally. Co-founders Girvan Patterson and John Roberts will continue in their current roles as president and chief technical officer, respectively.

Witham has over 30 years' experience in business development, international sales & marketing and operations management, and joins GaN Systems from Neoconix Inc, a manufacturer of high-density, high-performance miniature connectors. As president & CEO of Neoconix, he implemented strategic changes that dramatically increased revenue and resulted in the firm's acquisition by Unimicron Technology Corp.

Previously, Witham spent five years as president & CEO at Fultec Semiconductor, and has also held VP sales & marketing positions at



**CEO Jim Witham.** Sales & Marketing, based in Japan. As an engineering specialist at General Dynamics' Space System Division during the 1980s, Witham worked on fluid systems for the Space Shuttle and was on Mission Control for interplanetary missions.

Witham holds an MBA from Harvard and both M.S. and B.S. with distinction in Mechanical Engineering from Stanford University.

"Witham has extensive leadership experience in the power electronics industry, and his expertise will be invaluable in guiding the company through the next phase of its development," says chairman Ian McWalter. "As GaN Systems' unique product offering based on our proprietary Island Technology is commercialized this year and as we increase our worldwide market presence, Jim and our senior execu-

Aegis Semiconductor and Genoa Corp. Other career highlights include senior executive positions at Raychem, including director of Asia

utive team will grow GaN Systems into a significant player in the power electronics industry," he believes.

"Since John Roberts and I founded GaN Systems in 2008 to develop our Island Technology products, there has been increasing recognition of gallium nitride's advantages over silicon devices in power conversion applications," says Patterson. "Jim will be a great addition to our team as we look forward to the full commercialization of our product families and GaN power devices become the technology of choice in automotive, power, alternative energy and many other markets."

On behalf of GaN Systems' investors Chrysalix Energy Venture Capital and Rockport Capital, Mike Sherman, managing partner of Chrysalix EVC, comments: "The founders of GaN Systems have done an outstanding job of building the company to its present stage, and the addition of Jim Witham, with his proven leadership and global market experience, will allow the team to fully deliver their unique gallium nitride-based power conversion solutions to the world."

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

## GaN Systems appoints senior director of technical marketing, Asia

GaN Systems has appointed Charles Bailley as senior director technical marketing, Asia.

The appointment is part of its strategy to increase headcount worldwide to support early adopters of GaN-based devices while, the firm says, automotive, industrial and enterprise equipment manufacturers replace legacy silicon-based semiconductors with GaN power devices in order to achieve higher efficiency, power density and reliability.

Bailley's experience in the power semiconductor industry includes over 18 years of engineering and management in semiconductors and platforms at firms including Intel, Intersil and CHiL Semicon-

ductor (since acquired by International Rectifier). His background includes applications engineering, design engineering in both power electronics and analogue ICs, and marketing and business development. He has an MSEE from Florida Institute of Technology and a BSEE from the US Naval Academy, and he also holds a number of US patents.

"2014 is the year we will commercialize our broad range of GaN-on-silicon products, and Charles will play a key role in driving our business forward, including working with leading customers to define products for their markets," comments GaN Systems' CEO Girvan Patterson.

"It's very exciting to be joining GaN Systems as gallium nitride power technology matures and its market share is poised for rapid growth," says Bailley. "Asia is the largest market for power electronics and I'm very much looking forward to supporting customers in the region."

GaN Systems reckons that Bailley's addition further strengthens its global presence. He will work with founder & VP of business development Geoff Haynes (who leads business development worldwide), Tony Astley (responsible for managing business operations in Europe) and Julian Styles (business development director in the Americas).

## Cree selects Plextek RF Integration as preferred design resource for European GaN foundry customers

Plextek RF Integration (Plextek RFI) of Cambridge, UK, which designs and develops RFICs, MMICs and microwave/millimeter-wave modules, has been selected by Cree Inc of Durham, NC, USA as a preferred design resource to provide third-party design services to European customers of Cree's gallium nitride (GaN) foundry service.

Commercial availability of GaN transistors has provided a step change in achievable performance for solid-state power amplifiers (SSPAs), says Plextek. Cree has a growing portfolio of discrete transistors, microwave monolithic integrated circuits (MMIC), and GaN foundry services that allow customers to design their own transistors and MMICs for fabrication on Cree's processes.

Cree's European customers will now have access to Plextek RFI's



**Wafer processing at Cree.**

proven design capabilities to develop their own custom GaN MMICs. In addition to providing

design and layout services, Plextek RFI has in-house test facilities that allow evaluation of MMICs both in bare die form (directly on wafer) and as packaged parts.

"We see huge growth potential for GaN in Europe," says Cree's foundry services program manager Jeff Barner. "Plextek RFI's experienced design and development team will provide a significant advantage to our European customers," he adds.

"We have been seeing a steady increase in the amount of GaN MMIC design work we are taking on, and being able to provide our clients with access to one of the world's best foundry processes will significantly enhance the service we are able to offer," comments Plextek RFI's CEO Liam Devlin.

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

## IQE launches OpenIQE initiative to boost regional supply chains

### Open Innovation program to establish partnerships supporting development of key enabling technologies

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has launched its Open Innovation program 'OpenIQE', which aims to establish partnerships to support the development of a broad range of key enabling technologies (KETs).

The first major project under the new program is the IQE Open Technology Challenge, which was marked by a launch event at the SWALEC Stadium in Cardiff on 21 March.

The aim of the challenge is to engage with small and medium enterprises (SMEs), larger businesses and academic institutes, initially focusing primarily on the Welsh region, to develop new and enhance existing supply chains.

The project will focus on technology areas termed the Three Grand Challenges, identified in the Science for Wales strategy and other major international programs including the EU Horizon2020 Program. The three areas are life sciences and health; low carbon, energy and environment; and advanced engineering and materials.

Technology will play an increasingly important role in addressing a range of societal challenges, notes the firm. The IQE Open Technology Challenge is aimed at establishing partnerships along an end-to-end supply chain to develop and commercialize products that will meet real needs within the areas defined by the Three Grand Challenges.

"IQE has more than 25 years'

experience of working closely with partners and customers worldwide to meet demanding technical specifications," comments IQE's president & CEO Dr Drew Nelson. "We are delighted to be contributing our experience of collaborative innovation in the form of our new Open Innovation programme," he adds. "We are confident that the Open Technology Challenge has the potential to become a key stepping stone towards the establishment of a major technology cluster in the region, as well as building stronger links to the global technology community."

IQE's Open Innovation program is supported by the Welsh Government.

[www.openiqe.com](http://www.openiqe.com)  
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HBTs pHEMTs BiFET/BiHEMTs

## EpiGaN appoints Siemens/Infineon veteran as chairman

III-nitride epitaxial material supplier EpiGaN nv of Hasselt, Belgium has appointed Claus Geisler as chairman of the board of directors.

The firm says that Geisler has extensive expertise in the semiconductor industry, executive management and the investment community. He holds a degree in electrical engineering from the University of Applied Sciences in Bielefeld, and has more than 40 years of experience in the semiconductor industry. After sev-



**Claus Geisler.**

eral management positions, Geisler has worked for the last 18 years at Siemens/Infineon in Munich (where most of his time was dedicated to the power semiconductor business, in which Infineon is the market leader). Geisler retired as a senior

VP at Infineon and as a board member of the automotive division.

"Geisler will play a key role in setting the strategic direction of the company," says Germain.

"I look forward working with the management team to drive EpiGaN's expansion and to grow the business globally," says Claus Geisler.

"EpiGaN will play an important role in the industrialization of GaN (gallium nitride) technology in the near future," he believes.

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

## EpiGaN wins National Trends Gazelle Ambassador 'Starter' award

EpiGaN nv of Hasselt, Belgium has been awarded the title of National Trends Gazelle Ambassador 2014 in the category 'Starter' by Belgian financial-economics magazine Trends. The award was presented in Brussels by Flemish Minister President Kris Peeters.

The annual award recognizes EpiGaN for its fast growth in revenue and staffing over a three-year period. It was further selected for its innovative products addressing a large international market, offering prospects for further growth and local job creation.

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 epiwafers are used to make high-voltage power transistors and high-frequency RF components that help towards reducing energy loss, increasing performance and reducing size for applications such as adaptors for consumer electronics, industrial and server power supplies, AC

drives, cellular base stations, cable TV infrastructure, and hybrid and electric vehicles.

EpiGaN's cleanroom manufacturing facilities in Hasselt are in the Eindhoven-Leuven-Aachen triangle (ELAT). EpiGaN says that it is one of the few Flemish firms that do not outsource manufacturing of high-tech products, contributing to the local economy.

"EpiGaN has experienced positive revenue and cash flow since its inception in 2010," says Germain.

The firm now has ten staff and plans to grow further in 2014 to support its manufacturing expansion.

"This is just the beginning, as we are in the middle of expanding our production capacity to support volume growth driven by our worldwide customers," says Germain.

## Martini Tech offering GaN MOCVD on sapphire

Martini Tech Inc of Tokyo, Japan has started to offer a new gallium nitride (GaN) metal-organic chemical vapor deposition (MOCVD) service on sapphire substrates for LED applications.

Founded in 2013, Martini Tech offers microfabrication services including micro-electro-mechanical system (MEMS) design, development and foundry, sapphire wafer patterning, nanoimprint mold manufacturing (using materials such as silicon,

nickel and quartz), nanoimprint replica on film, GaN on patterned sapphire substrates (PSS) deposition by MOCVD, and sputtering deposition services (with more than 120 different materials available).

Widespread adoption of LEDs has so far been hindered by factors including relatively high price and lower light output compared with traditional incandescent light bulbs, notes Martini Tech.

One of the most promising techniques for improving the light output of LEDs involves the deposition of a thin GaN epi layer on a patterned sapphire substrate, adds the firm.

The service offered by Martini Tech includes MOCVD of undoped GaN and of n- or p-doped GaN for high-quality highly ordered crystalline layers up to 5µm thick.

[www.martini-tech.com/gan-on-sapphire-for-led](http://www.martini-tech.com/gan-on-sapphire-for-led)

# Keithley launches high-voltage power supplies for safe breakdown testing up to 10kV

Electrical test instrument and system provider Keithley Instruments Inc of Cleveland, OH, USA has introduced two power supplies optimized for high-voltage device and materials testing and high energy physics and materials science research. The Model 2290-5 5kV power supply and Model 2290-10 10kV power supply are suitable for high voltage breakdown testing of power semiconductor components, including devices made of wide-bandgap materials like silicon carbide (SiC) and gallium nitride (GaN) for use in energy-efficient power generation and transmission systems as well as hybrid and all-electric vehicles.

Other options on the market for sourcing 10kV lack many capabilities built into Series 2290 Power Supplies, claims Keithley. For example, some do not include a communication interface as standard equipment, do not offer an available protection module, or produce significantly higher output ripple. Compared with the Model 2290-10, the firm adds, one popular 10kV sourcing solution requires the purchase of a complete chassis-based semiconductor test system then the addition of a voltage expander, meaning that it costs 12 times more. This solution, designed for characterization of power components, also cannot address the high-voltage sourcing requirements of researchers in the basic sciences.

In contrast, Series 2290 power supplies are standalone voltage sourcing instruments that make it economical to create a high-voltage test solution, Keithley claims. For materials researchers and semiconductor device developers involved in creating and characterizing very high-voltage materials and devices, the maximum voltage output levels of either 5kV or 10kV complement Keithley's Model 2657A High Power System SourceMeter source measure unit (SMU) instrument, which provides source voltages up to 3kV. Series 2290 power supplies can



**The Model 2290-5 5kV and Model 2290-10 10kV power supplies.**

also be used in conjunction with test systems that include a Keithley Model 4200-SCS Parameter Analyzer and/or Parametric Curve Tracer configurations for more complex applications that require testing at up to 10kV.

## **Lowest noise performance**

When making leakage current or high-resistivity measurements with sensitive measurement instruments, a power supply with low output noise is essential, says Keithley. The extremely low noise performance of both Series 2290 power supplies' allows sensitive instruments to measure current accurately down to picoamp levels, the firm adds. Maximum output ripple is less than  $1V_{RMS}$  for the Model 2290-10 and just  $100mV_{RMS}$  for the Model 2290-5. Two selectable internal filters in the Model 2290-5 allow the reduction of its output ripple to only  $3mV_{RMS}$ , the lowest noise output in the industry.

## **Enhanced safety for both users and sensitive instruments**

To prevent overvoltage damage to lower-voltage instrumentation configured into the same test system as a Series 2290 power supply, Keithley has also introduced the Model 2290-PM-200 10kV Protection Module. When low-voltage instruments, such as many of Keithley's SMU instruments, are used in a high-voltage test circuit with a Series 2290 power supply to make

accurate leakage current measurements, the protection module safely clamps the voltage across the sensitive instrument to a maximum value of 200V, even if the device under test (DUT) breaks down and effectively becomes a short. The power supplies, the protection module, sensitive instrumentation, and Keithley software and accessories bring together all the elements needed to create a safe, high-voltage test environment.

Both Series 2290 power supplies have a built-in interlock circuit to disable the output voltage if a high-voltage test fixture's access door is not closed (a critical feature not available in all competing products, it is reckoned). In addition, they have low-voltage analog outputs to allow for safe monitoring of the high voltage and the output current. Keithley has developed LabVIEW and IVI drivers for the Series 2290 to speed and simplify test system development. The IEEE-488 interface that is provided standard in the Series 2290 simplifies the creation of automated high-voltage test systems and enhances safety by allowing the high-voltage instrumentation to be controlled remotely.

## **Low current output capabilities**

In addition to high voltage outputs, Model 2290-5 can output up to 5mA of current (25W) and Model 2290-10 can output up to 1mA (10W). Both offer current measurement resolution of  $1\mu A$ . The instruments' front panels provide voltage and current output displays, as well as a third display that shows the user's choice of four settings: output voltage, voltage limit, current limit, or current trip.

As well as high-voltage breakdown testing, applications for Series 2290 power supplies include high-energy basic science research, including voltage component and materials testing, insulation testing, and high-voltage resistivity measurements.

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

## 5N Plus appoints CFO to aid growth strategy

Specialty metal and chemical products firm 5N Plus Inc of Montreal, Québec, Canada has appointed Richard Perron as chief financial officer, effective 17 March.

He succeeds David Langlois, who is leaving the firm to pursue other interests. "I would like to thank David Langlois for his work and support over the years," comments president & CEO Jacques L'Ecuyer.

5N Plus provides specialty purified metals such as bismuth, gallium, germanium, indium, antimony, cadmium, selenium and tellurium, and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of

crystals for solar, LED and eco-friendly materials applications.

Perron has nearly 20 years of international experience as a finance professional. Since 2006, he has held progressively more senior roles, gaining experience within ArcelorMittal and more recently as CFO and strategy manager at Long Carbon Americas (one of ArcelorMittal's most important business units). In that role, he was responsible for all countries of the Americas (generating \$11bn in annual sales, with 17,900 staff and more than 25 key operations and plants in countries including Canada, USA, Mexico, Costa Rica, Trinidad and Tobago, Brazil and Argentina). From 1999 to 2006, he served as director, finance and con-

trol & chief information officer at Danfoss Turbocor Compressors Inc (part of The Danfoss Group).

Perron has a B.Com. degree in Accounting from Concordia University, an M.Sc. in Administration, Management and Accounting, and an M.B.A. from the University of Sherbrooke. He is a certified public accountant (CPA) in the USA (IL & DE) and a chartered professional accountant in the Province of Quebec, Canada.

"His broad in-depth knowledge of the market, strong leadership skills and hands-on approach will greatly contribute to help us execute our growth strategy, which calls for both organic and acquisition-related initiatives," comments L'Ecuyer.

[www.5nplus.com](http://www.5nplus.com)

## IPG Photonics expands GaAs laser production with extra Veeco GEN2000 MBE system

High-power fiber-laser and amplifier manufacturer IPG Photonics Corp of Oxford, MA, USA has purchased an additional GEN2000 production molecular beam epitaxy system to add to its fleet of MBE systems from epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA.

IPG will use the GEN2000 for high-volume manufacturing of laser diodes for fiber lasers. Founded in 1990, the firm now utilizes multiple Veeco MBE systems in its laser production operations. Following purchases of three GEN200 systems, in 2012 IPG installed a GEN2000 system to expand its production of gallium arsenide (GaAs)-based lasers.

The new GEN2000 complements IPG's existing set of Veeco MBE systems because of its throughput and low production costs, says Dr Alex Ovtchinnikov, senior VP, Components at IPG. "Having the ability to transfer production methods from our other Veeco MBE systems means we can ramp laser

diode production quickly and reliably to meet increasing demand for our fiber lasers," he adds.

With their performance, low power consumption and favorable ownership costs, fiber lasers are becoming the cutting and welding method of choice for materials processing applications, particularly in the automotive industry, according to a report on the laser cutting market from Markets and Markets.

As the technology continues to advance, fiber lasers are gaining adoption in other industries including semiconductor processing, 3D printing and smartphone making.

**Having the ability to transfer production methods from our other Veeco MBE systems means we can ramp laser diode production quickly and reliably to meet increasing demand for our fiber lasers**

"IPG is the clear leader in fiber laser production and has been utilizing our production MBE systems for years", says Jim Northup, VP, general manager for Veeco's MBE Operations. "The GEN2000 delivers the highest-throughput and lowest-cost-of-ownership MBE technology in the industry, making it the ideal system to manufacture IPG's high-performance laser diodes," he reckons.

The GEN2000 MBE system's cluster tool design provides what is reckoned to be the industry's most cost-effective 7x6-inch epiwafer growth of devices such as lasers, multi-junction solar cells, and pseudomorphic high-electron-mobility transistors (pHEMTs). The GEN2000 MBE system's cluster tool architecture also minimizes cleanroom space and downtime attributed to maintenance and allows for growth of different materials in connected modules, adds Veeco.

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

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

# AXT's revenue falls 9% in Q4 to \$18.6m, but decline in gallium arsenide levels out

**Operations being sized to fit demand while implementing programs to improve gross margin and cut operating expenditure**

AXT Inc of Fremont, CA, USA has reported full-year revenue of \$85.3m, down 3.5% on 2012's \$88.4m. This includes fourth-quarter revenue of \$18.6m, 1.6% below the \$18.9m a year ago but down 9% on \$20.5m last quarter.

"Our fiscal year 2013 was among our most difficult years, with a significant technology transition, market consolidation and customer-specific technical issues," notes CEO Morris Young.

By product sector for Q4/2013, gallium arsenide (GaAs) substrate revenue was \$8.9m, down 21% on \$11.3m a year ago but only slightly below the \$9m last quarter (following a 16% sequential drop the prior quarter). Indium phosphide (InP) substrate revenue was \$1.8m, up

on \$1.4m last quarter and \$1.6m a year ago. Raw materials revenue was \$4.3m, down slightly on \$4.6m last quarter and level with a year ago. However, germanium (Ge) substrate revenue was \$3.6m, more than double the \$1.7m a year ago but down 35% on \$5.5m last quarter.

Gross margin was 15.1%, rebounding from 11.9% last quarter but still below 19.5% a year ago. Full-year gross margin has more than halved, from 28.1% for 2012 to 13.9% for 2013.

Operating expenses were \$4.4m, cut from \$5.1m last quarter, due mainly to selling, general & administrative (SG&A) expenses falling from \$4.3m to \$3.6m. However, full-year operating expenses rose from \$18.9m in 2012 to \$19.5m.

Net loss was \$1.2m, cut from \$2.3m last quarter but above the \$0.8m a year ago. Full-year net loss was \$8m, compared with net income of \$3.1m for 2012. During Q4/2013, cash and cash equivalents fell from \$27.7m to \$25m.

"We are now focusing our efforts on growing our market presence in strategic areas, and leveraging our low-cost manufacturing as a competitive advantage," says Young. "In the meantime, we are sizing our operations to be more in line with the demand environment and are implementing a number of programs to improve our gross margins and lower our operating expenses," he adds. "We continue to focus on cash management."

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

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- Best surface quality for direct use in Epitaxy
- Backside thinning of fully structured wafer
- Thin wafer (60  $\mu$ m)
- Single wafer processing possible
- We buy used wafer and sell recycled wafer

# Veeco's Q4 revenue falls by a third year-on-year

## Losses rise, driven by dip in margins plus ALD-acquisition-related spike in operating expenditure

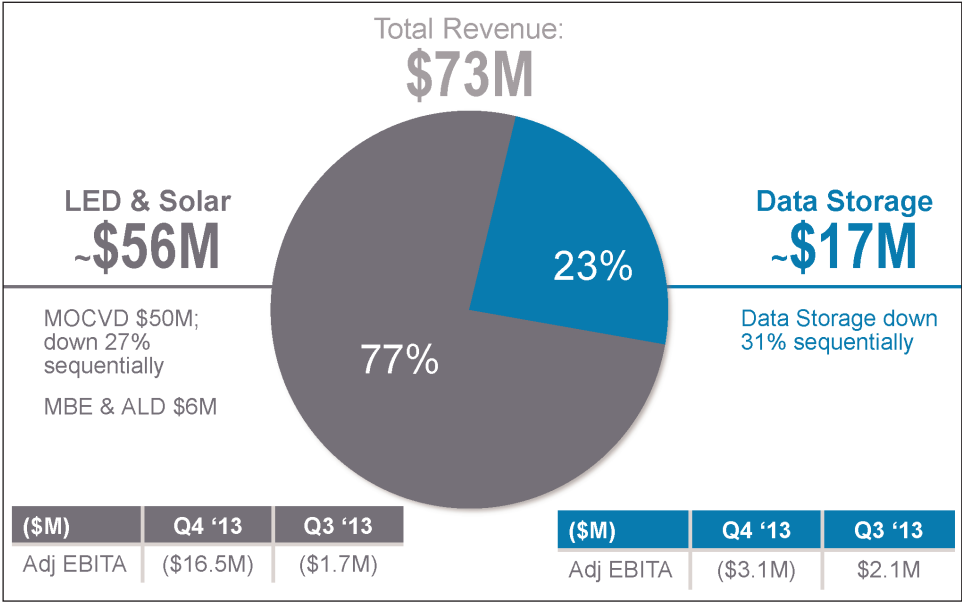
Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue for full-year 2013 of \$331.7m, down 36% on 2012's \$516m, with all of the firm's businesses experiencing down cycles. LED & Solar revenues have fallen 31% from \$363.2m to \$249.7m. Data Storage revenue has fallen 46% from \$152.8m to \$82m.

Fourth-quarter revenue was \$73.2m, down 26% on \$99.3m last quarter and 32% on \$106.8m a year ago (but at the high end of the \$65–75m guidance range).

In particular, system shipments in both metal-organic chemical vapor deposition (MOCVD) and Data Storage were very low. Data Storage revenue was \$16.7m (23% of sales), down 31% on \$24.3m last quarter. LED & Solar revenues were \$56.5m (77% of sales), down 25% on \$75m. Of this, \$50m was for MOCVD (down 26.5% on \$68m) and \$6m was for molecular beam epitaxy (MBE, down from \$7m).

Margins were unusually low (falling from 31% to 21%) due to the depressed volumes, continuing weak selling prices and higher cost of goods sold (which included items such as higher-than-normal supply chain cost). In 2013, margins averaged about 31% over the course of the year.

Operating expenses (OpEx) spiked higher in Q4, rising from \$39m last quarter to \$48m. "We're now carrying about \$4m of additional R&D and administrative cost related to the new ALD [atomic layer deposition] business [Synos Technology], which was acquired in early October," notes chief financial officer Dave Glass. "OpEx included a few non-recurring items such as a reserve for bad debt expense in Asia, acquisition-related legal and accounting fees, and special performance and retention bonuses," he adds.



"Very weak gross margins and high operating expenses contributed to poor bottom line performance," chairman & CEO John R. Peeler.

On a non-GAAP basis, adjusted EBITA (earnings before interest, taxes and amortization) has worsened further, up from –\$5.1m last quarter to –\$26.6m. Of this, –\$16.5m was due to LED & Solar (up from –\$1.7m) and just –\$3.1m to Data Storage (compared with +\$2.1m). Full-year adjusted EBITA went from +\$61.1m in 2012 to –\$49.6m in 2013. Of this, –\$26.4m was due to LED & Solar (compared with +\$41.6m in 2012) and just –\$0.7m due to Data Storage (compared with +\$24.4m in 2012). However, the new ALD business is now included in the LED & Solar segment. "Since it's still pre-revenue, it represents a drag on EBITDA for that segment," notes Glass. Net loss has risen from \$3m (\$0.08 per share) last quarter to \$16.4m (\$0.42 per share).

"A highlight for the quarter was our continued solid cash management in a challenging environment," says Peeler. During Q4, cash and short-term investments have fallen from \$573m to \$495m. However, this is down only slightly after adjusting for \$76m used for

acquiring Synos Technology Inc (now Veeco ALD Inc).

In the fourth-quarter, order bookings were \$85m, down 7% on \$91.5m last quarter. In particular, LED & Solar orders were \$63.3m (74% of total bookings), down 14% on \$73.5m. Of this, MBE orders rose by 56% from \$7m to \$11m, but MOCVD orders fell 22% from \$67m to \$52m. "While MBE did see some positive tractions with multiple GENxplor orders as well as one production system order, the weakness in MOCVD bookings continued in Q4 at what we are considering trough levels [for over two years now]," says Glass. This has counteracted a rise in Data Storage orders to \$21.6m (26% of total bookings), up 20% on \$18m last quarter (albeit still quite weak by historical standards).

Full-year bookings have fallen 15% from \$392m in 2012 to \$331.6m in 2013. This includes LED & Solar orders falling from \$305.2m to \$237.6m, counteracting a rise in Data Storage orders from \$86.7m to \$94m.

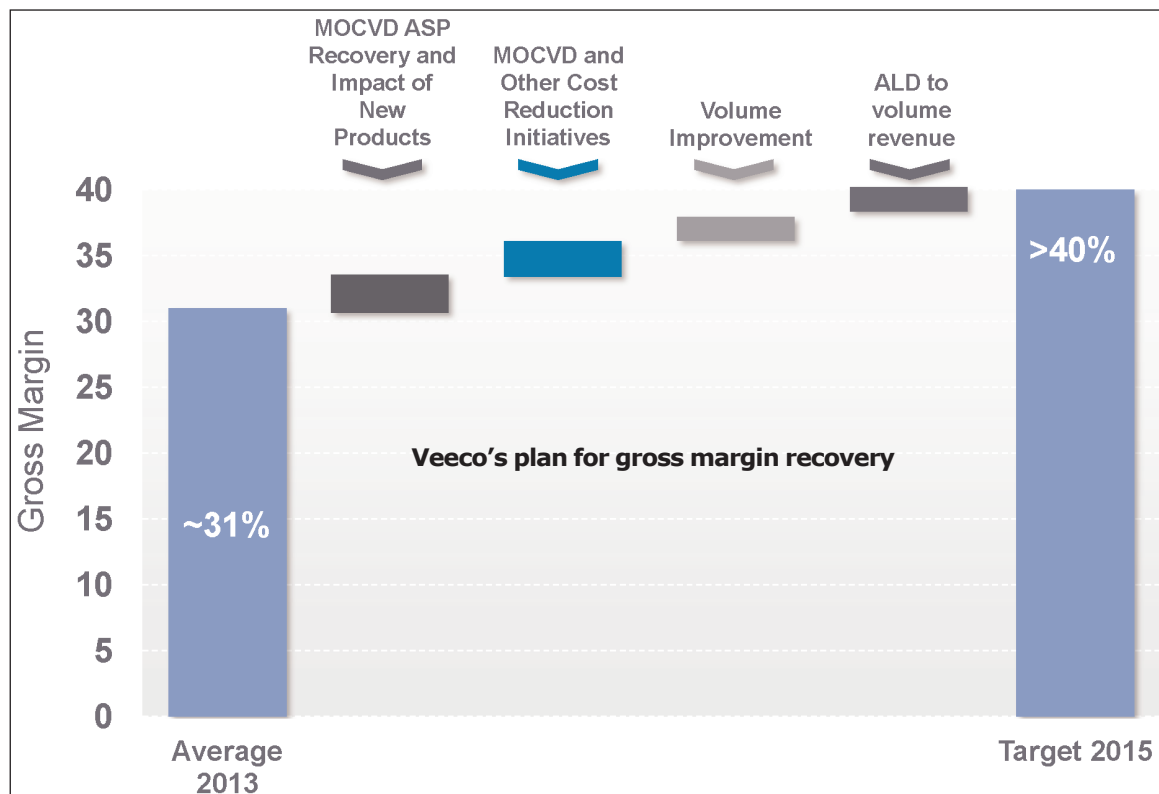
Total order backlog at the end of Q4/2013 was \$143m. "We haven't yet seen a recovery in business conditions," comments Peeler. ➤

▶ “While not included in reported fourth-quarter bookings [since the revenue recognition timing for it is still uncertain], we received a purchase order from the world leader in mobile OLED displays for a next-generation Fast Array Scanning Atomic Layer Deposition (FAST-ALD) prototype system,” says Peeler. “While 2013 was a challenging year, we remain positive about trends in LED lighting and our new growth opportunity in flexible OLED encapsulation for mobile phones,” he adds.

“While it is too early to call a turn in our MOCVD business, we are seeing some encouraging signs,” comments Peeler. “LED fab utilization rates appear to be relatively stable and high at all key accounts, and solid-state lighting adoption is accelerating. Top customers in China and Taiwan have over 90% fab utilization and they did not shut down for the Chinese New Year,” he adds. “We are talking to leading customers about potential capacity expansions, and our orders are likely to improve this quarter... Some Korean customers are adding capacity by upgrading older systems and buying new tools to keep up with demand.”

For first-quarter 2014, with orders likely to increase, Veeco expects revenue to rebound to \$85–95m (driven mainly by MOCVD).

Gross margin should rise to 33–35%. “We do see the likelihood of improvements as certain MOCVD deals with better ASP [average selling price] roll out of backlog and the impact of various cost improvements are first gaining traction,” says Glass. “For example, a new cost-down version of MaxBright will positively benefit our margin starting this quarter.”



Operating expenditure is expected to be back down to more normal levels of \$42–43m. “With the accounting review now behind us, we expect significantly lower outside advisor and accounting cost,” says Glass. However, this lower spend will be largely replaced by new ALD business OpEx.

“R&D is front-end loaded in the first half of 2014, and this is likely to trend down in the second half of the year,” notes Glass. “As a result, we do expect OpEx to tick down in the second half. This, along with the expectation of better margins, should be effective in driving our quarterly breakeven revenue down to below \$100m later in 2014,” he adds.

“Our priority for 2014 is to take the steps necessary to transition the company back to profitable growth,” says Peeler. “We are focused on four areas to improve our performance: (1) developing and launching game-changing new products that enable cost-effective LED lighting, flexible OLED encapsulation and other emerging technologies; (2) executing manufacturing cost reduction initiatives and lowering expenses wherever possible; (3) driving process improvement

initiatives to make us more efficient; (4) improving product differentiation, customer value and pricing to stem margin erosion,” he adds. “We anticipate that Veeco will run at a loss for a couple of quarters, but see a very bright future for the long run.”

Regarding Veeco’s plan for recovery in gross margin, Glass notes that it is likely to remain in the low-to mid-30s until the firm sees higher shipment volumes again and after MOCVD chamber ASPs return to a more normal level, aiding the ongoing incremental cost-reduction improvements that the firm is continually driving. However, achieving better margins for MOCVD will require new products to drive growth in lighting and power electronics, Glass adds. In addition, some wins in OLED and adjacent markets for the newly acquired ALD business should help to achieve the gross margin target of 40% or more in 2015, he reckons. “Except for the cost-reduction improvements which are ongoing, we see most of these factors starting to take shape in the second half of this year, but they are unlikely to be a strong force for margin recovery until 2015.”

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

# Aixtron's quarterly revenue rises 10% in Q4/2013, but demand remains subdued

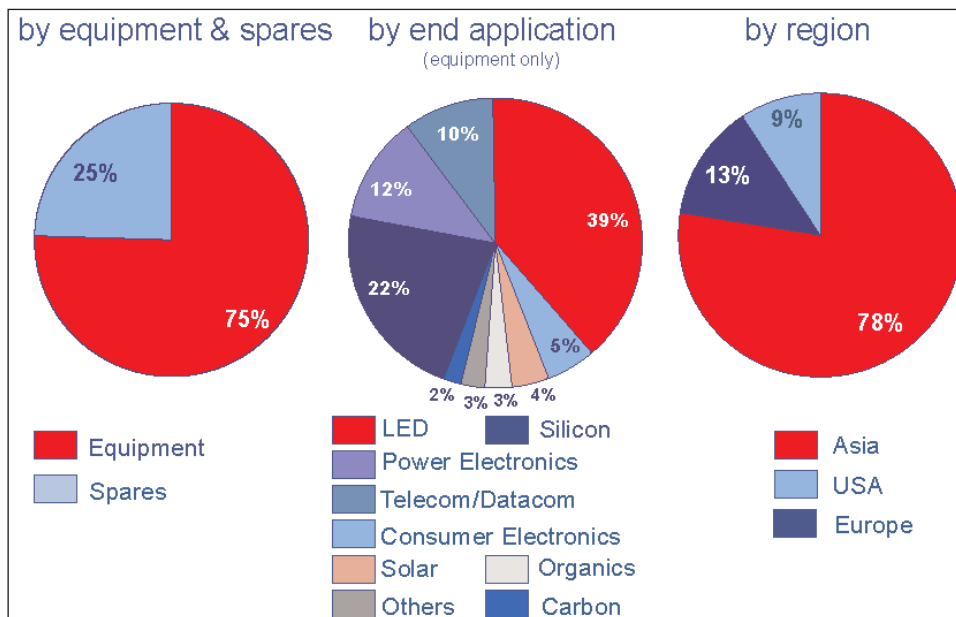
## Cost cutting enables 2014 target of EBIT break-even on €250m in annual revenue

For full-year 2013, deposition equipment maker Aixtron SE of Aachen, Germany has reported a 20% drop in revenue from 2012's €227.8m to €182.9m. However, although down 34% on €77.5m a year ago, fourth-quarter revenue was €51.1m, up 10.6% on €46.2m Q3/2013.

Quarterly gross margin has risen from 23% in Q3 to 34% in Q4. But, influenced by several unusual items, full-year gross profit has fallen from €0.4m in 2012 to -€7.4m in 2013, resulting in negative gross margin of -4%, as decreased revenue-related costs were more than offset by lower selling prices for metal-organic chemical vapor deposition (MOCVD) equipment and a -€5.1m impact from inventory destroyed in a fire.

Despite the 20% drop in annual revenue, the full-year EBIT operating result (earnings before interest and taxes) has improved by €36.6m from -€132.3m (an EBIT margin of -58% of revenue) in 2012 to -€95.7m (-52% of revenue) in 2013, as write-downs and restructuring expenses recorded throughout the year were more than offset by insurance proceeds plus cost reductions and efficiency gains realized via the 5-Point-Program initiated in Q1/2013. Full-year operating costs have been cut by more than 20% from €124.9m in 2012 to below the previously targeted €100m in 2013. Excluding unusual items, Q4 EBIT was -€8.3m, a slight improvement on -€9.2m last quarter.

Quarterly free cash flow was -€0.2m in Q4/2013, an improvement from -€6.5m last quarter. For full-year 2013, free cash flow was -€1.1m (a big improvement on -€61.6m in 2012). However, this followed a capital increase in October of €101m. Aixtron's executive and supervisory boards will propose to the shareholders'

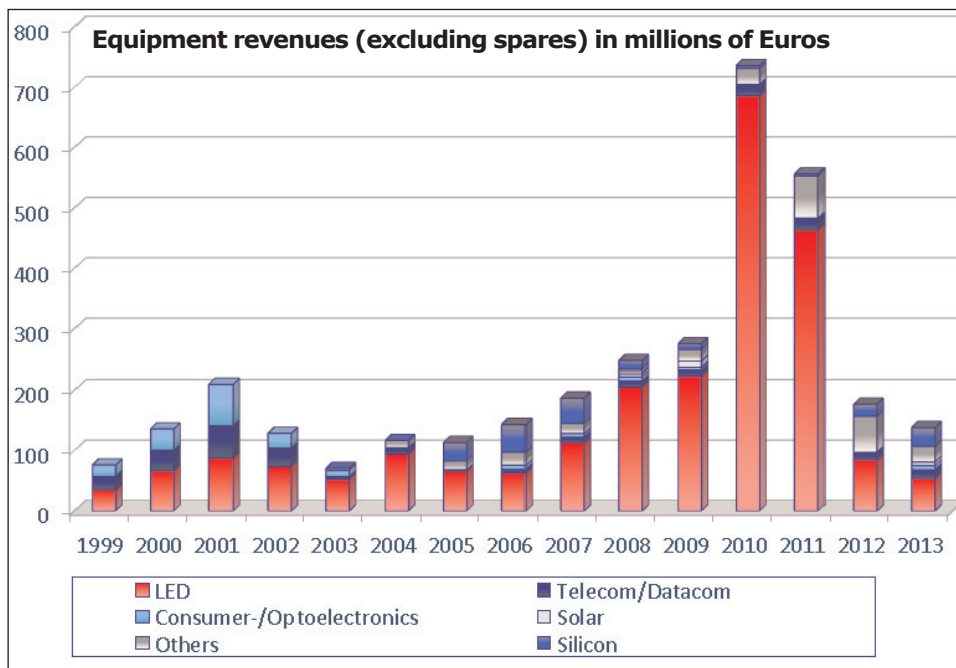


Breakdown of Aixtron's full-year 2013 revenue.

meeting that the 2013 loss (-€1.1m in free cash outflow) should again be carried forward and consequently no dividend payment should be made for 2013.

Aixtron says that, although it recorded increased cash outflow from restructuring-related payments, the significantly improved

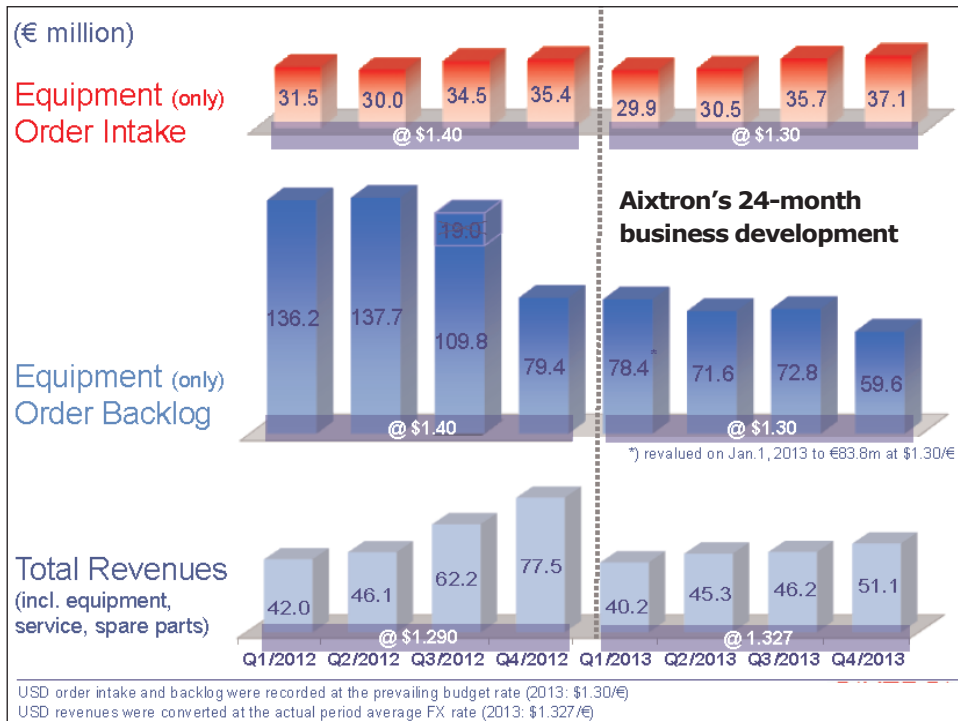
free cash flow for full-year 2013 underlines its successful liquidity management. As a result of October's capital increase, the firm has strengthened its financial position. With cash and cash equivalents rising from €205.5m at the end of 2012 and €207.5m at the end of Q3/2013 to €306.3m at the end of



► 2013, the firm says that it maintains a sound capital base for future business development.

"The structural improvement of the result, in particular within the second half of 2013, has reinforced our view that we have set out on the right path by consolidating and reorienting Aixtron," comments president & CEO Martin Goetzeler. "As planned, we did not only manage to reduce our 2013 operating costs (excluding unusual items) by more than 20% to less than the targeted €100m through our 5-Point-Program, but we also generated a nearly balanced free cash flow that also contributed to the stabilization of our financial position," he adds. "Moreover, and in spite of all our cost reduction and process optimization efforts, we have continued our targeted research and development investments in the most important technology fields to further strengthen and diversify Aixtron's future product portfolio."

Although capacity utilization rates in Aixtron's target industries have increased significantly (e.g. at leading Taiwanese and Korean LED chip makers), demand for production equipment remained at a very low level throughout 2013. Consequently, full-year equipment order intake of €133.2m for 2013 was broadly unchanged from €131.4m



in 2012, despite quarterly equipment order intake rising 5% from €35.5m a year ago and €35.7m last quarter to €37.1m in Q4. Total equipment order backlog has fallen 25% from €79.4m at the end of 2012 and €72.8m at the end of Q3 to €59.6m at the end of Q4, emphasizing sustained weakness in demand.

Due to the still very low order visibility, Aixtron's management says that it is unable to provide any precise revenue or earnings guidance for full-year 2014. However, as a consequence of the already

advanced restructuring of the company and the cost reductions realized, it expects further year-on-year improvement in 2014. Based on its consideration of current market demand, management believes that 2014 revenues will be on a par with 2013, with a still negative but significantly improved operating result. Assuming a target gross margin of 40% and operating costs of about €100m, EBIT break-even may now be reached with annual revenue of about €250m.

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

## EpiWorks expanding MOCVD production capacity

EpiWorks Inc of Champaign-Urbana, IL, USA, which manufactures compound semiconductor epitaxial wafers for applications in optical components, wireless devices and high-speed communication systems, has announced a major multi-faceted expansion of its production capacity.

"A clear migration toward applications that require significantly higher volumes, particularly in the area of optical materials and photonics, is underway," says director of sales & marketing Nick Kolarich. "The markets include consumer electronics, sensors and displays, digital projection, and data commu-

nications," he adds. EpiWorks' latest expansion is part of an "aggressive, long-term production capacity roadmap to satisfy increasing demand from photonic and RF customers".

The expansion increases the firm's ability to produce high volumes of 4-inch and 6-inch wafers for vertical-cavity surface-emitting lasers (VCSELs), edge-emitting lasers, detectors and photovoltaics with what is claimed to be an industry-leading cost structure. The new capacity includes upgrades to existing tools and the latest Aixtron 2800 G4 metal-organic chemical vapor deposition (MOCVD)

technology, allowing EpiWorks to quickly meet demand while providing greater flexibility for new product development.

"For many years EpiWorks has been the leading US-based manufacturing and development partner for novel and advanced photonic and optical devices," claims CEO Quesnell Hartmann. "Customers have leveraged our development expertise to commercialize numerous complex advanced technologies from the lab into next-generation photonic products," he adds.

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

# LayTec's EpiCurve TT AR used to demo crack-free a-plane GaN layers containing low-temperature AlN interlayers

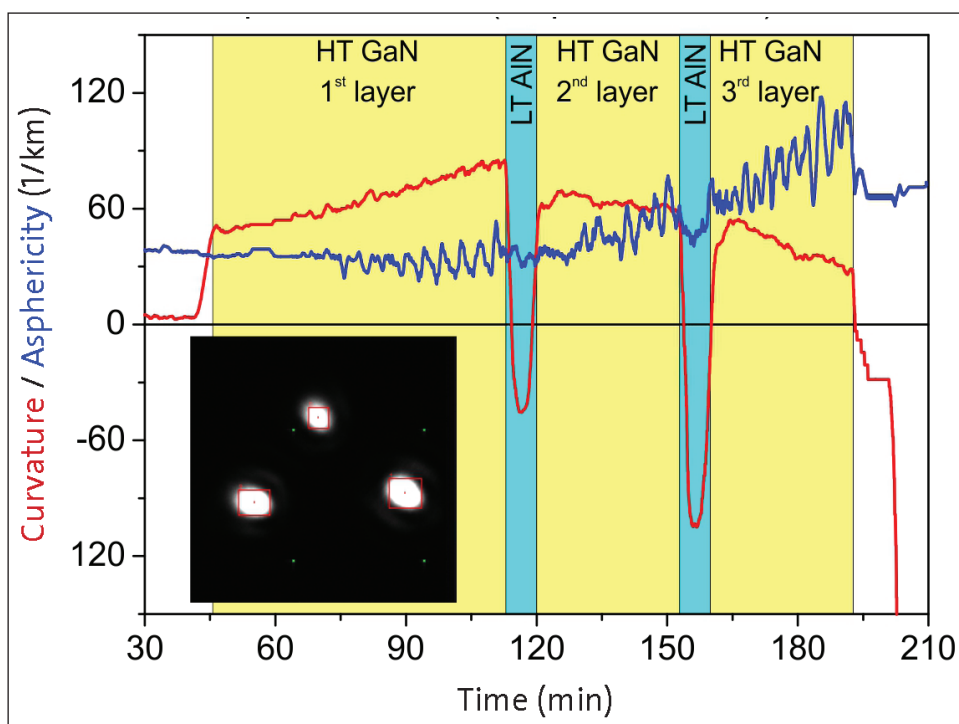
In-situ metrology system maker LayTec AG of Berlin, Germany notes that it is known that some properties of gallium nitride (GaN)-based light-emitting quantum wells (QW) can be improved by using a-plane III-nitrides. However, during hetero-epitaxial growth on r-plane sapphire substrates, a-plane GaN layers are tensely strained in the growth plane, resulting in crack formation.

To achieve thick crack-free a-plane GaN buffer layers, low-temperature aluminium nitride interlayers (LT AlN IL) are used for strain engineering (M. Wieneke et.al., abstract book ICMOVPE 2012).

At the annual conference of the German Society for Crystal Growth (DGKK) last December, Matthias Wieneke of Otto-von-Guericke University in Magdeburg, Germany reported the impact of LT AlN IL on a-plane GaN films.

For the studies, his team applied LayTec's EpiCurve TT AR in-situ metrology system with advanced curvature resolution (AR). The tool uses three laser spots for curvature measurements (see photo in the Figure) and, therefore, also provides information on wafer curvature asymmetry along two perpendicular directions (as is typical for a-plane III-N growth).

The in-situ curvature measurements are demonstrated in the Figure by



**In-situ curvature measurements with EpiCurve TT AR of a-plane GaN samples containing two low-temperature AlN interlayers.**

a red line for (spherical) curvature and a blue line for curvature asphericity. During growth of the tensely strained a-plane GaN buffer layer, the curvature (red) increases, while it decreases after the insertion of LT AlN IL.

Thus, the interlayer reduces the tensile strain, as in the case of c-plane GaN growth. However, after the growth of the interlayers, the asphericity (Figure, blue) increases, indicating an increase in anisotropic

strain. This anisotropy has been proven by subsequent ex-situ x-ray diffraction measurements (M. Wieneke et al., abstract book DGKK 2013).

"By measuring the aspheric bow component quantitatively with EpiCurve TT AR, our team obtains additional real-time information on a-plane layer formation," comments Wieneke.

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

[www.laytec.de/solutions/advanced-rd](http://www.laytec.de/solutions/advanced-rd)

## In-situ metrology for graphene growth

For several years, graphene has been the subject of intense research activity aimed at exploiting its unique properties.

Although the growth of graphene is a very new and complex process, in-situ metrology system maker LayTec AG of Berlin, Germany has developed a solution for in-situ reflectance analysis of the surface changes during growth.

The first tests have been conducted during graphene growth on copper/silicon (Cu/Si) in a commercial CVD reactor. "Our in-situ reflectometer has clearly demonstrated its sensitivity to surface processes like de-oxidation and roughening during graphene CVD on Cu," says LayTec. "Furthermore, we could see that in case of growth on Cu/Si, the combination of temperature,

low pressure and CH<sub>4</sub> supply does change the surface properties of the copper substrate and causes copper removal from the surface," it adds. "Therefore, a sensor able to monitor in-situ both surface temperature and reflectance, like LayTec's EpiTT, can deliver valuable information to understand and optimize the deposition process."

[www.laytec.de/solutions/advanced-rd](http://www.laytec.de/solutions/advanced-rd)

## MKS to acquire Granville-Phillips vacuum gauge division of Brooks Automation

MKS Instruments Inc of Andover, MA, USA (which provides instruments, subsystems and process control solutions that measure, control, power, monitor and analyze critical parameters of manufacturing processes) has agreed to purchase the assets of Granville-Phillips (a division of Brooks Automation Inc of Chelmsford, MA) for \$87m.

Granville-Phillips is a provider of vacuum measurement and control instruments to the semiconductor, thin-film and general industrial markets, with sales of about \$30m in 2013. Founded in 1954, it operated as an independent company until its acquisition by Helix Technology in 1998. It became part of Brooks Automation through the merger of Helix and Brooks in 2005.

"Granville-Phillips is an ideal complement to our vacuum gauge business," says MKS' CEO & president Gerald G. Colella. "While we are the leader in direct pressure measurement, they are a well-regarded leader in indirect vacuum gauges, with a premium brand and an excellent reputation for quality, reliability and performance. The acquisition is well aligned with our stated strategy to grow our core semiconductor business, while

diversifying into other high-growth advanced markets," he adds.

"We have numerous opportunities to grow the Granville-Phillips business, leveraging our existing sales channels and expanding our product portfolio," believes Jack Abrams, senior VP global sales. "We can offer a broad range of advanced vacuum gauges that will be highly responsive to the needs of customers in our served markets," he adds.

"We see the potential for both revenue and cost synergies as we integrate Granville-Phillips into MKS," continues Colella. "Their profitability and cash-flow metrics are aligned with our own operating model, and we expect the acquisition to be accretive to our earnings in 2014," he adds. "Going forward, with the revenue growth potential that we believe we can achieve with this business, as well as operating synergies to be realized over the next few years, we expect this acquisition to meet or exceed our target return thresholds."

The acquisition is subject to regulatory approvals and other customary closing conditions and is expected to close in Q2/2014.

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

[www.brooks.com/products/gauges-modules-controllers](http://www.brooks.com/products/gauges-modules-controllers)

## Lake Shore discusses new 8500 Series THz system for material characterization at APS

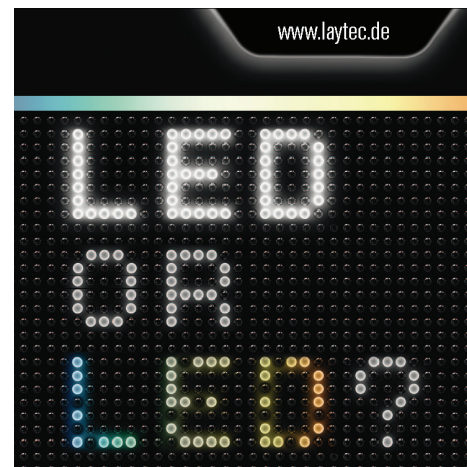
At the American Physical Society (APS) March Meeting in Denver, Lake Shore Cryotronics Inc of Westerville OH, USA, which makes scientific sensors, instruments and systems for measurement and control, discussed its new 8500 Series terahertz (THz) system for electronic, magnetic and chemical materials research and characterization.

The fully integrated platform uses non-contact THz-frequency energy and an integrated low-temperature,

high-field cryostat to measure material spectroscopic responses across a wide range of frequencies, temperatures and field strengths.

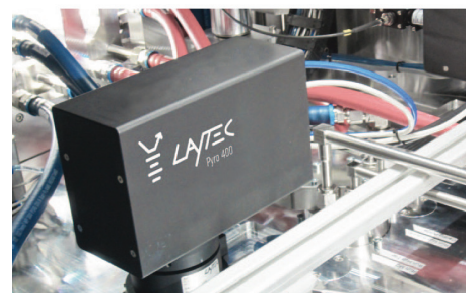
The system is said to be the first affordable, integrated, convenient solution specifically tailored for characterization of research-scale electronic and magnetic materials, including the properties of emerging materials in thin-film semiconductor applications.

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



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## IN BRIEF

### Zeta appoints COO

Jeff Donnelly has joined optical profiling and inspection system maker Zeta Instruments Inc of San Jose, CA, USA as its chief operating officer.

Donnelly's career spans executive roles at startups and established tech leaders, and most recently a 15-year tenure at KLA-Tencor. Reporting to the CEO as VP of the Growth & Emerging Markets Group, he drove KLA-Tencor's growth in sectors including LEDs and back-end, and played a key role in the firm's mergers and acquisitions.

"Jeff is a proven entrepreneur with a demonstrated track record of delivering innovative products, launching new companies and leading mergers and acquisitions," says Zeta's CEO & founder Rusmin Kudinar.

"Zeta is poised for significant growth," believes Donnelly.

[www.zeta-inst.com](http://www.zeta-inst.com)

## Tsinghua University purchases Oxford Instruments plasma systems for quantum computing

Research into the emerging field of quantum computing will be carried out at the Institute for Interdisciplinary Information Sciences (IIIS) at Tsinghua University in Beijing using recently purchased plasma systems from UK-based etch and deposition system maker Oxford Instruments.

The IIIS is currently installing a new cleanroom, and has selected tools from Oxford Instruments to provide three systems to undertake this key research. The PlasmaPro100 ICP etch system, PlasmaPro100 PECVD deposition system with TEOS, and a FlexAL ALD system are all suitable for this type of research due to their high performance, flexibility and ease of service, says Oxford Instruments.

"We chose Oxford Instruments systems after a stringent tendering process, comparing system functionality and cost," says Dr Song, associate researcher at Tsinghua

University. "Our decision to purchase its plasma etch and deposition tools was due to Oxford Instruments' wide range of processes and applications, the suite of systems available from this one global supplier, and the excellent service and support available to customers," he adds.

"IIIS aims to become one of the leading research centres on interdisciplinary information sciences in the world as well as to offer a facility for the research and education of theoretical computer science and quantum information science in China," Song continues. "We are committed to building and operating a world-class Quantum Nano-Fabrication facility, to the combined benefit of Tsinghua University's researchers and collaborators."

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

[www.iiis.tsinghua.edu.cn](http://www.iiis.tsinghua.edu.cn)

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# Meaglow's hollow cathode plasma source reduces oxygen contamination by orders of magnitude

Meaglow Ltd of Thunder Bay, Ontario, Canada, which produces migration-enhanced afterglow epitaxy equipment and molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD) accessories, has announced what it claims is a breakthrough in semiconductor production.

As computer chips become smaller, advanced production techniques such as atomic layer deposition (ALD) have become more important for depositing thin layers of material. Unfortunately, ALD of some materials has been prone to contamination from the plasma sources used, says the firm. Meaglow has developed a hollow cathode plasma source that has reduced oxygen contamination by orders of magnitude, allowing

the reproducible deposition of semiconductor materials with improved quality.

This has been reported in a recent publication of oxygen-reduction figures for the hollow cathode plasma source supplied last year to the group of professor Necmi Biyikli of the Institute of Materials Science and Nanotechnology at Turkey's Bilkent University (Journal of Materials Chemistry C 2 (2014) 2123).

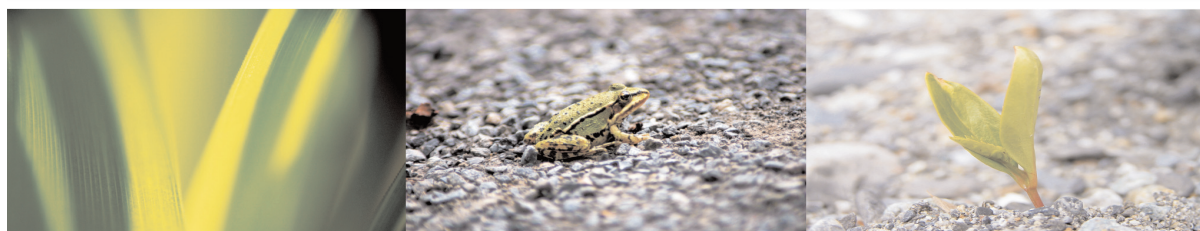
The plasma source was used to upgrade their existing ALD system by replacing an inductively coupled

**The plasma source was used to upgrade an existing ALD system by replacing an inductively coupled plasma source**

pled plasma source. The results show a reduction in oxygen content of orders of magnitude. There is also a marked improvement in material quality, says Meaglow. These results render the older inductively coupled plasma sources obsolete for many applications.

Meaglow is seeking other customers interested in improving the material quality of their ALD and other plasma-grown nitride layers. The hollow cathode plasma technology can also scale to large deposition areas. The plasma source can be used to retrofit existing systems or can be integrated with equipment manufacturers, says Meaglow. It can also be utilized in applications including MBE and LPMOCVD.

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



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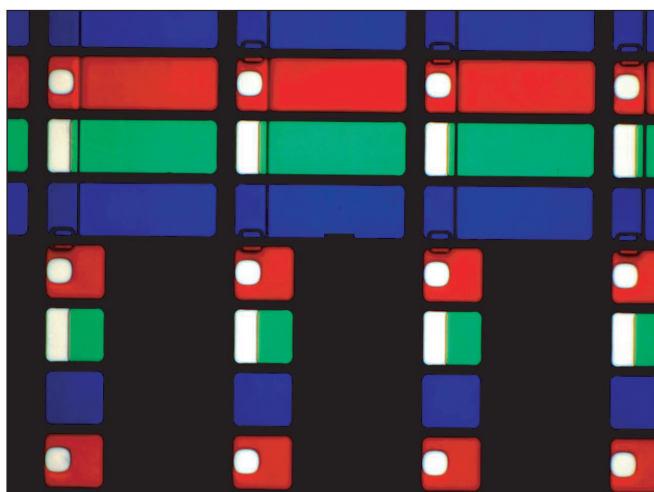
[www.cscleansystems.com](http://www.cscleansystems.com)

## CRAIC launches FilmPro software for microspot film thickness measurement

CRAIC Technologies of San Dimas, CA, USA has introduced the FilmPro film thickness measurement software package, designed to plug in to the firm's microspectrophotometers and their controlling Lambdafire software to allow measure rapid and non-destructive measurement of thin-film thickness.

Able to analyze films of many materials on both transparent and opaque substrates, FilmPro enables the user to determine thin-film thickness on everything from semiconductors, MEMS devices, disk drives to flat panel displays. The powerful and flexible software can be used in many different fields and in everything from research to industrial settings, adds the firm.

"Many of our customers want to measure the thickness of thin films of smaller and smaller sampling areas for rapid quality control of their products," says president Dr



Paul Martin. "This software was built in response to customer requests for a powerful, flexible film thickness tool that can measure sub-micron areas on both transparent and opaque substrates."

The complete CRAIC microspot film thickness solution combines an advanced microspectrophotometer with the FilmPro software. The soft-

ware is a plug-in module to CRAIC Lambdafire instrument control software. It enables the user to measure film thickness by either transmission or reflectance of many types of materials and substrates. Due to the flexibility of the CRAIC design, sampling areas can range from over 100µm across to less

than a micron. Designed for both research and the production environment, it incorporates a number of easily modified processing recipes, the ability to create new film recipes, and tools for analyzing data. With the addition of spectral mapping from CRAIC, film thickness maps of entire devices can be created.

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

## EVG establishes China subsidiary in Shanghai Regional HQ houses local service center and spare parts management facility

EV Group (EVG) of St Florian, Austria, a supplier of wafer bonding and lithography equipment for MEMS (microelectromechanical systems), nanotechnology and semiconductor applications, has opened the new subsidiary EV Group China Ltd in Shanghai, which will serve as regional headquarters for all of EVG's operations in the People's Republic of China. Housing a local service center and spare parts management facility, the subsidiary will strengthen EVG's presence in the region and support the firm's ongoing efforts to improve service and response times to local customers.

EVG says that, as China continues to increase its technology development efforts to become a leading

manufacturing region for the semiconductor, compound semiconductor, power device, advanced packaging, light-emitting diode (LED) and MEMS industries, it has expanded its operations in order to be more effective and efficient in meeting the needs of its growing customer base in the region. EV Group China is an integral part of the firm's worldwide customer support network, serving as the first point of contact for all service and customer support issues.

"The significant growth in business that we've seen in China, coupled with the continued huge market potential in this region, makes establishing a new subsidiary in China an effective way to continue to build upon our presence here

and strengthen support for our local customers and partners," says executive sales & customer support director Hermann Waltl.

EVG has had an active presence in China for more than a decade. Success in the region has allowed order intake from Chinese customers to multiply over the past several years. EVG has now established five wholly owned subsidiaries across the globe.

EVG's high-volume manufacturing solutions for the semiconductor, compound semiconductor, power device, advanced packaging, LED and MEMS industries were on display at the SEMICON China trade show in Shanghai (18-20 March).

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

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

# MEI launches FluidJet batch wet processing metal lift-off system for compound semiconductor production

MEI Wet Processing Systems and Services (a subsidiary of MEI LLC) of Albany, OR, USA has launched the FluidJet batch wet processing system for metal lift-off in MEMS (micro-electromechanical system) and compound semiconductor manufacturing, delivering higher-yielding, more cost-effective metal lift-off processing.

MEI says that its FluidJet batch wet processing system for metal lift-off achieves breakthroughs with no metal re-deposition on either the front-side or back-side of the wafer, eliminating device damage while using 80% less chemical than existing single-wafer processing solutions. FluidJet also enables highly efficient, easily obtained gold and metal reclaim, reducing waste and downtime, adds the firm. FluidJet also saves manufacturing floor space by reducing the wet process footprint requirement by at least 60% over comparable-throughput single-wafer spray tools, it is claimed.

"By adopting the FluidJet metal lift-off system, semiconductor manufacturers will increase yield while reducing downtime and chemical costs and disposal," reckons MEI LLC's president & CEO Dan Cappello. "As part of our metal lift-off solution, we incorporated the patent-pending FluidJet system. FluidJet processing is especially important for sensitive

metal features and thin lines because the FluidJet cleans the surface gently, improving metal lift-off performance at a lower cost," he adds. "MEI has completed numerous customer demos where side-by-side 'split lot' comparisons of lift-off performance were evaluated for several major compound semiconductor manufacturers. This data demonstrates superior performance on many lift-off and resist strip layers while reducing defects, providing significant reductions in chemical use."

The firm says that the FluidJet metal lift-off system is unlike conventional single-wafer metal lift-off systems, using patented batch immersion processing to remove metals and eliminate re-deposition and defects. Conventional metal lift-off solutions rely on aggressive, high-pressure sprays. These high velocity sprays produce metal debris that can scratch or tear fine metal features, says MEI. Metal debris can also re-deposit, causing shorts and focus issues. The high-pressure spray at elevated temperatures is a significant factor in the consumption of massive amounts of chemical per wafer processed, adds the firm.

The FluidJet system's self-cleaning tanks and easily accessed metal collection baskets enable lifted

metals to be more easily and completely reclaimed, says MEI. Strainer baskets are emptied in minutes and sized to easily hold several thousand wafers worth of lifted metal, it adds.

FluidJet targets semiconductor and MEMS processing applications where metal lift-off is required to create gallium arsenide (GaAs) bipolar field-effect transistor (BiFET) device structures for mobile communications devices.

MEI's IDX proprietary control automation software mines process data from the FluidJet wet processing system, allowing engineers visibility into what is occurring in any tank or chamber. The firm also models airflow and fluid flow with special CAD software for detailed design, analysis, documentation, and configuration management. MEI leverages the CAD software's CFD (computational fluid dynamics) capability to support its in-house engineering analysis and design of customers' process and exhaust systems.

The FluidJet system is available for purchase. Upon request, MEI will run tests for potential customers (providing verifiable data) and deliver the correct equipment needed to meet specific metal lift-off goals.

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

# Rubicon raises \$4.3m through over-allotment option of public offering of common stock by selling stockholders

Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, semiconductor and optical industries) priced its underwritten public offering of 2,500,000 shares of common stock by selling stockholders (announced on 18 March) at \$13 per share (worth \$32.5m). In addition, Rubicon granted the

underwriters a 30-day option to purchase up to an additional 375,000 shares (worth \$4.875 in total) to cover over-allotments.

The offering closed on 24 March. Rubicon did not receive any proceeds from the sale of common stock by selling stockholders. However, the firm received net proceeds of about \$4.3m from the sale of over-allotment option shares.

Rubicon intends to use the net proceeds to fund its research and development of new products, for expansion, and to provide funds for general corporate purposes.

Canaccord Genuity Inc acted as sole book-running manager for the offering, and D A Davidson & Co acted as co-manager.

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

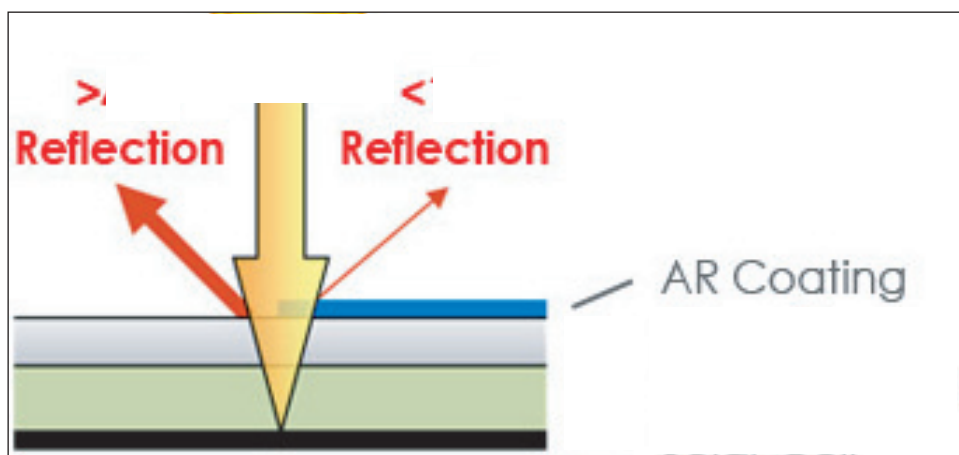
[www.sec.gov](http://www.sec.gov)

# EVG and Brisbane Materials introduce anti-reflective coating solution for increasing LED lighting output

At Strategies in Light 2014 in Santa Clara in late February, EV Group of St Florian, Austria, a supplier of wafer bonding and lithography equipment for MEMS (microelectromechanical systems), nanotechnology and semiconductor applications, and specialty materials firm Brisbane Materials Technology (BMT), which is based in both Brisbane, Queensland, Australia and Silicon Valley, introduced a new anti-reflective (AR) coating solution based on BMT's XeroCoat materials, which is designed to substantially increase lumen output of LED devices.

The jointly developed manufacturing solution, which leverages a combination of AR coating processing equipment and tunable, durable, inorganic coating material, enables lumen output increases of up to 8%, it is reckoned. The AR coating manufacturing solution can be seamlessly integrated with established production schemes, the firms say, allowing the coating of LED components at room temperature and atmospheric pressure.

"Improving light efficiency is a constant goal for LED chip and luminaire manufacturers in order to drive down the total cost of LED lighting," says EVG business development manager Dr Antun Peic. "However, extracting further improvements in light output from the LED chip design and epitaxial layer growth process has become increasingly difficult and costly. As a result, any incremental improvements in light output that can be gained from other areas with minimal cost or disruption to the LED manufacturing flow can have a significant impact on reducing overall system cost," he adds. "Through our partnership with BMT, we have developed a turnkey manufacturing solution that has achieved a significant breakthrough in improving LED light efficiency, which can help accelerate new applications for solid-state lighting such as smart



lighting and smart building."

Under a strategic cooperation agreement, EVG has optimized its precision coating systems for BMT's unique materials and processes, enabling high-yield fabrication of AR coatings. The technology enables the creation of a nano-porous silicon dioxide ( $\text{SiO}_2$ ) coating from a liquid precursor at room temperature and atmospheric pressure on plastic and glass lenses and luminaires. The  $\text{SiO}_2$  film (which has undergone rigorous testing, including a 2.5-year accelerated aging test equivalent to more than 20 years of field application) is covalently bonded to the surface to give maximum durability and field reliability.

"Our collaboration with EV Group in the solar market over the past several years has proven the ability of our joint AR coating solution to provide significant improvements in solar cover glass transmission," notes BMT's founder & CEO Dr Gary Wiseman.

**Our collaboration with EV Group in the solar market over the past several years has proven the ability of our joint AR coating solution to provide significant improvements in solar cover glass transmission**

"Our unique solution provides a simple and cost-effective way for customers to increase lumen output," he claims. "Working with our equipment partner EVG, we provide the equipment, materials, and process as a turnkey solution."

The large-area spray deposition method employed for this new process provides maximum processing flexibility as well as scalability, it is reckoned. "The large-area spray coating technology used in this process has been in commercial production in the display technology space for well over 10 years," notes Paul Lindner, EVG's executive director of technology. "This field-proven equipment solution, combined with BMT's novel material, allows us to quickly and uniformly coat nano-scale films onto a large number of luminaires — a key requirement to meet the challenging volume and cost targets of our LED customers," he adds. "In addition, spray coating allows for coating over a large range of form factors — for instance, lenses with highly curvilinear features — which is another important requirement for the LED luminaire market."

The firms had a shared booth at Strategies in Light. In addition, Peic presented the joint AR solution on the exhibition floor.

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

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

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

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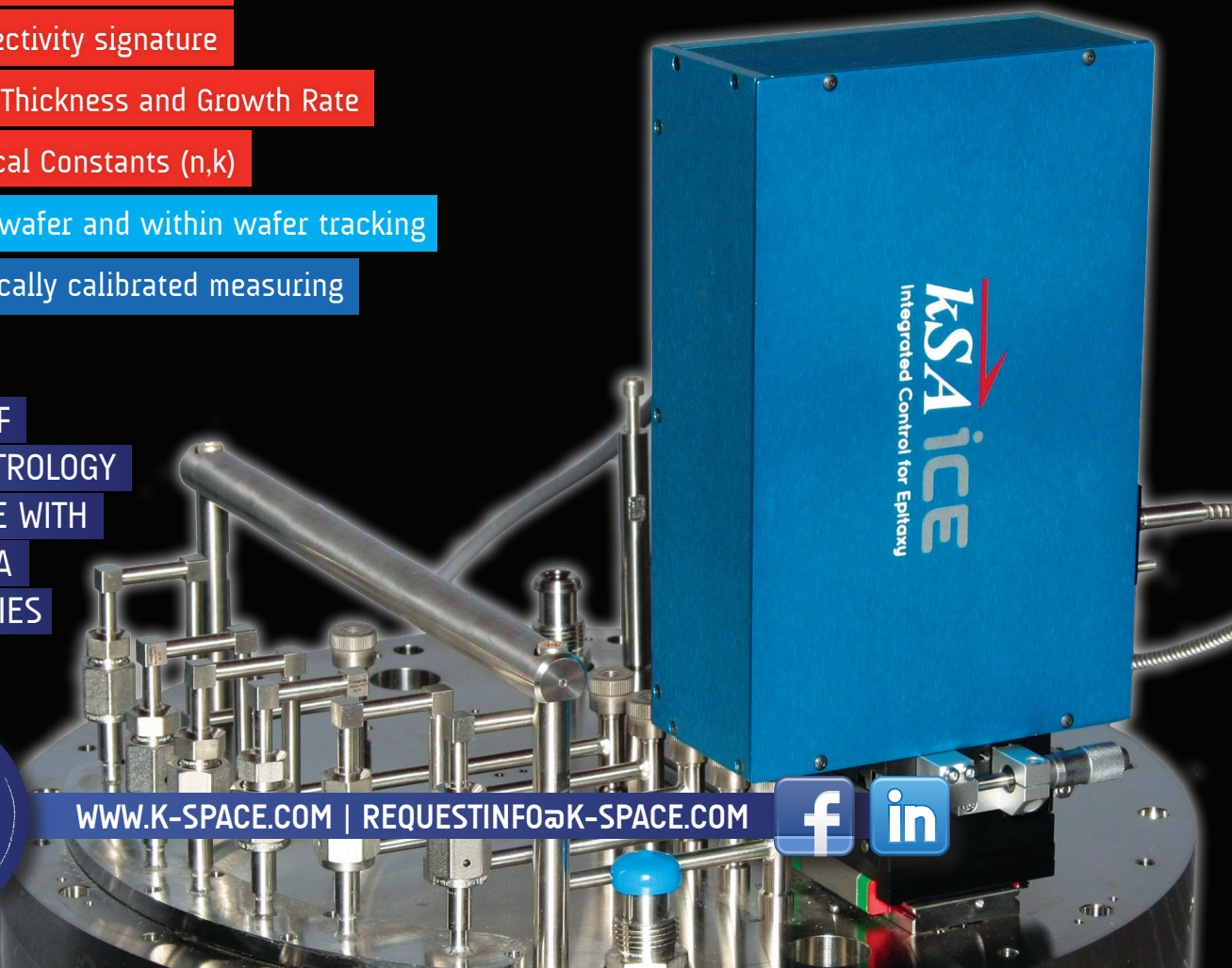
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## SemiLEDs' EV-W ReadyWhite-phosphor LED chips deliver high CCT uniformity to low-profile packages

LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has announced sampling and volume availability of the EV-W series of white LED chips, providing LED packagers with an increased range of capabilities while lowering production costs.

Based on SemiLEDs' proven Enhanced Vertical product line, the new EV-W chips incorporate the firm's proprietary ReadyWhite phosphor technology, which delivers a highly uniform phosphor coating across the emitter surface, increasing color precision and correlated color temperature (CCT) uniformity, says the firm.

The availability of high-output, high-consistency unpackaged white chips offers LED packaging and luminaire manufacturers a wide variety of new chip-on-board (COB) and package options by eliminating the phosphor application from the packaging process. Innovative package-level implementations can include variable-CCT single-package solutions, and greatly simplified RGBW, WWRA, WWWR or WWGR solutions to provide enhanced CRI and higher efficiency red/amber/green augmentation.

The new EV-W LEDs are available in high-power 40-, 45-, and 53-mil low-profile vertical chips and can deliver up to 140 lumens with efficiencies of 130lm/watt at a drive current of 350mA, depending on the



**SemiLEDs' packaged EV-W LED.**

chip bin and chosen packaging approach. Standard CCT/CRI options range from 6500K/70CRI to 2700K/80CRI, and include distributions as tight as 1/4 of a standard ANSI bin. Additional customization, including specialized phosphor options, is also available.

"A traditional barrier to the availability of creative new LED packages, especially lower-profile implementations, has been the issue of phosphor application within the packaging process," says Mark Tuttle, general manager for SemiLEDs Optoelectronics Co Ltd. "The additional capital requirements, expertise, processing time, overspray and wastage issues have all either limited packaging options or unnecessarily driven up costs," he adds. "By combining our rugged vertical-metal EV blue chips and the proprietary ReadyWhite phos-

phor coating technology, SemiLEDs' EV-W eliminates blue-leakage while delivering an impressive level of color uniformity and tight binning options for low-profile and multi-color white packaged LEDs."

Historically, manufacturers that assemble LED chips into low-profile packages have been faced with a substantial challenge when it comes to uniformity and cost issues, says SemiLEDs. While the industry has developed effective techniques to evenly cover the blue chip in a cavity-based package, current dispensing and spray-coating techniques tend to deliver a domed distribution rather than a flat, uniform coating. While moving to a vertical-metal chip solves the problem of blue leakage that would typically emanate from the sapphire substrate with a dispense-coated or spray-coated horizontal chip, SemiLEDs says that its ReadyWhite technology additionally addresses the equally important issue of uniformity.

The EV-W chip series is designed for manufacturability and rugged longevity and is available with an option of gold/tin (AuSn) metallization to support eutectic bonding to further enhance thermal characteristics. The EV-W series is RoHS compliant, with production quantities available now.

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

[www.veriphos.com/client/semileds/evw](http://www.veriphos.com/client/semileds/evw)

## SETi unveiling SMD-based 10mW UVC LEDs at Pittcon

At the Pittcon Conference and Expo in Chicago (2-6 March 2014), ultraviolet light-emitting diode (UV LED) maker Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA launched the latest product in its line of surface-mount UVC LEDs.

The new SMD consists of a large-area single-chip device packaged in a 4.2mm x 4.2mm ceramic package that can deliver 10mW of

optical power at 275nm.

The current line of surface-mount UVTOP LEDs was launched at the beginning of 2013 to drive standard 1mW UV LED technology into ultra-high-volume applications, and the market response has been overwhelming, according to SETi. The new 10mW product is designed to further drive down the cost per milliwatt of UVC power for high-

volume, power-intensive applications such as water, air and rapid surface disinfection.

"The new 10mW SMD-based UVC LED strengthens SETi's leadership in the UV LED market and demonstrates our commitment to new high-volume market opportunities," says president & CEO Dr Remis Gaska.

[www.s-et.com](http://www.s-et.com)

# Seoul Semiconductor launches Acrich MJT 2525 series of compact high-voltage mid-power LEDs

South Korean LED maker Seoul Semiconductor has released a new generation of LEDs with high performance and lumen density in the mid-power class. The new Acrich MJT 2525 series features the firm's proprietary high-voltage Acrich MJT (multi-junction chip technology) architecture in a mid-power package, enabling simpler, smaller, cheaper and more efficient driver topologies, the firm claims.

The 2525 series offers a compact symmetrical package with dimensions of 2.5mm x 2.5mm and wide beam angles, making the LEDs suitable for applications requiring uniform illumination. Optimized light extraction from the package results in high luminous efficacies, says the firm.

The Acrich MJT 2525 LEDs have a typical forward voltage of 22V. At a correlated color temperature (CCT) of 3000K and a color rendering index

(CRI) of 80, brightness is 95lm and efficacy is 105lm/W at an operating current of 40mA at 25°C. The lumen density of 15lm/mm<sup>2</sup> is five times that of any other mid-power package, making it suitable for space-constrained lighting applications. The wide viewing angle also helps to implement omnidirectionality in replacement lamp designs.

Acrich multi-junction technology incorporates multiple junctions on a single monolithic chip, eliminating the usage of multiple wire bonds between several die to create the high-voltage architecture. This improves reliability of the LED package, since it reduces the potential number of failure modes associated with wire bonds within the LED package. This high-voltage architecture also enables the use of simpler, more cost-efficient drivers, compared to conventional LEDs.

The improved efficiency of the driver electronics also results in less heat generation and fewer electronic components used in the driver design, allowing more space for thermal management within the luminaire, the firm adds.

"The new 2525 Series has unparalleled lumen density in the mid-power class of LEDs, not only reducing the total system costs for designers but also enabling new possibilities in lighting design," says Jay Kim, executive VP of Seoul Semiconductor's Lighting sales division. "The MJT 2525 series has higher cost efficiency than most mid-power packages and has already been adopted worldwide in a number of designs by key customers," he claims.

The product is in mass production and is globally available through Seoul Semiconductor's distributors.

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

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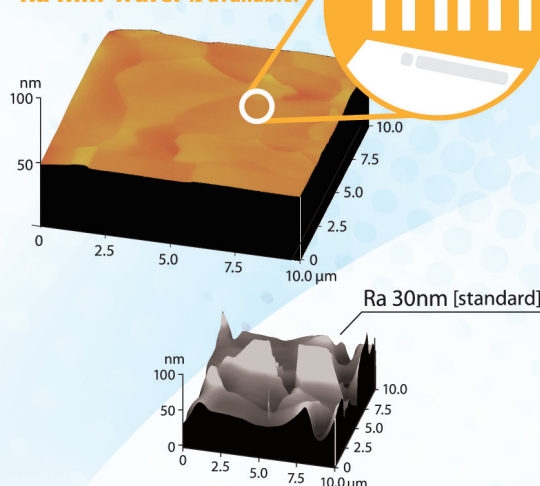
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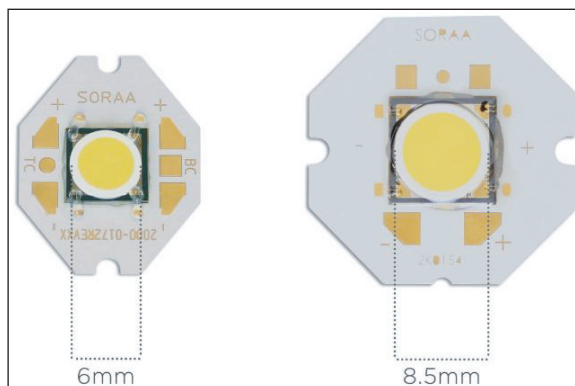
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# Soraa's third-generation LED boosts efficiency by 30%

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has launched what it claims is the world's most efficient LED, which it will integrate into the market's first full-visible-spectrum, large-form-factor lamps.

Soraa's third-generation (Gen3) GaN-on-GaN LED achieves what is reckoned to be record wall-plug-efficiency of 75% at a current density of 35A/cm<sup>2</sup> and a junction temperature of 85°C (outperforming the nearest competitor by 20% under normal operating conditions). says In just one year, Soraa has achieved a 30% increase in white lumen per watt (lm/W) efficiency over its prior-generation LED. "We expect to repeat these significant year-over-year performance gains in the future," says CEO Jeff Parker.



**Soraa's Gen3 chip-on-board package.**

Soraa leverages the properties of the native GaN substrate and a chip-on-board LED package design to create a robust, single-point source that enables what is reckoned to be excellent beam control. Also, with a proprietary three-phosphor combination, the Gen3 LED emits full-visible-spectrum light (including violet), which excites optical

brightening agents and perfectly renders whiteness as well as colors, it is claimed.

The Gen3 LED will be available in second-quarter 2014 in a variety of products (modules, large-form-factor PAR and AR lamps, and MR16 lamps).

Powered by its Gen3 LED, Soraa's full-visible-spectrum PAR30L lamp will have a color rendering index (CRI) of 95 and R9 of 95, and a

center-beam intensity (CBCP) of 28,250cd at 8° beam angle (10% higher than the CRI-85 offering of the nearest competitor, it is reckoned).

Soraa displayed its new full-visible-spectrum large lamp products at Strategies in Light in Santa Clara, CA (25-27 February) and at the Light + Building event in Frankfurt, Germany (30 March — 4 April).

## Soraa launches high color temperature, full-visible-spectrum Vivid 2 MR16 LED lamps

Soraa has launched what it claims are the first high correlated color temperature (CCT), high color rendering index (CRI) MR16 LED lamps — suiting gemstone jewellery and other high-end retail displays. The new 4000K and 5000K CCT, full-visible-spectrum Vivid 2 LED MR16 renders colors and whites as they would appear in natural light; without the high heat/UV emissions associated with ceramic metal halide (CMH)/halogen lamps and beam striations, artifacts or multiple shadows visible in other manufacturer's LED products, it is claimed.

"Our full-spectrum technology renders colors vividly and whites accurately; our single-source LED and innovative optics create perfectly uniform beams of exceptionally high intensity light, casting clear single shadows; and our lamps are ideally suited for fully enclosed, non-ventilated fixtures," claims CEO Jeff Parker. "Now, with

our 4000K and 5000K products, you can bring the energizing feel of natural light indoors without sacrificing light quality and compatibility."

In certain environments, higher-CCT light is preferred because it helps to create an engaging and energizing environment, says Soraa. However, because of their broken spectra, LED and CMH lighting products of 4000K and 5000K CCT create spaces that feel unnatural and cold. The Vivid 2 MR16 solves this trade-off by representing every visible color in the right proportion, resulting in scenes that feel warm and natural, adds the firm. The full-visible-spectrum emission of the LEDs results in a CRI of 95 and an R9 greater than 90. Plus, the violet component of the spectrum makes whites stand out in their natural brightness and tint.

Soraa's LED lamps are available in 12V and line voltage configur-

ations, as well as in a wide range of color temperatures (2700K, 3000K, 4000K and 5000K) and beam angles (10°, 25°, 36° and 60°), allowing lighting flexibility for any type of indoor or outdoor environment. This includes lighting suitable for smooth and textured fabrics, gold, diamonds, skin tones, and a broad array of other applications, says the firm. Its narrow 10° lamp works with its magnetic accessory SNAP System. With a simple magnetic attachment, beam shapes and color temperature can be modified.

The firm's LED lamps are compatible with a wide range of dimmers, having been tested and characterized extensively through its 'Works with Soraa' program. Also, a novel heat-sink design and thermal management system allows the lamps to run cool and deliver efficient light intensity over a long period of time, it is claimed.

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

## Plessey appoints chief commercial officer

As it gears up to grow global sales of its LED technology, Plessey Semiconductors Ltd of Plymouth, UK has appointed Dr Jose (Joe) Lopez as chief commercial officer (CCO). Reporting to Plessey's CEO Michael LeGoff, he will assume overall responsibility for the commercial and customer aspects of the organization, with the main focus being to grow Plessey's LED sales.

Plessey says that, during a 25 year career in the semiconductor industry, Lopez has been a key player in the solid-state lighting (SSL), communications and consumer market segments.

"Having spent the last three and a half years at Cree in a leading global sales role, Joe brings a wealth of LED commercial experience, key customer contacts and senior-level relationships within the SSL industry," comments LeGoff. "Joe will drive new levels of customer engagement and revenue



**Dr Jose Lopez.**

growth as we move into commercializing our LED technology."

Plessey has developed a process to produce high-brightness LEDs at what is reckoned to be a fraction

of the current cost. Its GaN-on-Si (gallium nitride on silicon) LEDs are produced using standard silicon-based semiconductor manufacturing processes, in contrast with existing generations of LEDs that use expensive sapphire and other materials.

The firm's aim is to drive global uptake of its patented MAGIC (Manufactured on GaN-on-Si I/C) technology as a cost-effective alternative to existing lighting systems, and expand its UK manufacturing facilities in Plymouth.

"Plessey is one of UK's leading technology brands and I believe it is years ahead of the industry with its proprietary GaN on silicon process technology," comments Lopez. "Plessey's LEDs offer performance comparable to that of sapphire, but at a substantially lower cost," he comments. "This makes the Plessey LEDs ideal for high-volume, cost-sensitive applications such as linear fluorescent tube replacement, indoor commercial and retro-fit bulb markets that characterize the high-growth general lighting segment."

Lopez has a degree in Computer Science and a PhD in Computer Engineering from the University of Sussex and an MBA from the Open Business School. He has lived and worked in the UK, Germany, France and Spain and speaks a number of European languages.

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

## Plessey signs Matrix to expand distribution network into Iberia

Plessey Semiconductors Ltd of Plymouth, UK has entered into a distribution agreement with Matrix Electrónica S.L. for the Iberian market for Plessey's gallium nitride on silicon (GaN-on-Si) LED products. Headquartered in Madrid with offices across Spain, Portugal and Chile, Matrix is an electronics distributor and provider of complete electronic solutions.

Plessey says that its GaN-on-Si LEDs are produced using standard silicon-based semiconductor manufacturing processes, in contrast with existing LEDs that use more expensive sapphire and other exotic materials. The firm aims to drive global uptake of its patented MAGIC (Manufactured on GaN-on-Si I/C) technology as a cost-effective alternative to existing solid-state lighting (SSL) LED technologies.

"The combination of Plessey's innovative products and our exten-



sive knowledge of the market will be very successful," believes Matrix's president & CEO Jose María Vilallonga Presas. "GaN-on-Si technology is going to be a revolution in the solid-state lighting market, and Matrix will be a pioneer in introducing the new technology in Spain and Portugal," he adds.

"Plessey are very pleased to work

with a distributor who has been focusing on the solid-state lighting market for a considerable number of years," comments Plessey's regional sales director David Owen. "Matrix has a dedicated team working in the lighting segment and therefore considerable knowledge of the lighting industry and customer base in the region."

## Glo completes \$30m Series D financing round

### Funding to boost product portfolio, team, and strategic partnerships

Glo AB of Ideon Science Park, Lund, Sweden, which provides light source solutions for displays, illumination and automotive sectors using its proprietary nLED technology, has completed a \$30m Series D round of financing. The firm will use the funds to add to its product portfolio, team, and strategic partnerships.

Most of the new funding comes from new investors. A new investor led the round, with participation from existing shareholders including Wellington Partners, Teknoinvest, Nano Future Invest, Energy Future Invest, Foundation Asset Management and others. Carnegie Investment Bank acted as placement agent. GTK Partners is Glo's strategic advisor. Total funding is about \$115m to date.

Glo was spun off from Lund University's Nanometer Structure Consortium (nmC) in September 2005 to commercialize LEDs using the proprietary heterostructured semiconductor nanowire technology research of the team of Solid State Physics professor & nmC head Lars Samuelson (Glo's chief scientific officer). Specifically, Glo develops nanowire LEDs (nLEDs) based on non-polar m-plane gallium nitride materials. By using readily available, low-cost and large-area silicon substrates with mass-production-friendly technologies, the LEDs can emit at bright-

ness levels suitable for general illumination applications and with performance equal to or better than existing state-of-the-art planar chips, yet at much lower manufacturing cost at the die level, it is claimed. Glo controls a portfolio of patents and patent applications covering innovations in nanowire epitaxial growth and process technologies made by the Lund team and by Glo itself. The firm says that nLED technology sidesteps the limitations of the common planar LEDs, offering high-efficiency, stable red, green and blue emitters using a single material system. With a 60-person R&D and operations facility at Glo-USA Inc in Sunnyvale, CA, the company is focused on delivering color stability with high color rendering without the need for phosphor conversion, all using standard manufacturing equipment and materials.

"We and our customers are excited about the market entry of our first-generation nLED products, demonstrating superior color and competitive efficiencies," says Glo's CEO Fariba Danesh. "Glo's products are next-generation light sources that go beyond the technology limitations of standard planar LEDs. We are aggressively growing our capabilities and strategic partnerships to provide nLED products for all applications."

To further accelerate growth, the firm has augmented its management team and board of directors:

- Bart Markus, a partner at Wellington Partners, is now chairman. Bart and Wellington (who have been funding advanced semiconductor ventures for more than a decade) have been investors in Glo since 2010.

- Kambiz Hooshmand, former CEO of AMCC Semiconductor and former group VP at Cisco, has joined Glo's board. Kambiz serves on the board of public company Infinera, is an advisor to private equity firm SilverLake Sumeru, and is a co-founder of Archimedes Ventures.

- Shuo Zhang, VP of worldwide mobile sales for Cypress Semiconductor, has joined Glo's board. She has served in various senior management positions in sales and marketing while at Cypress. Previously, Shuo held senior marketing management positions at Avago Technologies and Altera Corp.

- James V. McCanna has joined as chief financial officer. He was previously CFO of private company iWatt (sold last year in registration for \$345m) and has 30 years of experience as a financial officer in technology companies.

- A sales and support office has been established for the Asian region in Tokyo, Japan.

[www.glo.se](http://www.glo.se)

## Toshiba launches 1W and 0.6W white LEDs for lighting applications

Tokyo-based Toshiba Corp has launched two new series of white LEDs: the 3.5mm x 3.5mm lens package 1W type TL1L2 series and the 3.0mm x 3.0mm flat package 0.6W type TL3GB series.

Utilizing gallium nitride-on-silicon (GaN-on-Si) process technology developed for LED lighting, the new white LEDs realize a low forward voltage ( $V_F$ ) and low power con-

sumption and can contribute to cost reductions, the firm says.

For the TL1L2 series,  $V_F$  is 2.85V at a forward current ( $I_F$ ) of 350mA. Luminous efficacy is 135lm/W (5000K, Ra70) at 1W operation ( $I_F=350mA$ ). Applications include sources for general lighting (including light bulbs, base lights, down lights and ceiling lights), street lights and floodlights.

For the TL3GB series,  $V_F$  is 5.76V at an  $I_F$  of 100mA. Luminous efficacy is 118lm/W (5000K, Ra80) at 0.6W operation ( $I_F=100mA$ ). Applications include sources for general lighting (including light bulbs, base lights, down lights and ceiling lights).

Six color temperatures are available, from 2700K to 6500K. Mass production will start by April.

[www.toshiba-components.com/LEDs](http://www.toshiba-components.com/LEDs)



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## Lumileds expands LUXEON Mid-Power LED portfolio

Philips Lumileds of San Jose, CA, USA declared 'Mid-Power March' in introducing multiple new mid-power LED products as well as significant upgrades to existing products. The firm reckons that, together with its high-power LEDs, the product launches affirm its position of having the most comprehensive line of emitters and arrays on the market.

"With this expansion of our mid-power LED portfolio, which covers a

broad range of CCT [correlated color temperature], CRI [color rendering index] options and different form factors, we now have a complete selection of LEDs to cover all the major lighting applications," says Khim Lee, director of Mid-Power Products.

The portfolio will cover different form factors, for various lighting applications, delivering luminous efficacy of 185lm/W.

The product launches are accompanied by the introduction of a new color binning structure that enables tight color control. The new products also offer hot color targeting, ensuring ANSI compliance at specified operating conditions.

In applications where either high-power or mid-power LEDs can be used, users now have full freedom to select from the highest-performance options, says Lumileds.

### Lumileds delivers first hot-color-targeted mid-power LED, plus new 1/9th micro color binning

Lumileds has launched what it claims is the first mid-power LED with hot color targeting, which ensures that performance is compliant with ANSI specifications at real-life operating temperatures. The LUXEON 3030 2D is intended for high-flux applications such as retrofit bulbs, downlights, as well as high-bay and low-bay luminaires.

"Without hot color targeting, if a user purchases an LED that was performing on a bin edge at room temperature, it would likely shift out of the specification at application temperatures and cause an undesirable shift in color for the fixture," says Mark Chang, senior

product line manager of Mid-Power Products. Hot color targeting remedies this problem by targeting slightly above the black-body locus at room temperature. At application conditions, the color temperature remains within ANSI specifications.

The LUXEON 3030 2D is also being introduced with a new 1/9th micro color binning structure. Users can now accurately select 3- or 5-step MacAdam Ellipse for optimal color control. "Designers can also easily pair different bins to hit a 3/4/5 SDCM color point," says Chang.

The LUXEON 3030 2D LED uses

an epoxy molding compound (EMC) QFN package for reliability and lumen maintenance. Typical warm-white (2700K) performance is 87lm at a color rendering index (CRI) of 80 at 120mA. Cool-white efficacy reaches 133lm/W at 80 CRI and 120mA. When driven at the maximum drive current of 240mA, the LED can deliver 160lm at 6500K and 80 CRI.

"Depending on CCT, the lumen output of the LUXEON 3030 2D is 10–15% higher than previous-generation 2-die mid-power emitters," notes Chang.

[www.philipslumileds.com/LUXEON30302D](http://www.philipslumileds.com/LUXEON30302D)

## Lumileds debuts first hot-color-targeted low-power emitter with 1/9th micro color binning

Lumileds has launched the LUXEON 3014 low-power emitter for linear and omnidirectional lighting applications such as under cabinet lighting, refrigerator display lighting, troffers, TLEDs and retrofit bulbs. Delivered in a rectangular 3.0mm x 1.4mm x 0.7mm footprint, it is claimed to be the industry's first low-power LED offered with the advantages of hot color targeting and a 1/9th micro binning structure.

"Traditionally, an LED that performs on a bin edge at room temperature would shift out of the specification at application temperatures, resulting in a different color



for the fixture than was intended," says product manager Michael Howley. Hot color targeting remedies this problem by targeting slightly above the black-body locus at room temperature. At application conditions, the color temperature

remains within ANSI specifications.

The new 1/9th micro color binning structure enables tighter color control for a given application.

"Designers can easily pair different bins to hit a 3/4/5 SDCM color point," says Howley.

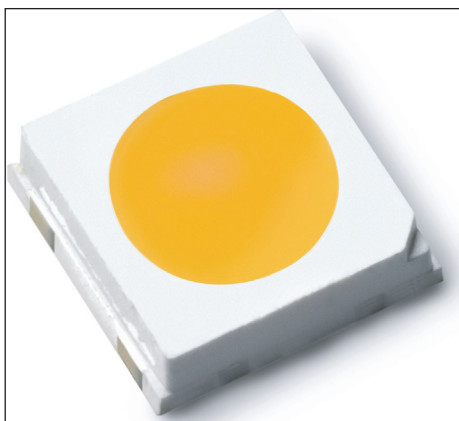
The LUXEON 3014 can deliver 10–12lm of uniform light at a drive current of 30mA in neutral white and can be driven as high as 100mA to reach 33lm. "The LUXEON 3014 is offered in an industry-standard QFN package, allowing compatibility with leading manufacturers' 3014 designs," notes Howley.

[www.philipslumileds.com/LUXEON3014](http://www.philipslumileds.com/LUXEON3014)

## Lumileds launches LUXEON 3535 HV mid-power LED, offering high lumens and compatibility with less expensive high-voltage drivers

Philips Lumileds has launched the LUXEON 3535 HV mid-power LED, which allows lighting manufacturers to design-in high-voltage drivers that are diminutive in size compared to standard drivers, enabling simplified design of compact fixtures as well as lower total cost of the overall lighting solution.

The firm's high-voltage mid-power portfolio is available in both 24V and 48V configurations. "The advantage of designing-in high-voltage LEDs is that they utilize drivers containing on average less than 20 components, relative to standard LED drivers that can contain up to 50 components," says product manager Michael Howley. "As a result, the total bill of materials (BOM) cost can be reduced and the amount of inventory they need to carry to design



the driver is minimized," he adds.

Applications for the LUXEON 3535 HV include space-constrained lamps such as retrofit bulbs, downlights, wall sconces, wall packs, and pendant luminaires. "Manufacturers of wall packs, wall sconces and pendants in many different regions of the world are interested in

high-voltage LED technology and the design simplicity it affords," notes Howley.

Lumileds is providing LM-80 data for the 24V and 48V LUXEON 3535 HV LEDs. They are also offered with a 1/9th micro color binning structure with 3- and 5-step color accuracy, offering tight color control.

At a correlated color temperature (CCT) of 4000K and a color rendering index (CRI) of 80, typical lumen outputs and luminous efficacies at a drive current of 20mA are, respectively, 120lm and 125lm/W for the 48V LED and 60lm and 125lm/W for the 24V LED.

Lumileds also maintains an ecosystem of demonstrative driver designs for the 24V and 48V LEDs.

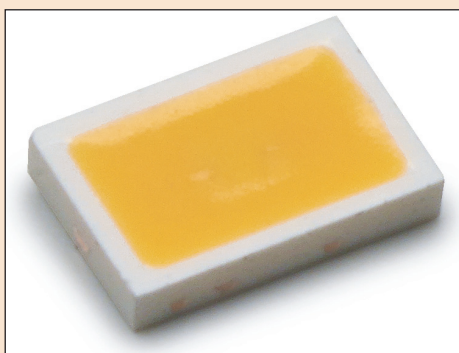
[www.philipslumileds.com/LUXEON3535HV](http://www.philipslumileds.com/LUXEON3535HV)

## Lumileds' hot-color-targeted LUXEON 3020 LED exceeds 1000lm/\$ threshold

Philips Lumileds of San Jose, CA, USA has launched the LUXEON 3020 emitter, which aims to drive a variety of long-awaited commercial LED lighting fixtures into the mass market, including lamps and troffers.

"The LUXEON 3020 is the most affordable of all our mid-power LEDs, delivering over 1000 lumens per dollar," says product manager Orson Lo. "This product will inspire the market with the next generation of high-quality, efficient and attractively priced LED lamps," he reckons.

Like other offerings in the firm's mid-power portfolio, the LUXEON 3020 also features hot color targeting and a 1/9th micro color binning structure. Lumileds' hot color targeting ensures that the color temperature remains within ANSI specifications at operating



conditions. **Lumileds' hot color targeting ensures that the color temperature remains within ANSI specifications at operating conditions.** With the new binning option, users have the ability to select portions of the bin structure that are within the

ANSI, 5-step MacAdam Ellipse or 3-step MacAdam Ellipse regions, achieving the color point needed for a particular application.

For designers of lamps, troffers, TLEDs, and high-bay and low-bay luminaires, the LUXEON 3020 produces 90lm at a correlated colour temperature (CCT) of 6500K and a color rendering index (CRI) of 80 when driven at the maximum forward current of 240mA. It also features the use of epoxy molding compound (EMC) along with QFN packaging technology to boost reliability and thermal properties.

Typical efficacy is 135lm/W at 6500K at a CRI of 80 and drive current of 120mA.

LM-80 data is available for the LUXEON 3020.

[www.philipslumileds.com/LUXEON3020](http://www.philipslumileds.com/LUXEON3020)

# Cree breaks 300lm/W efficacy barrier for white LEDs

## Record raised from 276lm/W set by Cree in February 2013

Cree Inc of Durham, NC, USA has raised its previous R&D industry record for white high-power LED luminous efficacy from 276 lumens per watt (announced in February 2013) to a new record of 303lm/W. The firm claims it has surpassed the landmark of 300lm/W much faster than previously believed possible.

"Achieving this level of LED efficacy amplifies the potential for the solid-state-lighting industry to deliver smaller, lower-cost lighting solutions, and even larger-than-expected energy savings," comments Steven DenBaars, professor and co-director of the Solid State Lighting and Energy Center at University of California, Santa Barbara (UCSB).

Cree says that the 303lm/W efficacy was measured at a correlated color temperature (CCT) of 5150K and a drive current of 350mA.



Progress of Cree's R&D in raising luminous efficacy for white LEDs.

Standard room temperature was used to achieve the results.

"We continue the pursuit of 100% LED adoption," says John Edmond, Cree's co-founder & director of advanced optoelectronics. "Pushing

the boundaries of LED performance is critical to enhancing LED lighting designs, and this 303 lumens-per-watt result will enable more cost-effective lighting solutions."

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

## Cree cuts LED Bulb prices by up to 23% and adds 100W replacement

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA says that, in just one year, its LED Bulb has become the best-selling LED bulb in America, enabling a cumulative total of more than \$1bn in lifetime energy savings for consumers. Cree and The Home Depot are now lowering the prices of the firm's LED Bulb product line by as much as 23%.

To further drive adoption and expand the market, Cree is also introducing what it claims is the first 100-watt replacement LED bulb to look and light like a light bulb. The new 100W Cree LED Bulb costs just \$19.97 — the lowest-priced 100W LED replacement bulb, it is reckoned.

"It is time to push LED lighting to the next level and give consumers even more reasons to switch to LED," says chairman & CEO Chuck Swoboda. "We are also addressing the last major product gap for LED bulbs — the 100W replacement...



the first true 100W LED bulb with the look and performance of a traditional bulb, but at a fraction of the energy consumption," he adds.

compact fluorescent lamp (CFL) alternatives.

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

<http://homedepot.com/cree>

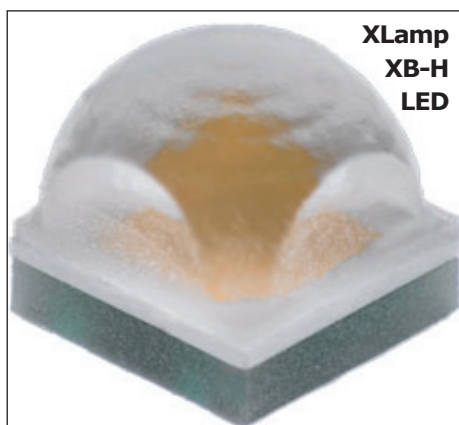
The new 100W Cree LED Bulb delivers 1600 lumens while consuming just 18W and is available in soft white (2700K) and cool, daylight (5000K) color temperatures. Using 82% less energy and designed to last 25 times longer, the 100W Cree LED Bulb's common A21 bulb shape and size allows it to fit in nearly any open lighting fixture in the home, including floor lamps, reading lights, high ceilings and hallways, unlike

## Cree's XB-H high-density discrete LED combines high lumen output and optical control in smaller package

Cree Inc of Durham, NC, USA has introduced the XLamp XB-H LED, the brightest discrete in the firm's high-density (HD) class of LEDs, delivering a combination of high lumen output and efficacy in a small package.

The XB-H LED brings the lighting-class performance of the XP-G2 LED into a package that is 50% smaller, says Cree. Delivering more than 500 lumens at 1.5A (25°C) in a 2.45mm<sup>2</sup> package, the XB-H LED can enable luminaires that use the same-size-footprint XB-D LED to triple their light output at the same efficacy, the firm adds.

The XB-H joins the XQ-E in the family of HD-class discrete LEDs that offer what is claimed to be the industry's highest optical control factor (OCF, a measurement of how LED size and performance benefit directional lighting applications). High-OCF LEDs enable lighting manufacturers to improve the performance of any lighting design, create smaller and less expensive systems, and develop new lighting solutions that were previously not possible, says Cree.



"Cree is the first LED manufacturer to bring this level of performance to such a small size," comments Roger Suen, supply chain management director at LED lighting firm Light Engine Ltd. "With a high optical control factor, the XB-H LEDs enable new levels of brightness and optical control to improve design flexibility, increase performance and lower system cost without sacrificing reliability," he adds.

Utilizing Cree's proven ceramic package technology, the XB-H LED delivers long L70 lifetimes at both high temperature and current. It also offers compatibility with most optics designed for Cree's XP family

of LEDs, allowing lighting manufacturers to leverage the optics of existing lighting designs and improve time to market.

"Delivering up to 175 lumens-per-watt efficacy at 1W (25°C) in its small package, the XB-H LED sets a new performance standard for high-power LEDs," claims Dave Emerson, VP & general manager for Cree LEDs.

To improve time to market, lighting manufacturers seeking ENERGY STAR qualification can take advantage of the XB-H LED's successor status to the XP-G2 LED, so qualification can be achieved using just 3000 hours of LM-80 data instead of the normal 6000 hours.

The XB-H LED is available in color temperatures ranging from 2700K to 8300K and color rendering index (CRI) options of 70, 80, 85 and 90. Binned at 700mA (85°C), the XB-H LED delivers up to 499 lumens at 5W (85°C). Product samples are available now and production quantities with standard lead times.

[www.cree.com/LED-Components-and-Modules/Products/XLamp/Discrete-Directional/XLamp-XBH](http://www.cree.com/LED-Components-and-Modules/Products/XLamp/Discrete-Directional/XLamp-XBH)

## XSP Series street-light performance extended to outdoor area lighting

Cree is expanding its outdoor lighting portfolio with the XSP Series Area LED luminaire and the XSPW Wall Pack LED luminaire. Leveraging innovations from the XSP Series LED street light, the new luminaires are said to cut energy consumption by 65% (compared to metal halide wall packs and 400W probe start metal halide luminaires) and nearly eliminate maintenance costs to easily replace the millions of outdated HID luminaires currently installed in North America.

"The Cree XSP Series Area and XSPW Wall Pack luminaires represent the latest examples of Cree's mission to replace inefficient tech-



nologies with LED alternatives that provide the price, quality and energy savings that dramatically improve the lighting experience and save customers money," says Norbert Hiller, executive VP, lighting. "These new luminaires provide high-performance, nearly-

maintenance-free lighting for up to 100,000 hours, ending the need for compromised metal halide alternatives."

Sporting Cree's NanoOptic Precision Delivery Grid optic technology, the new luminaires deliver better optical control and more uniform, white light than metal halide fixtures, it is claimed. Both the XSP Series Area LED luminaire and the XSPW Wall Pack LED luminaire offer multiple mounting and optical options to support a variety of installations and applications. Both are backed by Cree's 10-year limited warranty.

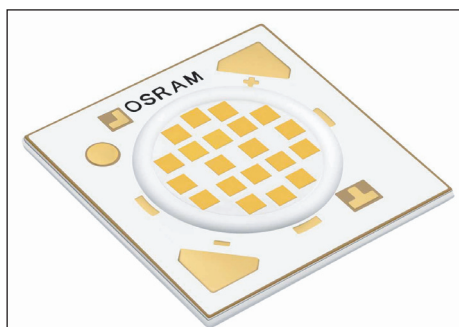
[www.cree.com/lighting/xspwall](http://www.cree.com/lighting/xspwall)  
[www.cree.com/lighting/xsparea](http://www.cree.com/lighting/xsparea)

# Osram launches CoB LED offering twice the light from half the surface, targeting compact spotlights

Osram Opto Semiconductors GmbH of Regensburg, Germany says that, for the first time, it is offering a chip-on-board (CoB) LED that is suitable for compact powerful spotlights such as those used in retail outlets and museums.

As the latest member of the Soleriq family, the Soleriq P 9 produces a luminous flux of 2000lm and has a luminous efficacy of 100lm/W (at a temperature of 85°C and 3000K) from a light-emitting surface with a diameter of only 9mm (64mm<sup>2</sup>) — twice as much light with the same efficiency from an area half the size compared with the existing Soleriq S 13.

This high brightness is made possible by the surface-emitting chips that are used. Even at very high packing densities, they can produce high luminous flux with above-average efficiency, says Osram. The small light-emitting surface means that extremely compact and therefore lightweight optics can be fitted for highly compact spotlights. The spotlights can therefore be less cumbersome and more cost-effective, while still providing the same luminous intensity, says the firm.



**Osram's new Soleriq P 9 LED.**

For example, just one Soleriq P 9 LED can match the luminous intensity of a 35W high-intensity discharge (HID) lamp. With package dimensions of 15mm x 15mm and a beam angle of 120°, the Soleriq P 9 has been designed for use in spotlights for directional indoor lighting and in particular for shop and museum lighting. The color rendering index (CRI) is a minimum of either 80 or 90, and the correlated color temperatures (CCT) are 2700–5000K (CRI 80) and 2700–4000K (CRI 90).

"The Soleriq P 9 is just the start of a series of LEDs with enormous brightness and efficiency, generated from a light-emitting surface of only a few millimeters in diam-

eter," says Andreas Vogler, responsible for the P 9 in the SSL division at Osram Opto Semiconductors. "Over the next few months we will be unveiling more products in the Soleriq P family, taking the benefits of the P series into different form factors and areas of application," he adds.

The new Soleriq is being tested and measured at a temperature of 85°C to simulate the thermal conditions in actual applications as closely as possible. Customers will therefore be able to directly plan the use of the LED in their applications and will not have to carry out time-consuming appraisals based on data sheet values, says Osram.

The P 9 is the first member of the new Soleriq P series; following the existing E and S series. All Soleriq versions are CoB LEDs and offer high brightness. They are suitable for indoor spotlight applications and are easy to install, says Osram. The Osram partner network 'LED Light for you' offers accessories such as holders, optics and drivers tailored to the Soleriq families.

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

## Plessey launches 1005-size SMT LEDs for wearable electronics

Plessey Semiconductors Ltd of Plymouth, UK has launched its smallest packaged MaGIC LED (Manufactured on GaN-on-Si I/C), which is aimed at the surging wearable electronics market. As the first product in the new dotLED family, the PLW138003 is a white LED in a 1005 SMT package designed specifically for the demand for ever smaller LED components producing highly collimated light. Plessey says that the new dotLEDs, weighing 0.2mg with a profile of 0.2mm, are suitable for any wearable application with LED content.

The 1005-size of the PLW138003 (1.0mm x 0.5mm) is a standard

electronic component size, handled by common surface-mount machines used in high-volume consumer electronics. With a height of 0.2mm, the dotLED is designed specifically for applications that demand low-profile electronic components.

The PLW138003 delivers up to 0.7lm of white light with a 130° viewing angle from a 5mA drive current. A blue version (the PLB138003) is also available. Further additions to the dotLED family will be color variants and a series in the larger 1608 footprint. Plessey also provides a range of blue LED die for customers needing a further breakthrough in size: the PLB030003 ultra-thin die

is just 200µm x 200µm x 75µm.

Plessey's LEDs are produced using its proprietary MaGIC technology. By using standard silicon semiconductor production techniques, the firm is able to produce high-volume industry-standard LEDs for the consumer electronics market. The 1005-size dotLEDs are the latest product family to be released using this technology.

"Plessey is demonstrating its commitment to bringing to market a comprehensive range of LED products across all markets and applications," chief commercial officer says Dr Jose Lopez.

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



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# CST to supply GaAs wafers to Optelian's Versawave unit

Optoelectronics device foundry Compound Semiconductor Technologies (CST) of Hamilton, Scotland, UK will supply grown gallium arsenide (GaAs) wafers to the Versawave Division of Packet optical networking system maker Optelian of Ottawa, Canada as a key component of Versawave's ultra-high-speed optical modulator technology.

CST was formed in 1999 by the universities of Strathclyde and Glasgow (together with Scottish Enterprise) as a 'pure play' foundry, designing, developing and manufacturing discrete and integrated III-V optoelectronic wafers and chips for clients in communications, defense, medical and instrumentation.

Acquired by Optelian in 2011, Versawave possesses patented polarization modulation technology. Under the new foundry agreement, CST will supply to Versawave fully processed GaAs wafers with an

optical coating, as designed and specified by Versawave.

"Their Class 50 cleanroom environment, combined with full ISO compliance, enables Optelian to maintain our exceptionally high manufacturing standards," says Optelian's CEO David Weymouth about CST.

Optelian has also ramped up Versawave facilities at its corporate and manufacturing HQ in Ottawa. Wafers from CST will be integrated into Versawave opto-electrical modules by Optelian's manufacturing team.

"Optelian is TL-9000 certified, which is a catalyst that helps create an environment of continuous improvement for the organization," says Dennis Isotti, VP of Operations. "We have the expertise to ramp up production of Versawave modules to orders of magnitude above the current production capacity."

Versawave module production will be transferred into a newly built custom cleanroom space where process and operations will be fully integrated into Optelian's production and quality control systems. Manufacturing is capable of 24/7 production, yielding shorter lead times while ensuring on-time delivery and quality, says Optelian.

"Moving R&D and Operations under the same roof will not only make us more efficient, but also more agile," reckons Simon Benwell, director of Advanced Optical Components at the Versawave Division. "By having R&D work in conjunction with the production teams, our NPI times will reduce significantly while our production capacity will drastically increase. These are both essential for our new products coming onto the market in 2014 and beyond."

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

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

# Advanced Photonix extends line of credit with lenders

Advanced Photonix Inc of Ann Arbor, MI, USA (which designs and makes APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) has reached agreements with both Silicon Valley Bank (SVB) and Partners for Growth III L.P. (PFG) to waive past covenant violations under the firm's respective loan and security agreements with SVB and PFG and (subject to certain terms and conditions) provide for an extension of the line of credit under the SVB loan agreement through 31 May. The firm plans to continue discussions with SVB to extend the line of credit beyond 31 May, based on its future business conditions.

The amendments provide for:

1. An extension of the SVB line of credit from 31 March to 31 May.
2. SVB's and PFG's waiver of the current covenant defaults under the loan agreements.
3. A reset of the loan agreements' trailing three-month adjusted

EBITDA (earnings before interest, taxes, depreciation and amortization) covenant to a negative \$1.2m for February, a negative \$800,000 for March, a negative \$600,000 for April and a positive \$1 for May.

4. A reset of the loan agreements' existing liquidity ratio to 1.30 as of 28 February, and 2.25 each month thereafter through 31 May.

5. The current interest rates under the SVB loan agreement to remain at the prime rate published in the Wall Street Journal (currently 3.25%) plus 4.0% for the line of credit and 4.5% on the existing term loan.

6. Certain changes to the SVB loan agreement to eliminate the firm's ability to engage in stock repurchases and to impose a uniform 30-day deadline to deliver monthly financial statements to SVB for all months, including those coinciding with the end of a fiscal quarter.

7. A revision to the EBITDA definition to add back fees associated with the negotiation of the amendments.

8. A \$10,000 fee payable to each of SVB and PFG for the modifications and waiver of the current covenant defaults and an additional \$5000 payable to SVB for the extension of the SVB line of credit.

9. Additional fees payable to SVB and PFG of up to \$50,000 and \$75,000, respectively, due on the earlier of 31 May and the date that all outstanding indebtedness becomes due under the loan agreements.

10. All other terms and conditions of the loan agreements would remain the same.

"We are pleased to have come to agreement with both Silicon Valley Bank and Partners for Growth, both of which have a rich history of working with growing high-technology businesses," says president & CEO Richard Kurtz. "We thank Silicon Valley bank and Partners for Growth, both for their deep understanding of the high-technology market and for their commitment to API."

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

## Daylight launches first laser-based IR microscopy platform

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, has launched what it claims is the first commercially available laser-based infrared microscopy platform.

Marketed under the name Spero, the microscope opens up research possibilities with chemical imaging and analysis on a real-time basis, says the firm. Powered by Daylight's proven broadly tunable QCL technology and designed specifically for analyzing biomedical and materials research samples, Spero offers what is claimed to be a unique combination of visibility, instantaneous results in 'live mode', and a small resource footprint to easily fit into a lab setting.

By incorporating a high-brightness, broadly tunable mid-IR laser source, Spero provides high image resolution with an ultra-wide field of view. This combination enables researchers to observe micron-scale features while also covering large areas very quickly for high-throughput applications. The instrument operates in the feature-rich mid-IR region and provides high-fidelity spectral data for the accurate identification of molecular and chemical components of complex, heterogeneous samples. Unlike current FTIR-based instruments, full-spectrum, high-resolution hyperspectral data cubes can be collected in just minutes and, with the 'live mode' capability, users can observe samples with discrete frequency illumination, allowing real-time imaging of individual spectral features. These capabilities are combined in a compact, desktop form factor that requires no liquid nitrogen cooling.

Spero is powered by an easy-to-use spectral imaging software platform that enables both novice and expert users to quickly generate high-quality images and accurate

spectral information, the firm says. Intuitive scripting and automation features are included to allow customized workflows to meet individual user needs. By taking a user-centric and context-aware approach to software development, Spero's full capabilities can be leveraged to accelerate research across a wide variety of chemical

imaging applications, the firm adds. "As the first laser-based infrared microscopy platform, Spero will provide rapid, high-resolution results for applications ranging from cancer research and drug discovery to food safety and materials manufacturing," says president Paul Larson.

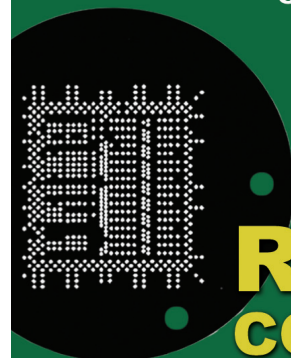
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# POET achieves new milestone and reports progress

## Operation of switching laser achieved within POET platform

POET Technologies Inc of Toronto, Canada – which, through subsidiary OPEL Defense Integrated Systems (ODIS Inc) of Storrs, CT, USA, has developed the proprietary planar-optoelectronic technology (POET) platform for monolithic fabrication of integrated III-V-based electronic and optical devices on a single semiconductor wafer – has announced the achievement of continuous-wave (cw) operation of its thyristor laser within its POET platform. The firm is also reporting progress on several other initiatives on its technical roadmap.

### POET switching laser

The firm has achieved the long-awaited milestone (MS-5) – operation of its switching laser within the POET platform. This has implications for on-chip and optical communications applications. The firm claims that this demonstration is an advance for an integrated circuit industry seeking ways to push complementary metal-oxide semiconductor (CMOS) processes past some challenging technical barriers.

“This is the most definitive step yet in our drive to enhance POET’s electronic and optical monolithic capability, beyond CMOS and silicon photonics,” says executive chairman & interim CEO Peter Copetti.

Specifically, switching operation was achieved with a laser threshold of 1mA, just above a thyristor holding current of 0.5mA, for a 10µm-diameter laser device, exhibiting a suppression ratio of 50dB. This enables optical short-reach applications found in data-center, server farms and high-performance computing, lowering system solution cost when compared to silicon photonics, the firm reckons.

### Facility upgrades

In accordance with its planned maintenance scheduled for the POET facility, the firm has completed its most recent wafer growth cycle. In association, POET is upgrading its molecular beam epitaxy (MBE) system to make critical additions

and to replenish source materials.

A critical addition is a high-volume indium (In) source to enable metamorphic growth on a gallium arsenide (GaAs) substrate of the POET epitaxy with a natural wavelength of 1550nm. This is expected to enable the production of long-wavelength lasers combined with high-In-content field-effect transistor (FET) channels for improved high-speed transistor performance.

### Drive for feature size to 100nm range (MS-8)

The firm recently introduced a milestone associated with reducing feature size to the 100nm range, and previously announced that it had realized submicron device operation from an initial 800nm down to 200nm.

The company is moving steadily towards the goal of 100nm feature sizes for transistors within the POET platform, and has stabilized feature definition at the sub-200nm level. Short-channel considerations are being addressed with new innovations, and the critical step of isolating source-drain and gate contacts with oxygen implantation is nearing completion. The 100nm goal is matched to state-of-the-art commercial III-V foundry capabilities and will demonstrate greater than 20x speed improvement together with 4–10x lower power consumption (depending on the application) compared with silicon at smaller nodes.

Although timelines are always subject to review depending on partner needs, the technical team sees no significant technical roadblocks ahead. POET anticipates completion of the 100nm milestone by the end of April.

### Technical development kits (TDK)

In addition to optimizing device parameters and yields, the firm is focusing on establishing POET’s technology design kits (TDKs). The TDKs comprise a comprehensive design rules and device parameter library, and will enable customers and partners to implement the POET process into preferred foundries. The TDKs are also intended to help licensed designs in a POET device ecosystem to proliferate and help existing silicon library functions migrate to POET technology-based circuitry in a minimum amount of time.

The firm is reporting that, with the help of select potential POET Development Alliance (PDA) partners, progress on this milestone is ahead of the schedule set by the former Special Strategic Committee. “It is gratifying to see our excitement shared by others, and we hope that excitement will be infectious as we head into the Global Semiconductor Forum [GSF, in Singapore on 12–14 March],” says Copetti. “We have a relentless focus on securing our intellectual property and in forging ties to industry, and this positions POET Technologies in its drive to extend Moore’s Law to the next level,” he adds.

The firm reckons that, by enabling increased speed, density, reliability, power efficiency, and much lower bill-of-materials and assembly costs, POET’s technology will allow continued advances in semiconductor device performance and capabilities for many years, overcoming the existing power and speed bottlenecks of silicon-based circuits. It also aims to influence the future development roadmaps of a broad range of semiconductor and other applications, including mobile and wearable devices, computer servers, storage arrays, imaging equipment, and networking equipment.

[www.poet-technologies.com](http://www.poet-technologies.com)

## Furukawa develops 1060nm VCSEL operating at 25G over 500m of multimode fiber from OFS and Corning Wavelength raised to overcome 200m limit of 850nm VCSELs at 25G

Furukawa Electric Co Ltd of Tokyo, Japan has developed a vertical-cavity surface-emitting laser (VCSEL) that operates at 25Gbps and has realized transmission of up to 500m over prototype multimode fibers developed by optical fiber product maker OFS of Norcross (near Atlanta), GA, USA (which is owned by Furukawa Electric) and Corning Inc.

"Both longer reaches and higher speeds are required for warehouse-scale data centers," says Dr Haruki Ogoshi, senior fellow at Furukawa. "Our customers are raising expectations as they implement next-generation data centers," he adds.

The rapid growth of cloud computing and expansion of 'big data' is causing a dramatic increase in the volume of data handled in data centers, notes Furukawa Electric. This has generated demand for greater throughput in servers, switches and routers in data centers. Increasing the serial speed of transmission of lasers and photo-detectors is one solution. In addition, there is a need to increase transmission distances between devices as data centers become larger. In mega data centers, for example, transmission distances of 300m or longer can be required. Currently, VCSELs emitting at a wavelength of 850nm are widely used for the low-

est-cost optical interconnects. However, it is known that, when the transmission speed is changed from 10Gbps to higher-speed 25Gbps, the transmission distance is limited to less than 200m due to the influence of chromatic dispersion in multimode fibers. To solve these issues, Furukawa has developed a VCSEL with a wavelength of 1060nm that operates at 25Gbps.

"Increasing the VCSEL wavelength from 850nm to 1060nm reduces chromatic dispersion of fibers by approximately two thirds," says Dr Durgesh Vaidya, senior manager Research and Development for OFS. "Accordingly, use of a multimode fiber with the modal dispersion minimized at 1060nm reduces transmission impairments and allows transmission distances to be extended," he adds. "It is widely expected that it will be easier to increase VCSEL speeds in the future beyond 25Gbps by moving from 850nm to higher wavelengths."

Furukawa created a prototype optical module integrating the newly developed 1060nm VCSEL in a small package with a driver integrated circuit and then conducted a transmission experiment close to actual operating conditions. When a multimode fiber from OFS or Corning was used with the modal

dispersion optimized for a wavelength of 1060nm, a long reach of 300m was achieved. In a joint experiment, a short length of modal-dispersion-compensating fiber developed by Corning was used in conjunction with standard OM4 multimode fiber, and a transmission distance of 500m was achieved. These results were obtained without the use of electrical compensation technologies such as a clock data recovery (CDR) or an error correction. In this way, the new VCSEL technology can enable an increase in speed and distance without complicating future systems, reckons Furukawa Electric.

"This collaboration shows that long-wavelength VCSEL technology can meet the demands of next-generation data centers when combined with new, wavelength-optimized fiber, or even standard OM4 fiber with new modal-dispersion-compensation fiber," says Dr Alan F. Evans, research director, Optical Physics and Transmission Technology, Corning.

Details of the experiment were presented at the Optical Fiber Communication conference (OFC 2014) in San Francisco (9–13 March).

[www.furukawa.co.jp/english](http://www.furukawa.co.jp/english)

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

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

## Daylight Solutions awarded ISO 9001:2008 certification

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, has announced ISO 9001:2008 certification for its quality management system. Certification was obtained in early February after completion of an on-site certification audit performed by TUV USA (part of

TUV NORD International).

ISO 9001:2008 is a quality management system standard developed by the International Organization for Standardization, an association of governmental and non-governmental organizations from 161 countries. ISO 9001:2008 is used to certify quality systems that focus on customer satisfaction, continuous improvement, active involvement of top management and employees, and the adoption of a

disciplined process approach. Certification under ISO 9001:2008 helps to ensure that customers benefit from products that are consistently reliable, available and that meet international regulatory standards.

"ISO certification reflects our focus on quality while we continue to drive our manufacturing readiness level (MRL) for defense and life science applications," says president & chief operating officer Paul Larson.

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

# IQE's VCSEL epiwafers enable IBM/Chalmers to achieve record 64Gb/s over multimode fiber

## High-capacity servers, data-centers and supercomputers targeted

IQE plc of Cardiff, Wales, UK says that its vertical-cavity surface-emitting laser (VCSEL) epiwafer technology has been used to develop high-performance optical links, as reported by IBM and Sweden's Chalmers University of Technology in paper Th3C.2 at the Optical Fiber Communications conference (OFC) in San Francisco (11–13 March).

As data transmission rates across optical interconnects continue to increase, from today's 25–28Gb/s to next generation interconnects with speeds in excess of 50Gb/s, there is

a need for step-change performance improvements in the optoelectronics and electronics hardware that support this technology, says IQE.

VCSELs provide the primary light source for optical interconnects and are now in production for high-capacity interconnect cables in data-centers and high-performance computing systems.

Recent work by IBM and Chalmers used IQE's VCSEL wafers to achieve a record speed of 64Gb/s. Data was transmitted over 57m of multimode optical fiber.

The VCSEL epiwafer material was provided by IQE's Photonics division in Cardiff. The VCSEL device was developed and fabricated at Chalmers and the full interconnect (including drive and receive circuitry) was produced, assembled and tested at IBM.

IQE says that the interconnect performance reveals the full potential of the VCSEL devices enabled by the epitaxial material.

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

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

[www.chalmers.se](http://www.chalmers.se)

## IQE delivers first 150mm VCSEL epiwafers for high-volume, low-cost applications

IQE has delivered what it says is the world's first 150mm (6") VCSEL epiwafer process for high-volume, low-cost applications.

Markets for VCSELs are proliferating rapidly as this type of laser is becoming the device of choice for many high-volume applications, says IQE, including:

- gesture recognition, for gaming and non-contact navigation (e.g. TV, smartphone, tablet);
- depth imaging for 3D vision, driving the next wave of handset innovation for must-have new phones;
- low-energy optical storage and fast switching in high-capacity data centers, servers and ultra-high-speed computing;
- high-speed datacoms, including active optical cables (AOCs);
- ultra-high-density magnetic storage using heat-assisted magnetic recording (HAMR);
- illumination for infrared cameras for security, safety, night-vision;
- industrial heating, including paint curing and commercial print shops;
- cosmetics and healthcare, including hair removal, antiwrinkle, blemish reduction.

A number of these applications

require multi-element array configurations that use greater surface areas and therefore more epiwafer material. They also offer higher optical power output compared with discrete devices.

Many of these markets are price elastic, and by moving to 150mm wafers — compatible with existing well established, state-of-the-art RF GaAs wafer processing lines — high-performance VCSELs can be manufactured in large volume using fabrication and testing techniques similar to those of LEDs, says IQE.

This combination will provide a high-volume manufacturing technology and capability to help drive down the cost of VCSEL-based photonics products for deployment in mass market, consumer applications, adds the firm.

The significantly improved cost structure will allow designers to utilize the unique operational and performance advantages of laser devices to further develop advanced sensing applications which are expected to drive the next wave of innovation in consumer products such as cell phones, tablets and other hand-held devices, reckons IQE.

Initial engineering evaluation and product qualification wafers have already been delivered and initial performances have replicated those of existing smaller wafer sizes. Production is expected to ramp over the coming year.

"VCSEL-enabled products such as gesture recognition and 'time of flight' sensing are expected to ramp significantly over the coming period as they become incorporated into next-generation handset and mobile communication devices, as well as a myriad of other high-volume applications," notes CEO Dr Drew Nelson. "By introducing our new 150mm VCSEL epiwafer process, which is compatible with existing high-volume RF GaAs chip processing lines, we are enabling a new low-cost manufacturing route for high-performance laser devices," he adds. "IQE has built a powerful technology platform for VCSELs, and recent announcements on record low-power-consumption VCSELs for datacenters and record high-speed data transmission with IBM for datacenter, servers and supercomputers are testament to the strength and depth of this platform."

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

## UCSB uses IQE's large-scale MBE to develop 1.3µm quantum dot lasers on silicon substrates

### Silicon photonics integration targets low-cost, high-volume datacoms

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that its epitaxial wafer technology has been used in conjunction with the University of California Santa Barbara (UCSB) to help develop 1.3µm-emitting quantum dot (QD) lasers on silicon substrates. The aim is to enable the integration of photonics devices with silicon technology for low-cost, high-volume data communication applications.

Silicon photonics, which combines compound semiconductor devices with low-cost silicon substrates, offers the potential to integrate sophisticated laser devices with more traditional low-cost CMOS driver and waveguide technology.

The researchers believe this work represents an important step towards large-scale photonic integration in an ultra-low-cost platform for high-volume consumer applications which will lead to the mass adoption of silicon photonics.

A key feature in enabling the cost-effective integration of photonic devices with silicon technology is the ability to grow compound semiconductor quantum dots onto silicon substrates using molecular beam epitaxy (MBE) growth technology that has a proven track record for high-volume manufacturing of wireless products.

Researchers at UCSB demonstrated a novel quantum dot laser design that not only is grown on sil-

icon but also performs as well as similar lasers grown on their native substrates.

IQE provided both the engineered germanium/silicon substrates and the III-V MBE template growth. The growth of the quantum dot laser structure and fabrication of the laser components were performed at UCSB.

The UCSB team discussed its record-breaking results in presentation W4C.5 'High Performance 1.3µm InAs Quantum Dot Lasers Epitaxially Grown on Silicon' at the Optical Fiber Communications conference (OFC 2014) in San Francisco (9–13 March).

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

<http://engineering.ucsb.edu>

## MACOM's crosspoint switches and signal conditioners and Avago's VCSEL MicroPOD modules demonstrate optoelectronic switching for 10 Gigabit Ethernet

At the Optical Fiber Communication event (OFC 2014) in San Francisco (11–13 March), M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) and Avago Technologies Ltd of San Jose, CA, USA and Singapore (a designer and supplier of III-V-based analog components for communications, industrial and consumer applications) gave a collaborative demonstration of a high-density 10Gbps Ethernet optoelectronic switching solution targeting enterprise and data-center applications. The demonstration showcased 12-channel 10Gbps traffic running over a 100m optical fiber cable switched through a 48-port low-latency cross-point device.

With rapid growth of data centers and a need for low-latency data-center configurability at the circuit

level, a combination of MACOM's cross-point switches and signal conditioners combined with Avago's optical transceivers delivers high-density and low-latency optoelectronic switching with signal regeneration and monitoring capabilities. MACOM has developed a portfolio of high-port-count cross-point switches and signal conditioners to address this need. The demonstration is achieved using MACOM's M31517 multi-port signal conditioner and M21048 48x48 11.88Gb/s cross-point switch and Avago's Micro POD 120G transmitter and receiver modules as well as 100m optical fiber cable.

"Increasing physical size of data centers combined with increasing support for cloud computing applications drives the need for long-reach optical connectivity and low-latency circuit switching," says MACOM's director of marketing Marek Tlalka. "The combination of

Avago's optical transceivers with MACOM's cross-point switches enables this capability as a complement to traditional packet switching solutions," he adds.

"As the size of data centers increases, we expect these embedded parallel optic modules as well as Avago's pluggable modules to continue to play an important role in data centers," says Sharon Hall, segment marketing manager for Fiber Optics Product Division at Avago. "The MicroPOD is an ideal low-power, small-form-factor device which can be leveraged across many switching platforms, enabling high-density 10Gbps Ethernet links."

MACOM's M21048 and M31517 devices are available now. Avago's MicroPOD and MiniPOD optical modules are in volume production.

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

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

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

# MACOM launches first monolithically integrated EML driver and CDR

## Four-channel integrated device for 100G claims lowest power consumption and smallest footprint

At the Optical Fiber Communication event (OFC 2014) in San Francisco (11–13 March), M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) launched what is claims is the first 100Gbps (4x28Gbps) electro-absorption modulated laser (EML) driver monolithically integrated with clock & data recovery (CDR) functions.

High-density front-panel networking applications utilizing small-form-factor pluggable modules require dramatic reductions in component power consumption and footprint, says the firm. MACOM's new M37047 four-channel device supports data rates required for multiple standards, including 100G Ethernet, enhanced data rate (EDR) InfiniBand, 32G Fibre Channel and Optical Transport Network (OTU-4).

By integrating laser drivers with MACOM's low-power CDRs, the device achieves what is reckoned to be the industry's lowest power

consumption and smallest footprint. It is optimized for transmitter functions in optical modules and allows users to complement the already available M37046 CDR device, which is optimized for receiver functions. Both devices are packaged in 4mm x 4.5mm form factors, making them a suitable chip-set solution for small-form-factor optical modules.

The new M37047 device expands on MACOM's family of signal conditioners, cross-point switches and physical media devices (PMDs) for networking and enterprise solutions.

"The transition of network connectivity to 100Gbps, combined with the need for high-density front-panel optics, drives the need for optical modules such as the CFP-4 and QSFP28," comments Beck Mason, vice president of R&D for optoelectronic chip and module maker JDSU of Milpitas, CA, USA.

"To enable these small-form-factor optics, semiconductor suppliers must break through traditional power consumption levels," he adds. "By utilizing their CDR technology

and monolithically integrating it with laser drivers, MACOM has been able to deliver a low-power device needed by JDSU to enable a 100GBASE-LR4 CFP4 optical module." JDSU partnered with MACOM and demonstrated a CFP4 module.

"Our new integrated CDR with laser driver further expands our product portfolio addressing 100Gbps optical interconnect applications," notes Hasnain Bajwa, senior VP & general manager, High Performance Analog, at MACOM. "The integration enables us to deliver low power demanded by our customers while reducing footprint, making our solution ideal for small-form-factor optical modules."

MACOM's M37047 is sampling exclusively to development partners, and will become available for sampling to the general market in second-half 2014. It was showcased in MACOM's booth and as part of JDSU's CFP-4 demonstration at OFC.

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

## MACOM launches low-power quad-channel 28Gbps laser drivers for 100GbE CFP2, CFP4 and QSFP28 modules

MACOM has announced additions to its portfolio of drivers for 100 Gigabit Ethernet (100GbE).

The MAOM-003401 is a quad-channel 28Gbps electro-absorption modulator laser (EML) driver that can deliver up to 1.6Vpp single-ended output while dissipating less than 230mW of power per channel. When paired with MACOM's M37049 quad-channel clock & data recovery (CDR) IC, it provides what is claimed to be the lowest-power and smallest-form-factor solution on the market for CFP2 and CFP4 transceivers. A demonstration of the full optical

transmitter line-up with CDR, driver and TOSA (transmitter optical subassembly) were on display at the Optical Fiber Communication event (OFC 2014) in San Francisco (11–13 March).

The MAOM-002304 is a quad-channel 28Gbps direct modulated laser (DML) driver that can deliver up to 70mA of laser bias current and 60mA of modulation current with less than 240mW of power dissipation per channel. The single-die solution can be integrated in a TOSA and directly DC coupled to the laser, minimizing losses and maximizing efficiency. The device

can also be paired with the M37049 low-power CDR to meet the stringent power requirements of QSFP28 modules.

"MACOM can continue to push the limits on power dissipation with these new products," says Optoelectronics product line manager Ray Moroney. "With the addition of CDRs and TIAs [transimpedance amplifiers] from former Mindspeed [acquired earlier this year], MACOM can continue to innovate and integrate to provide optimized solutions."

Samples of the MAOM-003401 and MAOM-002304 are available now.

# MACOM introduces low-power 4x28G TIAs

At OFC 2014, MACOM launched its latest family of ultra-low-power 4x28G transimpedance amplifiers (TIAs), which support data rates from 10.3Gbps to 28Gbps.

The devices have ultra-low power dissipation from a 3.3V supply and claim best-in-class sensitivity in a small bare-die layout, suiting high-density optical module applications. Four different versions include the discrete channel M03002 and array channel M03100, M03101 and M03102 (with input pitch sizes of 250µm, 500µm and 750µm, respectively), offering flexibility for various optical modules and interconnect applications.

The additions to the TIA product line complement MACOM's growing 100G product portfolio, which consists of what is claimed to be the industry's lowest-power 4x28G laser driver and clock & data recovery devices (CDRs). The new TIAs

improve optical sensitivity and dynamic range while adding key features such as an individual photodiode average receive current indicator and on-chip decoupling capacitors, reducing the overall cost of optical subassemblies.

"The TIA solution offered by MACOM is a critical component enabling low module power dissipation in next-generation 100G modules," says Sheng Zhang, chief scientist at optical communication product maker Source Photonics Inc of Chatsworth, CA, USA. "By combining Source Photonics' advanced optics with MACOM's high-performance TIA solutions, we will be able to address the demanding 100G module requirements."

The M03002, M03100, M03101 and M03102 can be used in conjunction with the M37040 and M37046 4x28G receive CDRs to form a

complete ultra-low-power 100G module receiver chipset solutions. "We continue to expand our optical PMD [physical media device] product offering as a trusted source for 100G CFP2, CFP4 and QSFP modules," says Angus Lai, product marketing director, High Performance Analog. "Our newest family of TIAs offers superior sensitivity and ultra-low power dissipation. Along with our highly integrated 4x28G CDRs, they enable the best-in-class 100G module solutions," he claims.

MACOM highlighted the new TIAs alongside established PMD solutions that are now part of its portfolio after this year acquiring Mindspeed Technologies Inc of Newport Beach, CA, USA (which designs network infrastructure semiconductors for communications applications).

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

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

## MACOM adds quad-channel modulator drivers for long-haul 100, 200 & 400G and metro 100G CFP & CFP2 coherent modules

At OFC 2014, MACOM announced the newest additions to its portfolio of modulator drivers for line-side applications at 100G and beyond.

The MAOM-003406 and -003408 are quad-channel 32Gbps modulator drivers in small-form-factor surface-mount packages. They are designed to operate with the latest surface-mount lithium niobate optical modulators, enabling the next generation of OIF transponders in the 4"x5" form factor. The new products expand on MACOM's portfolio of single- and dual-channel surface-mount drivers and quad-channel GPPO modules, which are shipping in volume in first-generation 100G systems.

The MAOM-003406 is a limiting driver that can deliver up to 7.2V<sub>pp</sub> output voltage. The 003408 is a linear driver with up to 6V<sub>pp</sub> linear output voltage. Both have differential inputs to minimize cross-talk and to optimize the interface to the digital-to-analog convertor (DAC)

on linear systems. The single-ended outputs are designed to interface directly to the modulator inputs with minimal parasitics. The drivers are integrated in 13mm x 19mm surface-mount packages and are pin compatible to enable a common board design across system platforms.

"MACOM can now claim the broadest portfolio of modulator drivers for coherent applications, with solutions for all data rates, modulator types and module form factors," claims Ray Moroney, product line manager for Optoelectronics.

MACOM also launched additions to its modulator driver family for metro applications at 100G and beyond.

The MAOM-003407 and -003409 are linear quad-channel 32Gbps modulator drivers in small-form-factor surface-mount packages. MACOM now offers a complete portfolio for metro applications covering limiting and linear systems using a single-ended or differential modulator.

The 003409 is a fully differential, quad-channel linear driver delivering up to 4V<sub>pp</sub> linear output. It is pin compatible with the MAOM-003404 limiting driver (launched in September) to enable a common board design across system platforms. Both parts are optimized for use with available InP and silicon optical modulators requiring differential drive voltages, and provide what is said to be the lowest-power and smallest-form-factor driver for coherent CFP and CFP2 modules.

The 003407 is a quad-channel linear driver with differential input and single-ended output for use with InP and lithium niobate optical modulators requiring single-ended drive voltages. The linear driver is pin-to-pin compatible with the MAOM-003405 for limiting applications (launched in January). Both parts offer ultra-low power dissipation and are also suitable for coherent CFP and CFP2 modules.

Samples are available now.

## MACOM showcases expanded portfolio of 100G products at OFC, including CDRs, TIAs and laser drivers

At the Optical Fiber Communication (OFC 2014) event in San Francisco (11–13 March), M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) showcased a complete portfolio of CDRs (clock data recovery ICs), TIAs (transimpedance amplifiers) and laser drivers for 100G applications

and beyond. Leveraging a combination of semiconductor technologies, MACOM creates solutions that cover the data-center, client access, metro and long-haul applications.

The products on show included:

- low-power 100G chipset solutions for CFP2/4 and QSFP28;
- the latest modulator drivers for coherent applications at 100G and beyond (including the lowest-power solutions for metro CFP and CFP2);

- a low-power 10G complete chipset for SFP+/XFP MSA modules;
- the latest-generation Gigabit passive optical networks (GPON) ONU/OLT (optical network unit/optical line terminal) complete chipset solutions, and
- the next generation of 10G-EPON (10 Gigabit Ethernet PON) and XG-PON1 (next-generation GPON) ONU/OLT chipset solutions.

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

## GigOptix launches TIA receivers enabling high-resolution natural user interfaces for consumer electronics

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has launched a family of transimpedance amplifier (TIA) products to address high-growth natural user interfaces and high-resolution 3D scanning markets.

"The new generation of high-speed gesture recognition, motion sensing, and natural user interface in 3D camera, interactive TVs, game consoles and a variety of other emerging applications are creating demand for the deployment of high-depth-resolution optical links in several high-volume markets," says Dr Raluca Dinu, VP & general manager of the High-Speed Communications division. "For example, for the natural user interface applications, there are many kinds of gesture systems competing in the market right now, with time-of-flight systems providing a very good alternative for high-accuracy applications," he adds. "GigOptix's consumer TIAs are designed specifically to address time-of-flight applications and flexible architecture that allow a rapid, yet robust, customization designs. From changing channels and adjusting volume on interactive TVs

with the wave of a hand, to full-body 3D depth-sensing cameras for a fully immersive gaming and personalized shopping experiences, GigOptix's TIAs provide high sensitivity and high signal-to-noise for increased accuracy and range."

In January, market research firm NPD DisplaySearch reported in its 'Gesture Sensing Control for Smart Devices Report' that gesture sensing solutions for smart device shipments would grow from less than 250 million units in 2014 to more than 1.8 billion units in 2018. Year-on-year shipment growth is projected to be over 40% in the 2015–2018 timeframe. 3D gesture-sensing technologies in connected smart devices identified in the report include mobile devices, smart TVs, game consoles, and PCs.

GigOptix's consumer TIA platform can be optimized for the following applications: high-resolution digital 3D scanning, hands-free automotive infotainment and range systems, immersive gaming and augmented reality, interactive TVs, desktop PCs, notebooks, gaming consoles, smartphones, tablets, and motion tracking and gesture control.

Global automotive proximity and gesture recognition of infotainment systems are estimated to grow

from about 0.7 million units in 2013 to more than 38 million units in 2023, according to IHS Inc's report 'Emerging Technologies: New Human-Machine Interface Trends'. A few automotive makers have already sold in 2012 cars with basic proximity recognition systems in them, and the report predicts that in 2017 the first high-resolution systems will appear. It further estimates that nearly 40% of all new automobiles sold worldwide in 2023 will come with some degree of proximity or gesture recognition.

"Many high-resolution time-of-flight systems are fundamentally limited by the performance of key building blocks, in particular the TIA performance," notes Dinu. "GigOptix's TIA family builds on years of experience in designing TIAs for active optical cables (AOCs) and pluggables for datacom markets and delivering millions of such devices. This deep experience enables us to design and ship extremely high-quality amplifiers to the emerging consumer electronics market," he claims. "We look forward to working with customers to enable customization of TIA devices for the next generation of innovative natural user interface systems."

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

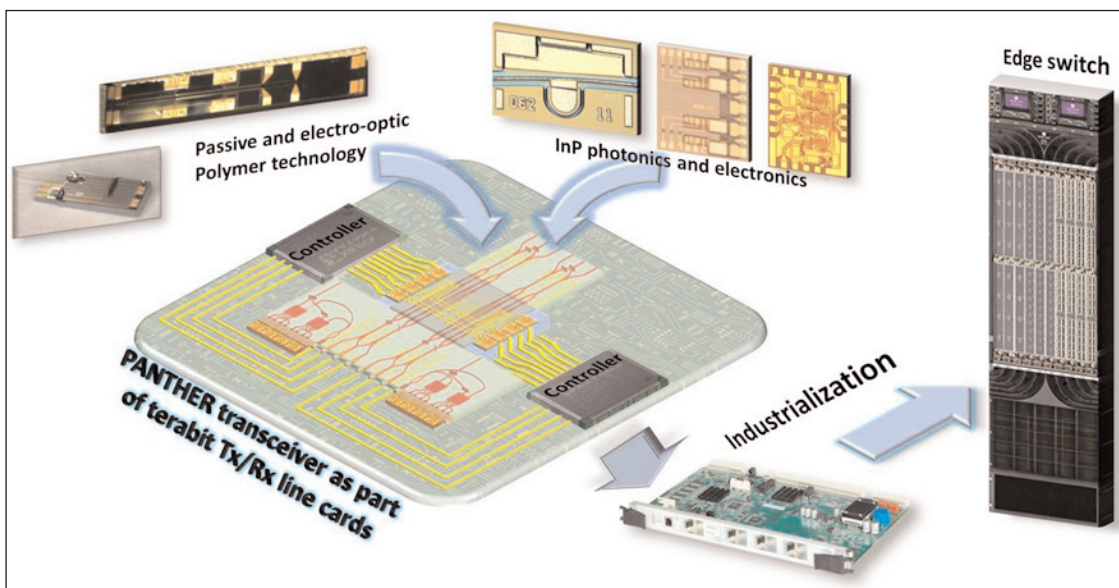
# GigOptix participating in PANTHER project on multi-flow Terabit transceiver for edge SDN switches & data-centers

## TFPS Mach–Zehnder modulator and 100G coherent linear driver contributing to polymer/InP technology

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has announced its participation in the research project PANTHER (Passive and Electro-optic Polymer Photonics and InP Electronic Integration for Multi-Flow Terabit Transceivers at Edge SDN Switches and Data-Center), which is funded in part by the Seventh Framework Programme (FP7), Information and Communication Technologies (ICT) of the European Commission (EC).

PANTHER aims to develop programmable transceivers with Terabit capacity for next-generation optical networks. The project aims to combine electro-optic with passive polymers for ultrahigh-speed modulation and enhanced on-chip functionality. It will also integrate the polymer platform with indium phosphide (InP) gain chips and InP photodiode arrays. For the driving electronics it will use InP double-heterostructure bipolar transistor (DHBT) technology. Finally, PANTHER will use 3D integration techniques to package these components in system-in-package transceivers, capable of 64 Gbaud operations with formats up to DP-64-QAM and flexibility in handling multiple optical flows on-chip.

The project's total budget is €5,355,744, including €3,369,926 from the EC. The project started officially on 1 January and will run for three years. Headed by the National Technical University of Athens (GR), the consortium comprises GigOptix' subsidiary



**Architecture and assembly of Terabit transceiver modules in PANTHER project.**

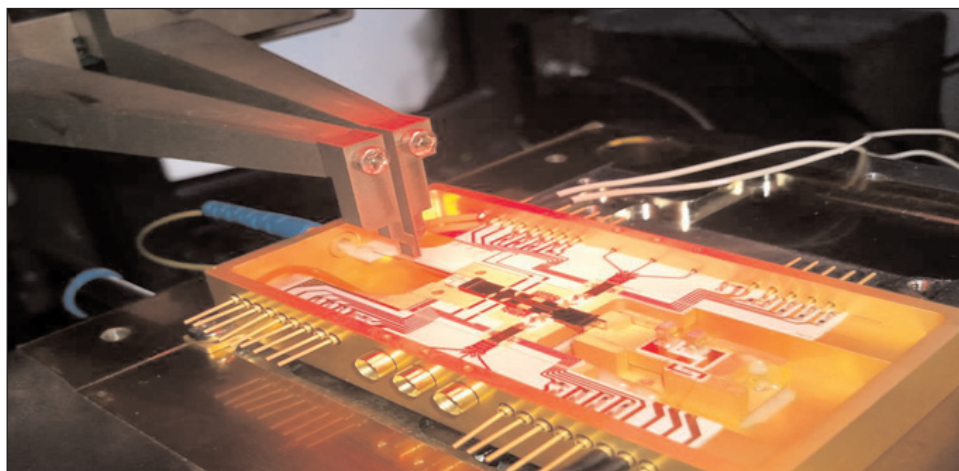
GigOptix-Helix AG in Zurich, Switzerland, III-V Lab (the joint Alcatel-Lucent, Thales and CEA-Leti industrial research lab) in France, the Fraunhofer Heinrich Hertz Institute (HHI) in Berlin, Germany, Alcatel-Lucent Bell Labs France, Linkra S.R.L. in Italy, the Danmarks Tekniske Universitet, and Telecom Italia S.p.A.

"A successful PANTHER program will represent a meaningful contribution to technology development in the field of telecommunications, and is in line with GigOptix product development roadmaps addressing

the ever growing demand for ultrahigh-capacity coherent transmission systems," believes Dr Raluca Dinu, GigOptix VP & general manager High Speed Communications products.

GigOptix's ultrahigh-speed Thin-Film-Polymer-on-Silicon (TFPS) Mach–Zehnder modulator (MZM) and 100Gbps coherent linear MZM driver (the technology parts contributing to the PANTHER project) were demonstrated at March's Optical Fiber Communication conference (OFC) in San Francisco.

[www.ict-panther.eu](http://www.ict-panther.eu)  
[www.gigoptix.com](http://www.gigoptix.com)



## Source Photonics introduces first 100G LR4 transceiver in QSFP28 form factor for data-center application

Optical communication product maker Source Photonics Inc of Chatsworth, CA, USA has announced what it claims is the first 100Gb/s LR4 optical transceiver in the compact QSFP28 form factor.

Based on the IEEE 100GBASE-LR4 standard, the transceiver demonstrates typical power consumption of 3.5W and delivers 100G capability with 40% lower power consumption compared with the industry-best CFP4 form factor, it is reckoned.

The transceiver offers data-center operators the capability to support connections between rack switches and the core of the network using 100G data-rate technology and provides 150% increased face-plate

bandwidth density compared to 40G QSFP solutions, the firm adds. The QSFP28 form factor also allows for up to 48 modules per standard face plate, compared to only 12 with currently available 100G CFP2 products. Source Photonics says that its new transceiver is suitable for existing large data-centers with increasing link distance requirements and to future-proof single-mode fiber installations.

Building on a track-record of developing and supplying pluggable transceiver products to the telecom, datacom, enterprise and mobile markets, Source Photonics is offering a vertically integrated solution employing internally devel-

oped and manufactured key technology, including the high-bandwidth laser sources and novel optical sub-assembly technologies enabling what is claimed to be industry-leading power consumption in a scalable and cost-effective design.

Source Photonics is currently working closely with system-level partners to optimize performance in preparation for sampling in mid-2014.

Source Photonics demonstrated its 100G QSFP28 LR4 transceiver at the Optical Fiber Communication event (OFC 2014) in San Francisco (11–13 March).

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

## Skorpios demonstrates 100G QSFP28 transceiver; launches micro-ITLA tunable laser

At the Optical Fiber Communication event (OFC 2014) in San Francisco (9–13 March), fabless integrated silicon photonics system-on-a chip company Skorpios Technologies Inc of Albuquerque, NM, USA demonstrated a 100G QSFP28 transceiver in which, utilizing Skorpios' template assisted bonding (STAB) process, the lasers, modulators, detectors and optical multiplexer/de-multiplexer are monolithically integrated into a single die, providing cost, size and power benefits unachievable with any alternative technologies, it is claimed.

"With our unique integration approach, we can build solutions such as this product, which meet the increasing challenges of bandwidth growth within data centers," says Alfredo Viglienzoni, senior VP sales, marketing & business development. "This is particularly attractive for those customers who have to operate within fixed infrastructure constraints to minimize capex," he adds.

"The Skorpios QSFP28 underscores our ability to integrate higher-level module solutions based on our STAB process," comments Glenn Li, VP engineering, Enterprise. "It operates without active cooling, and has a reach of up to 10km, making it ideal for the mega-scale architectures which are emerging to support cutting-edge services," he adds. "This product represents our first step towards multi-Tb/s interconnect bandwidth with small footprint, low power consumption, and low cost. Our high-speed WDM solutions enable bandwidth increase by better utilizing and without altering the existing cabling structure, thus offering a low-barrier, future-proof upgrade path."

Also at OFC, Skorpios is demonstrating a new micro-ITLA tunable laser utilizing its STAB process. The laser was designed to meet the stringent demands of next-generation high-bandwidth coherent 100G transceivers, with linewidths of less than 100kHz, low optical noise,

high power and high stability.

"Launching our micro-ITLA is an important inflection point for Skorpios," says John Zyskind, VP engineering. "Not only have we productized one of the hardest types of laser to develop, but we have initiated production based on our STAB platform, where we integrate a small amount of heterogeneous material using a wafer-scale process within a commercial CMOS fab. This gives us a very attractive cost structure, as well as high reliability because the device is natively hermetic. The Skorpios micro-ITLA will be used as a springboard into more highly integrated devices with a wide range of applications," he adds.

"Using Skorpios' micro-ITLA, customers are able to deploy coherent modules and transceivers, which have a significantly lower cost and power consumption than are achievable with current technologies," says Rob Stone, VP of marketing.

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

# OIF completes three implementation agreements for 100G electrical interfaces; starts project for 400G

Optical Internetworking Forum (OIF) members have approved revision 3.1 of the Common Electrical Interface (CEI) implementation agreement (IA) document, which specifies the electrical characteristics of transmitters, receivers and channels for interface speeds up to 28Gb/s. The latest revision of the IA is key to addressing the challenges of 100G technology and includes two new clauses defining additional CEI-28G interfaces that are currently being implemented in products by suppliers.

"The OIF has focused on keeping the CEI IA up-to-date and forward looking," says OIF Physical and Link Layer working group chair & board member David Stauffer of Kandou Bus S.A. of Lausanne, Switzerland and Northampton Science Park, UK (a semiconductor firm that designs serial links, SerDes and associated technologies). "These new interface definitions are important as the industry is currently deploying 100G applications and needs to continually support faster and more cost-effective electrical interfaces to optical components."

CEI-28G-VSR specifies a chip-to-module electrical interface for the range 19.6–28.1Gs/s, with up to 10dB of loss and a single connector. This clause of the IA defines the characteristics required to communicate between an optical module and a host chip and meet interoperability requirements at the module connector. CEI-28G-VSR is the definitive module interconnection for the 28G generation and has been implemented by several optical module products.

CEI-28G-MR defines requirements for a chip-to-chip medium-reach high-speed electrical interface between nominal baud rates of 19.90Gs/s and 28.1Gs/s with 20dB of loss. Past work from the OIF found the need for a specifi-

cation optimized for medium-reach, shorter-length backplane channels with lower loss. Transmitters and receivers optimized to meet CEI-28G-MR and used in medium-reach applications will offer power advantages over components designed for higher-loss backplanes. The CEI-28G-MR signals the completion of the 28G IAs.

New project and workshop seek to develop 56Gb/s requirements

The OIF is working on several electrical 56Gb/s specifications that will enable higher-density 100 and 400Gb/s systems. These specifications will be suitable for use in both chip-to-module and chip-to-chip applications and are expected to play a key role in enabling the next generation of many different high-speed systems. The new project (started during the first-quarter meeting) will address medium-reach applications and is in addition to 56Gb/s projects started for short-reach interface applications.

Also at the quarterly meeting, the OIF conducted a workshop on 56G that tackled next-generation electrical link technology to support 400G. This workshop cultivated input from industry leaders on where 56G is heading and how to address the next-generation applications. The OIF says it will continue to seek industry input as necessary for the success of 400G standards. It is anticipated that 400Gb/s interfaces will require denser electrical links than current 28Gb/s serial link technology.

Other developments from the quarterly meeting include elections for 2-year terms of Kandou's Dave Stauffer as the OIF Physical and Link Layer Working Group chair and Ed Frlan of Semtech as the OIF Physical and Link Layer Interoperability Working Group chair.

[www.oiforum.com/public/documents/OIF\\_CEI\\_03.1.pdf](http://www.oiforum.com/public/documents/OIF_CEI_03.1.pdf)

## IN BRIEF

### Broadcom exec for NeoPhotonics' board

NeoPhotonics Corp of San Jose, CA, a vertically integrated manufacturer of both InP and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems, has appointed Dr Rajiv Ramaswami to its board.

Ramaswami is Broadcom's executive VP & general manager of the Infrastructure & Networking Group, responsible for Ethernet controller, switching and physical layer products, optical solutions, storage products, and security and embedded processors.

From 2002 to 2010, Ramaswami served as VP & general manager for a variety of business units in optical, switching and storage networking at Cisco Systems, most recently as general manager of the Cloud Services and Switching Technology Group. Prior to Cisco, he served in various technical and leadership positions at Xros, Tellabs and IBM's Thomas J. Watson Research Center.

"I know NeoPhotonics quite well from serving on their technical advisory board for the past four years," says Ramaswami.

"Advances in PIC technology have enabled it to become a leading provider of integrated components for coherent and other high-speed network applications. Given trends in wireless and wireline networks, and in data-center and enterprise networking requirements... The need will only grow for this type of core technology, and lead to further advances in systems features and benefits," he adds.

"Rajiv has a tremendous amount of experience in technology strategy and telecom networking," says CEO & chairman Tim Jenks. "His achievements and insights for business expansion in these areas can bring an important new dimension to our board."

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

# Oclaro's OFC product line-up features 100G solutions with higher densities, lower power and smaller form factors

For the Optical Fiber Communication (OFC 2014) conference & exposition in San Francisco (11-13 March), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) gave product demonstrations and announcements leveraging its core competencies in lasers, photonic integration and advanced packaging. Delivering what is said to be higher performance, increased densities, lower power dissipation and smaller form factors, Oclaro says that the product line-up provides the innovation needed to deploy high-speed optical networks that can handle the demand for new and fast-growing applications such as social networking, cloud computing and video streaming.

"Oclaro continues to focus its product development efforts on the high-growth, high-speed segments of the optical network markets, with a special emphasis on 100G technology where we can leverage our expertise to drive higher densities, lower power, smaller form factors and increased performance," says Jim Haynes, president of Oclaro's Integrated Photonics Business.

**Coherent CFP2 pluggable module**  
Oclaro demonstrated a coherent CFP2 pluggable module that, with a compact form factor and power dissipation of only 12 Watts, delivers what are claimed to be new levels of performance and flexibility for optical networks operating at 100G and beyond.

The coherent CFP2 module represents the first generation of coherent transceivers offered in a pluggable format and delivers the small form factor, low power dissipation and high performance needed to upgrade systems to 100G and beyond, says Oclaro. The coherent CFP2 can be deployed with a range of external digital signal processor (DSP) options, allowing selection of the optimal

combination of optical and electronic solutions for specific applications.

## **New tunable 10G wideband SPF+ module**

Building on Oclaro's history of 10G DWDM products, the firm also demonstrated a new tunable SFP+ module utilizing the firm's next-generation high-efficiency indium phosphide (InP) tunable laser platform. The tunable SFP+ leverages a re-designed compact monolithically integrated laser Mach-Zehnder (ILMZ) chip, is fully compliant with the SFP MSA (multi-source agreement) form factor, and operates at 1.5W at 70°C with what is claimed to be excellent optical signal-to-noise ratio (OSNR) performance.

Oclaro will also demonstrate a tunable SFP+ module operating up to 85°C that will enable higher-density line-card solutions in the future when cooling capacity for users is expected to be even more challenging.

## **Micro-iTLA with Flex Grid**

Oclaro also says that it has qualified and is ramping production of its second-generation LambdaFlex micro-iTLA TL5350 with flexible grid operation. As a provider in tunable products for transmission systems, the new Micro-iTLA TL5350 builds on the legacy of Oclaro's InP portfolio. Key features include:

- advanced locker technology to enable the user to set the optical carrier to any optical frequency in the C-band with 0.2GHz channel-setting resolution;

- optical output power of 15.5dBm at less than 4.5W of power dissipation;

- designed to the OIF multi-source agreement;

- 3x smaller form factor than a standard iTLA with significantly reduced power consumption; and

- high optical output power combined with power and frequency fine tuning to give greater flexibility to network designers.

## **CFP2 ER4 demonstration**

Oclaro claims that, at OFC, it was the first firm to showcase a working demonstration between 25G EML (electro-absorption modulated laser) light sources and 25G APD (avalanche photodiode) arrays for 100G CFP2 ER4-Lite applications, enabling error-free operation over 40km of single-mode fiber (SMF). The availability of a CFP4 ER4-Lite application will enable users to transition to access networks where longer reach is required, says Oclaro. Key product highlights include:

- expands product portfolio of multi-rate Ethernet and OTN-compatible 100G transceivers by extending reach coverage from 10km up to 40km while maintaining low power consumption and low cost;

- enables intermediate reach of 100G connections up to 40km within core/metro/access networks; and
- provides better solution in terms of long-term 100G form-factor roadmaps compared with existing PIN-PD + SOA implementations, which require more power consumption and cost due to additional SOAs (semiconductor optical amplifiers).

## **Technical papers and presentations at OFC**

At OFC, Oclaro presented nine technical papers on topics such as CFP2, advanced packaging design, and tunable lasers. The firm also participated in a Market Watch panel on coherent pluggable modules for 100G and 200G.

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

## Oclaro unveils 10G wideband tunable SFP+ module based on new InP laser platform, consuming under 1.5W at high operating temperature

At the Optical Fiber Communication (OFC 2014) conference & exposition in San Francisco (11–13 March), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) demonstrated a tunable SFP+ module based on a new InP tunable laser platform.

Building on Oclaro's history of 10G tunable DWDM products, the new tunable SFP+ module is based on the latest version of a compact monolithically integrated laser Mach–Zehnder (ILMZ) chip, enabling the module to achieve what is claimed to be leading-edge optical signal-to-noise ratio (OSNR) performance while providing about 60% reduced power consumption and 50% smaller form factor than existing tunable XFP offerings.

Tunable across the full C-band (with 96 channels on the ITU-T 50GHz grid) and enabling multi-rate operation at 9.95–11.3Gb/s, Oclaro says that the new tunable SFP+ module is a key building block for next-generation data-center, metro and regional optical network equipment because it can reduce the size and power consumption for 10G connections while supporting the network operators' rapidly increasing capacity needs driven by data-heavy network applications.

First-generation tunable SFP+ modules were not widely adopted because they did not meet the critical requirement of less than 1.5W of power consumption at high operating temperatures without compromising performance when stacking multiple transceivers on high-density line cards. In addition, some of these first-generation products were designed with a non-standard mechanical footprint that allowed for heat dissipation, but did not enable the re-use of existing reference board designs.

Oclaro says that, with its new tunable SFP+ laser design, it has now solved these critical issues through an innovative chip design and the use of next-generation materials that enable the module to be fully compliant to the SFP MSA form factor and operate at 1.5W at 70°C with excellent OSNR tolerance.

"Oclaro has been at the forefront of tunable laser technology advancements with its leading portfolio of iTLAs, 300-pin MSA transponders and pluggable T-XFP transceivers," claims Yves LeMaitre, president of Optical Connectivity Business at Oclaro. "With our new tunable SFP+ module, we've leveraged this expertise to solve the challenges our customers face

when they need high-density cards operating at high temperatures while remaining within the power budget and offering the same level of performance and reliability as previous tunable offerings."

Featuring proprietary laser and modulator control algorithms integrated in the product firmware, the new tunable SFP+ module takes advantage of new materials that improve the performance of digital supermode distributed Bragg reflector (DS-DBR) tunable lasers designed on an InP photonic integration platform. This includes the use of aluminium quaternary active layers embedded into the device structure to significantly reduce power consumption and shrink the size of the laser and modulator chip.

To highlight the tunable laser's ability to deliver reduced power consumption at very high temperatures, during OFC Oclaro is demonstrating the SFP+ module operating up to 85°C, validating the ability of users to develop higher-density line-card solutions in the future, when cooling capacity is expected to be even more challenging.

The new tunable SFP+ module is sampling now. Volume production will be ready in third-quarter 2014.

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

## Windstream deploys Infinera Intelligent Transport Network

Infinera Corp of Sunnyvale, CA, USA say its DTN-X platform, featuring 500Gb/s super-channels, is being deployed across the long-haul express network of Windstream of Little Rock, AK, USA, which provides network communications (including cloud computing and managed services) to businesses nationwide, as it scale its network.

Windstream's network spans 118,000 miles of fiber and 27 data-center locations across the USA, providing cloud communication

needs, in addition to a data, voice and video network that provides 100 Gigabit Ethernet services.

"The DTN-X platform enables us to offer services that result in lower latency for mission-critical applications while providing a network that is even more reliable and enables rapid provisioning of services," says Randy Nicklas, executive VP of engineering & chief technology officer.

"As the proliferation of content-rich and low-latency applications place greater demands for ultra-high band-

width speeds, coupled with advances in optical technologies driving more efficient and cost-effective network infrastructure solutions, carriers deploying state-of-the-art 100G upgrades are well positioned to meet the increasing network capacity requirements and to capitalize on the expected growth in 100GigE services," says Roopashree (Roopa) Honnachari, program manager for Business Services at market research firm Frost & Sullivan.

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

## IN BRIEF

### Telstra upgrading submarine routes

Telstra Global, which supplies managed network services and international data, voice and satellite services, is upgrading key ultra-long-haul submarine cable routes, optimizing capacity and providing scalability and reliability. The Infinera Intelligent Transport Network should enable it to quickly deploy 10G, 40G & 100G Ethernet and OTN services on:

- Telstra Endeavour – a 9124km submarine cable connecting Sydney and Hawaii;
- Telstra's Designated Fibre Pair on the Asia America Gateway (AAG) submarine cable connecting Hawaii and California; and
- Reach North Asia Loop (RNAL), spanning 9000km between Hong Kong, Taiwan, Japan and South Korea.

"Demand for network services in the Asia Pacific region is growing exponentially and the addition of Infinera's DTN-X platform means we will be well placed to meet speed and capacity needs," says Telstra Global's chief operating officer Darrin Webb.

"As global businesses turn to cloud-based offerings, we're seeing increasing demand for reliable, global connectivity," notes Infinera's chief technology officer, co-founder & president Dr David Welch. "With an Infinera Intelligent Network deployed across Endeavour, AAG and RNAL, Telstra can deploy highly reliable, differentiated services to their customers while reducing capital and operating costs through scale, multi-layer convergence and automation," he adds. "Telstra Global's deployment is a great example of how long-haul super-channels with SD FEC [soft-decision forward-error correction] are accelerating the pace of global communities."

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

## Oclaro demonstrates 100G coherent CFP2 pluggable module at OFC

At the Optical Fiber Communication (OFC 2014) conference & exposition in San Francisco (11–13 March), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) will be demonstrating a coherent CFP2 pluggable transceiver module.

Oclaro says that the module's compact, coherent pluggable form factor, with a power dissipation of only 12 Watts, delivers what are claimed to be new levels of performance and flexibility for optical networks operating at 100G and beyond.

The firm claims that, compared to conventional solutions, the coherent CFP2 pluggable transceiver features an unprecedented small form factor to enable increased density at the face-plate, reduced power dissipation, and optimal optical performance. Such advances are considered to be key enablers for delivering next-generation coherent networks that can support the growing demand for cloud computing, streaming video, social networking and other bandwidth intensive applications, Oclaro adds. In addition, the CFP2 pluggable form factor enables users to minimize first installation costs and maintain flexibility to scale networks over time by adding more capacity as needed.

"The availability of coherent CFP2 pluggable modules is going to drive a significant increase in the number of 100G and 200G coherent ports we expect to see in 2015," comments Daryl Inniss, VP & practice leader of Components at Ovum. "The market has been demanding the higher densities, lower power and smaller form factors that are possible with CFP2 coherent technology, and Oclaro has positioned itself well, as the first company to bring this technology to market."

Oclaro says that its coherent CFP2 module represents the first genera-

tion of coherent transceivers offered in a pluggable format and delivers the small form factor, low power dissipation and high performance needed to upgrade systems to 100G and beyond. The coherent CFP2 can be deployed with a range of external digital signal processor (DSP) options, allowing users to select the best combination of optical and electronic solutions to suit a specific application.

Oclaro lists the product highlights as follows:

- Leverages Oclaro's indium phosphide (InP) transmitter and receiver photonic integrated circuit (PIC) technology to deliver increased levels of performance, density and cost requirements.
- Compatible with both 100G PM-QPSK and 200G 16-QAM modulation formats with the appropriate DSP and driver technology.
- Meets performance requirements of metro, regional and long-haul applications.
- System-level performance on a par with conventional lithium niobate technology has been demonstrated in conjunction with several of Oclaro's customers.
- CFP2 form factor delivers maximum face-plate density.
- Provides scalability to enable customers to add more bandwidth as required in the future.
- Supports OIF and CFP MSA (multi-source agreement) standards for coherent CFP2.

The new coherent CFP2 pluggable transceiver module will be sampling to key customers in second-quarter 2014.

At the OFC conference, Oclaro presented several technical papers on coherent CFP2 technology. A complete listing of all of Oclaro's presentations, which include nine technical papers and participation on a Market Watch panel, can be found at:

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

# Oclaro ramps production of dual-rate 100G CFP2 LR4 client-side pluggable transceiver

## Extended-reach APD-based CFP2 demoed, for launch in second-half

Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) says that it is ramping up production capacity of its dual-rate 100G CFP2 LR4 transceiver to respond to the fast market adoption of the smaller form factor.

With about 50% smaller footprint and 30% lower power consumption compared with deployed 100G CFP LR4 transceivers, CFP2-compatible line-cards can immediately double the port density and bandwidth of a high-end core router or optical transport system, says the firm.

Oclaro says that its 100G CFP2 LR4 meets the needs of network operators wanting to simplify their network operation by collapsing multiple network layers while continuing to increase the available bandwidth. These new converged packet-optical networks require the most economical 100G client solutions to interconnect high-end routers to the optical infrastructure, adds the firm.

"Our solution is not only backward compatible with deployed CFP slots, but it also offers the flexibility of dual-rate operation to simplify our customers' system and network design," says Yoshikazu Era, general manager, Oclaro Japan Module

Division. "Furthermore, our roadmap will not stop at CFP2 and we will continue to aggressively invest in laser, receiver and advanced packaging technology to further shrink the size and reduce power consumption of 100G client solutions," he adds.

Oclaro says that, after it made the 100G CFP2 LR4 available to the market in 2013, several tier-1 customers re-designed their client interface line-cards to accommodate the new form factor and expedited product qualification. With most of the design slots reaching general availability in 2014, Oclaro is now expanding its investment in manufacturing and testing capacity to stay ahead of market demand.

Oclaro offers a CFP2 that is fully interoperable with existing CFP transceivers supporting both OTU-4 and 100GbE interfaces. The firm says that the support of 'dual-rate operation' (at both 103.125 and 111.810Gb/s) is critical to users demanding the flexibility to use the product both in native Ethernet and OTN transport environments (fully compliant with IEEE 100G Ethernet 802.3a 100GBASE-LR4 and ITU-T G.959.1 4I1-9D1F standards). As well as being fully compliant with MSA, IEEE and ITU-T specifications,

Oclaro's CFP2 is Telcordia qualified to GR-468. The CFP2 dual-rate operation is made possible by leveraging the efficiency of Oclaro's indium phosphide (InP) distributed feedback laser (DFB) structure. The CFP2 also has an OIF CEI-28G-VSR standard-compliant board interface.

### Extending CFP2 reach to 40km

In addition, at the Optical Fiber Communication (OFC 2014) conference & exposition in San Francisco (11–13 March), Oclaro unveiled a technical solution to further expand the reach of CFP2 up to 40km. By eliminating the power-hungry semiconductor optical amplifier (SOA) used in previous IEEE 100GBASE-ER4 products, power consumption can be drastically reduced to allow for the transition to a smaller form factor such as CFP2, Oclaro says. With the broad adoption of 100G from core networking into access, there is demand for products that can reach beyond the LR4 10km standard. At OFC, Oclaro is demonstrating interoperability between a 100G CFP2 and a 25Gbps avalanche photodiode (APD) receive optical sub-assembly (ROSA) on a 40km transmission link.

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

## Service Electric deploys Infinera Intelligent Transport Network

Cable operator Service Electric Cable TV & Communications has deployed the Infinera DTN platform across its new regional network serving central and northeastern Pennsylvania and Northwestern New Jersey.

Service Electric provides residential and commercial cable and telecoms services to over 125,000 people in Pennsylvania and New Jersey. By deploying the DTN, it can quickly deliver services ranging from 155Mb/s to 100Gb/s, says Infinera. The platform's operational simplicity

allows the existing engineering team to manage the regional network without the need for extra engineering resources, adds the firm.

"We're looking for intelligent solutions that simplify network operations and accelerate new service turn-up. This allows us to focus on growing our business," says Service Electric's president John M. Walson. "With one-time optical layer engineering coupled with intelligent software that automates many provisioning operations that were previously manual, the Infinera

solution allows our engineers to turn up services quickly," he adds.

"The Infinera DTN, enabled by photonic integrated circuits and integrated digital switching, allows operators to add capacity to their network quickly without complicated engineering, and the DTN's reliability means MSO [multi-system operator] engineers can spend more time generating new revenue rather than fixing problems in the network," says Mike Kelly, Infinera's VP of Cable Sales.

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

# NeoPhotonics adds integrated coherent transmitter for 100Gbit/s coherent optical transport; samples small-form-factor narrow-linewidth tunable laser and Type 2 intradyne coherent receiver

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, is adding an integrated coherent transmitter (ICT) to its suite of next-generation small-form-factor PIC-based optical components for 100G coherent transport. The products use photonic integration to reduce the size and power requirements of 100G coherent optics to enable higher port densities on line-cards and in transponders.

The ICT is designed to reduce the size of the transmitter optics for a 100G coherent transport link by a factor of four compared to current approaches. The device combines a narrow-linewidth tunable laser with a dual-polarization QPSK modulator in a single, compact package. The modulator section uses PIC integration to combine multiple elements onto a single chip and consists of four indium phosphide (InP)-based Mach-Zehnder modulators including integrated phase and balance control along with variable optical attenuator (VOA) functionality and monitor photodiodes. The ICT also provides a second optical output port that can be used as the local oscillator for the coherent receiver, reducing the number of lasers required in a coherent line-card or transponder. NeoPhotonics expects to begin sampling the ICT to key customers in mid-2014.

In addition to the ICT, NeoPhotonics offers both narrow-linewidth tunable lasers (NLW-TL) and intradyne coherent receivers (ICR) in standard form factors and has now added small-form-factor ver-

sions of each of these components to its portfolio. These new products build on NeoPhotonics' field-proven PIC technology and take advantage of established, reliable and high-volume manufacturing capability.

The narrow-linewidth, micro-integrable tunable laser assembly (micro-ITLA) utilizes NeoPhotonics' PIC technology, which allows the integration of many active and passive photonic functions within single-chip elements, and is designed to fully support the OIF implementation agreement (OIF-microITLA-01.0). The micro-ITLA is designed to support the high optical output power and the narrow linewidths required for next-generation coherent network architectures, while at the same time lowering the electrical power consumption and reducing the laser footprint on a line-card by more than a factor of three. The micro-ITLA supports off-grid tuning and incorporates a VOA function. NeoPhotonics is currently sampling multiple customers with the micro-ITLA and expects it to enter general availability in second-half 2014.

**The ICT, micro-ITLA and Type 2 ICR allow NeoPhotonics to provide all the optical elements necessary for next-generation systems. Photonic integration is the key to providing the high performance, small size and lower electrical power consumption that are necessary to achieve the line-card densities now required**

NeoPhotonics is also sampling to multiple customers its Type 2 small-form-factor intradyne coherent receiver (Type 2 ICR), which is less than half the size of existing ICRs. Built on the same PIC integration platform as NeoPhotonics' standard Type 1 ICR, the Type 2 ICR is designed to fully support the OIF Implementation Agreement (OIF-DPC-RX-01.2) and incorporates an integrated VOA on the signal path, a monitor photodiode (MPD), and automatic gain control operation (AGC). The RF pins are on 1mm pitch and follow a GSSG format. The versatile device is suited to both single incoming channel and multiple incoming channel applications, says the firm. NeoPhotonics expects the Type 2 ICR to enter general availability in second-half 2014.

The small form factor products are also designed to scale to 200G and 400G applications using higher-order modulation schemes.

Taken together, the ICT, micro-ITLA and Type 2 ICR allow NeoPhotonics to provide all the optical elements necessary for next-generation systems, says chairman & CEO Tim Jenks. "Photonic integration, such as NeoPhotonics possesses, is the key to providing customers with the high performance, small size and lower electrical power consumption that are necessary to achieve the line-card densities that are now required," he adds.

NeoPhotonics exhibited its suite of standard and small-form-factor PIC-based components for 100G coherent line-side applications, along with its 100G client-side CFP and CFP2 transceivers and its next generation transceivers for access networks, at the Optical Fiber Communications exposition (OFC) in San Francisco (11-13 March).

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

# NeoPhotonics samples low-power dual-rate 100G LR4 CFP2 form-factor pluggable transceiver for client-side applications

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, has announced sample availability of its dual-rate 100G LR4 CFP2 transceiver module for client-side applications.

The 100G LR4 CFP2 requires less than half the power and is half the size of the existing 100G LR4 CFP form factor, making it an attractive form factor for bandwidth-hungry data-center applications where

both face-plate port density and lower electrical power are highly desired, says NeoPhotonics.

The 100G LR4 CFP2 transceiver is designed to fully comply with the IEEE 802.3ba 100GBASE-LR4 standard for links up to 10km and also supports the higher OTU4 datarate for telecom applications. It utilizes a 4-channel PIC-based integrated transmitter based on NeoPhotonics' proven high-volume manufacturing platform for 28G electro-absorption modulator laser (EML) lasers and drivers, which are designed to meet stringent OTU-4 optical performance requirements.

"The introduction of our second 100G client transceiver module underlines our commitment to the ultra-high-speed segment of the transceiver market," says chairman & CEO Tim Jenks.

At the Optical Fiber Communications exposition (OFC 2014) in San Francisco (11–13 March), NeoPhotonics showcased its 100G client transceivers alongside its existing product portfolio, including intra-dyne coherent receivers and narrow-linewidth tunable lasers for 100G coherent communications, as well as its line of next-generation transceivers for access networks.

## NeoPhotonics launches modular multicast switches for CDC ROADMs in 100G coherent networks

At the Optical Fiber Communications (OFC 2014) event in San Francisco (11–13 March), NeoPhotonics introduced new configurations of its multicast switch (MCS) modules. These are designed to be combined in a modular fashion to increase the number of degrees or directions supported by a reconfigurable optical add-drop multiplexer (ROADM) node, reducing initial costs and providing a 'pay as you grow' model to scale with network growth. For example, with this modular approach, two 4x4 MCSs can be combined to form a dual 8x4 configuration, supporting a total of 8 input ports. Similarly, two modules of the dual 4x16 MCS can be combined to form a dual 8x16 that can be extended further to a 12x16 configuration.

NeoPhotonics multicast switches are designed to be used in a next-generation ROADM node to direct any wavelength to any port (Colorless), accept input wavelength channels from multiple different directions (Directionless), and be able to drop two identical

wavelengths from different directions through the same switch (Contentionless), thereby increasing network flexibility and efficiency. One of the biggest challenges for designers of these next-generation 'colorless, directionless and contentionless' (CDC) networks is managing the up-front initial installation costs required to support the large number of degrees or directions that may eventually be required in dense mesh networks, even though initial deployments may only use a small number of degrees. NeoPhotonics' new modular approach to next-generation ROADM design allows network equipment manufacturers to initially install low-port-count modules that provide only the ports and directions that are initially needed.

As the complexity of the network deployment grows, NeoPhotonics' modular multi-core approach uses PIC technology to allow customers to increase the number of add/drop channels, and to expand the number of degrees or directions, on a pay-as-you-grow basis.

Additional ports and directions are only added when traffic exists to support the expansion. The multicast switch enables users to upgrade existing first-generation 'rigid' ROADMs to the next-generation any-wavelength-to-any-port CDC-capable metro and long-haul networks. In fact, for some metro networks with a small number of coherent optics-based add/drop ports with 100Gb/s or beyond capacity, it may be possible to add CDC functionality with no additional add/drop optical amplifiers needed.

NeoPhotonics' modular approach to next-generation CDC ROADMs addresses a critical problem for systems designers and carriers by reducing the first install costs of CDC ROADMs without compromising the ability of these systems to scale with network growth, says CEO Tim Jenks. "The modular multicast switch design is made possible by NeoPhotonics' advanced photonic integration technology, which efficiently combines many functions on a single silicon chip."

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

## Molex's zCD active optical cable interface chosen for CDFP MSA's 400G hot-pluggable module

High-speed fiber-optic interconnect firm Molex Inc of Lisle, IL, USA says that the interface of its recently released zCD active optical cable (AOC) interconnect solution has been selected by the CDFP MSA (multi-source agreement) as the interface for the consortium's 400Gbps hot-pluggable module. The zCD AOC assembly was highlighted at the Optical Fiber Communications exposition (OFC 2014) in San Francisco (11–13 March).

The zCD AOC is one of the highest-density interconnect assemblies available on the market, claims Molex's global group product manager Scott Sommers. "The zCD AOC solution delivers a winning form factor that will serve to advance industry adoption of 400Gbps data-rate technology," he adds.

Scalable up to 400Gbps, the zCD

interconnect is suitable for high-bandwidth telecoms, networking and enterprise computing data signaling rates. Based on single-mode silicon photonics technology, Molex's zCD AOC assembly transmits 28Gbps over 16 bi-directional channels with what is claimed to be excellent signal integrity, electromagnetic interference (EMI) protection, and thermal cooling properties. The tight pitch of the zCD interconnect solution enables OEMs to design systems of up to 5 terabytes capacity on one line-card.

The zCD AOC transmits up to 4km for a fraction of the cost and power of long-reach optical modules. At 6W of power dissipation, it offers what is reckoned to be one of industry's lowest-power fiber-optic solutions and longest AOC reaches. The assemblies are designed for

Ethernet, InfiniBand and proprietary protocol applications.

The mating zCD connector is available in a short-body version for passive or active copper cables and a long-body version for AOCs and transceivers, and features a straight, back-route footprint with a 0.75mm pitch. An elastomeric gasket or metal spring fingers provides EMI containment and suppression. Designed to accept a broad range of thermal modules and heat sinks, the press-fit connector design ensures a robust and simple board termination, the firm says.

"The zCD interconnect solution offers a high level of integration, performance and long-term reliability for Molex customers requiring 400Gbps with individual lane data rates up to 28 Gbps," says Sommers.

[www.cdfp-msa.com](http://www.cdfp-msa.com)

## Molex to release QuatroScale 28G silicon photonics AOCs for low-power, long-reach 100–400G data-center designs

As demand surges for long-reach, low-power solutions supporting next-generation 28Gbps products and data-center applications, Molex plans to unveil a line of QuatroScale active optic solutions for 100, 200 and 400Gbps products.

"Market indications are that the average data-center interconnect in the US is now over 130m in length, operating with 25Gbps multi-mode (MM) vertical-cavity surface-emitting laser (VCSEL) solutions which target a reach of only 100m," says Brent Hatfield, product manager for active optics. "Data-center architects and OEM providers are discovering that silicon photonics based optics bring significant advantages in terms of longer reach, with exceptionally low power consumption," he adds.

The new QuatroScale solutions are designed based on silicon photonics CMOS technology, which achieves the longest reach and

lowest bit error rate (BER), coupled with the highest reliability of any 28Gbps product on the market, it is reckoned. QuatroScale 100Gbps zQSFP+ active optical cable (AOC) and on-board module solutions run at a low 1.5W per 100Gbps, but can go up to 4km in distance. Low-power QuatroScale AOCs deliver an achievable  $10^{-18}$  BER (bit error rate), and over 3 billion device hours accumulated without an in module failure. The compact form-factor QuatroScale zCD AOCs deliver 16 bi-directional channels operating at 28Gbps, with data rates scalable up to 400Gbps bandwidth.

Molex reckons that, providing economical installed cost solutions, its QuatroScale portfolio is uniquely qualified to meet market demand for large and distributed HPC (high-performance computing) data centers. This summer, Molex plans to begin offering samples of

the following products based on its silicon photonics optical platform:

- 100Gbps QSFP28 AOCs;
- 200Gbps mid-board optical modules (available in 200Gbps or 2x 100Gbps port products); and
- 400Gbps CDFP MSA AOCs

"The added economic value of the soon-to-be-released modular QuatroScale solutions, combined with the lowest-cost single-mode structured cabling, translates into Molex providing customers with the most economical choice in silicon photonics solutions for next-generation data centers," reckons Hatfield.

The new QuatroScale 28Gbps solutions was highlighted at the Optical Fiber Communications event (OFC) in San Francisco (11–13 March), where there was a 1km transmission demonstration of silicon photonics 28Gbps QSFP+ technology.

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

## MACOM's M37040 and M37041 CDRs reach volume shipment; demonstrated with Molex's silicon photonics transceivers in 100G zQSFP+ AOC

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog, RF, microwave and millimeter-wave applications) says that its M37040 and M37041 4x28Gbps clock & data recovery ICs (CDRs) have achieved a production release status. Also, at the Optical Fiber Communication conference & exposition (OFC 2014) in San Francisco (11–13 March), they have been demonstrated with silicon photonics based transceivers from high-speed fiber-optic interconnect firm Molex Inc of Lisle, IL, USA, as part of a fully re-timed 100Gbps parallel single-mode (PSM4) zQSFP+ active optical solution.

High-density front-panel applications (using quad small-form-factor pluggable (QSFP) modules and on-board optical engines driving optical backplanes) require dramatic reductions in component power consumption and footprint, says MACOM. The firm's four-channel CDRs support data rates required for multiple standards, including 100G Ethernet, InfiniBand enhanced data rate (EDR), and 32G Fibre Channel and optical transport network (OTU-4). The low-power CDRs integrate key features, such as a limiting amplifier with what is claimed to be industry leading input sensitivity, output de-emphasis to optimize link performance, as well as test pattern generation and checking for system-level diagnostics. The devices are reference-free, eliminating the need for reference crystal oscillators (reducing the number of components and cost required to implement a re-timing function).

The M37040 and M37041 CDR devices are the industry's lowest-

power production CDRs, claims Gary Shah, VP of marketing, High Performance Analog, at MACOM. "With our roadmap commitment to low power, we are also demonstrating MACOM's next-generation, lower-power M37046 and M37049 CDRs." Low power consumption and small footprint make MACOM's CDRs a suitable chip-set solution for CFP-2, CFP-4 and small-form-factor QSFP optical modules such as the transceivers demonstrated by Molex, Shah adds.

"Molex's silicon photonics-based solutions, in combination with MACOM's low-power CDRs, deliver 100Gbps optical connectivity up to distances of multiple kilometers in small-form-factor optical modules with the option of re-timing in both transmit and receive directions," says Adit Narasimha, director of active optics at Molex. "This solution overcomes the challenges that interconnect manufacturers face when trying to meet the footprint, power consumption and thermal constraints that the market demands."

MACOM's CDR devices are a part of growing family of signal conditioners, cross-point switches and physical media devices (PMDs) for networking and enterprise solutions. The M37040 and M37041 are available in 7mm x 7mm packages and are now shipping in volume production. The M37046 and M37049 are available in what is claimed to be the industry's smallest-footprint package (4mm x 4.5mm) and are shipping in sample quantities. The devices were showcased at OFC in the booths of both MACOM and Molex.

[www.macomtech.com](http://www.macomtech.com)  
[www.molex.com](http://www.molex.com)  
[www.ofcconference.org](http://www.ofcconference.org)

### IN BRIEF

#### DSP-based coherent 100G CFP and single carrier 200G pluggable transponder

At the Optical Fiber Communication (OFC) event, CIVCOM Devices & Systems Ltd of Petach Tikva, Israel launched its next-generation product line for high-speed communication networks.

CIVCOM's coherent 100Gbps CFP transponder is claimed to be among the first modules on the market to use the DP-16QAM modulation format, enabling the industry's lowest power consumption and best spectral efficiency for metro applications up to 600km.

CIVCOM has also launched a single carrier 200G transponder in a dual CFP pluggable module based on the DP-16QAM modulation format with a unique slim single-slot design offering what is claimed to be the best cost-per-bit on the market.

Both transponders are the first in CIVCOM's new line of products based on a line of digital signal processors (DSPs). The firm says that the products offer an optimized solution for each of the network segments from metro to ultra-long-haul and sub-marine applications, providing equipment vendors with differentiators such as multiple modulation schemes together with what is claimed to be superior optical signal-to-noise ratio (OSNR) tolerance and the highest chromatic dispersion tolerance on the market.

"CIVCOM is focused on the high-speed optical market, targeting equipment vendors who rely on DSP-based modules," says CEO Gabby Shpirer. "Our diverse product portfolio enables CIVCOM's customers to provide a competitive end-to-end solution."

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

# OpenOptics MSA to define 1550nm silicon photonics QSFP transceiver for 100G data-center networks on SMF

## Mellanox and Ranovus target 2km 100G WDM standard

Mellanox Technologies Ltd of Sunnyvale, CA, USA and Yokneam, Israel (a supplier of end-to-end interconnect solutions for data-center servers and storage systems) and Ranovus Inc of Ottawa, Canada and San Jose, CA, USA (a provider of multi-terabit interconnect solutions for data-center and communications networks) have announced the founding of an industry consortium to standardize wavelength division multiplexing (WDM) for an interoperable 100G WDM standard for 2km reach, covering large cloud data-center interconnectivity requirements.

The OpenOptics multi-source agreement (MSA) combines a 1550nm WDM laser and silicon photonics for QSFP-based solutions enabling the lowest-cost, highest-density and highest-bandwidth single-mode fiber (SMF) connectivity, significantly improving terabit-scale data-center infrastructure return on investment (ROI).

"As the migration of data-center network connectivity towards Leaf and Spine architecture accelerates, operators require innovative interconnect solutions to enable a scalable infrastructure at much better economics," says Ranovus' chief marketing & sales officer Saeid

Aramideh. "The application of a multi-channel laser source coupled with silicon photonics to enable connectivity in the 1550nm band in QSFP form/factor is a game changer in reducing the data-center fiber plant connectivity cost by 4–7 times compared to legacy multi-mode fiber implementations," he believes. Founded in February 2012 and with experience in product development and commercialization of optoelectronics components and transceiver subsystems, Ranovus manufactures interconnects for the telecoms and IT industries. Its portfolio includes quantum dot multi-wavelength laser technology and digital and photonics integrated circuit (PIC) technologies.

The OpenOptics MSA aims to add additional members to this consortium to achieve a true multi-sourcing supply chain.

Key highlights of the OpenOptics MSA specification are:

- 100Gb/s, 1550nm C-band, 4x25Gb/s WDM;
- industry-standard media — a single pair of single-mode fiber (SMF);
- reach of 2km and beyond;
- standard WDM spacing (ITU-T grid);
- industry-standard QSFP28 form factor; and
- scalable data rates of 400G and

beyond.

"Our cloud customers want to deploy data-center infrastructure that allows seamless upgrades to the interconnect just as they do in server, storage and network hardware," says Mellanox's chief operating officer Shai Cohen. "With 100G interconnects approaching commercialization in data centers, the OpenOptics MSA brings 100G WDM technology to data-center economics, density, power consumption, and 2km link scalability on single-mode fiber infrastructure," he adds.

"Data center needs are accelerating," comments Karen Liu, principal analyst with Ovum. "The growth of cloud data centers poses a triple challenge for technology: first, they need 100G sooner than others, but they also need it to be high-density, low-cost and easy to deploy from the start. The third challenge will be that they will move on quickly to the next speeds of 400G and 1Tb soon," she adds. "Alignment of industry efforts like OpenOptics MSA will be critical to meet this challenge by bringing WDM and single-mode fiber solutions tailored for data centers."

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

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

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

## Infinera super-channel transmission deployments reach 1Pbps

Infinera Corp of Sunnyvale, CA, USA says that customers have deployed more than 1 petabit per second of super-channel transmission capacity in live networks globally.

In 2012 Infinera claimed to be first to ship 500Gb/s long-haul super-channels commercially. Now, nearly two years later, it remains the only firm delivering volume shipments of super-channels into production networks.

The Infinera Intelligent Transport Network features the DTN-X packet-optical transport networking

platform, delivering 500Gb/s super-channels based on what are claimed to be the only commercially deployed large-scale photonic integrated circuits (PICs). In 2013, Infinera announced the second generation of super-channels, enhanced with soft-decision forward-error correction (SD-FEC) to increase transmission range, and recently it launched its third-generation super-channel line-cards, which support flexible grid operation based on the new ITU-T G.694.1 frequency grid.

"Infinera recognized the opportunity to offer an economically disruptive product just as the mass market for 100G transport took off," says Rick Talbot, principal analyst, Optical Infrastructure at market research firm Current Analysis. The milestone validates Infinera's plan to play a leading role in that market and confirms the demand for long-haul super-channels, whose economics depend on implementation of the 500G photonic integrated circuit, he adds.

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

# Mellanox announces LinkX product family of cables and transceivers for data-center infrastructure

Mellanox Technologies Ltd of Sunnyvale, CA, USA and Yokneam, Israel, a supplier of end-to-end InfiniBand and Ethernet interconnect solutions for servers and storage systems, has launched its LinkX product portfolio of cables and transceivers supporting interconnect speeds of 10, 40 and 56Gb/s for both Ethernet and InfiniBand data-center networks.

As data centers transition to Open Platform and open standards — including software-defined networks (SDN), Open Ethernet and Open Compute Project (OCP) — interconnection solutions in a generic form factor that are highly reliable and scalable are required for data-center connectivity. The broad LinkX portfolio provides technology for such applications, as follows:

- cost-effective LinkX copper cables connect QSFP ports for short reaches;
- VCSEL transceivers and active optical cables (AOCs) connect QSFP ports for intermediate reaches;

- single-mode fiber transceivers connect QSFP ports for long reaches;
- patented quad to serial adapters (QSAs) can be used to connect a 40G QSFP port to a 10G SFP+ port; and
- splitters connect a QSFP port on a top-of-rack (ToR) switch to four SFP+ server ports.

"A big advantage of LinkX QSFP solutions is our ability to scale to 100Gb/s networks," says VP of marketing Gilad Shainer. "While most LinkX products shipping today are 10, 40Gb/s or 56Gb/s, innovations in silicon photonics and low-power electronics will enable our QSFP transceivers to reach speeds of 100Gb/s and distances of 2km," he adds. "It is our plan to make 100Gb/s networks as flexible and as easy to install as 10Gb/s networks today."

Mellanox says that, to ensure that every LinkX cable or transceiver works the first time and every time, it subjects its products to a full system test in a stressed environment.

Network engineers do not have to waste time debugging a new installation with untested products. With LinkX products, installation experts can bring up new clusters fast; with fewer interconnect problems and fewer product returns, says the firm.

LinkX interconnect products are subjected to full system testing to a bit error rate (BER)  $10^{-15}$  in order to maximize overall data-center performance. A BER of  $10^{-15}$  provides 1000 times fewer transmission errors than many competing products, it is claimed. Fewer transmission errors translate to fewer re-tries, higher system performance, and more revenue generating traffic.

Mellanox says that, whether the application is Ethernet or InfiniBand, cloud or Web 2.0, server to top-of-rack, server to storage, or switch to switch, LinkX interconnect products maximize return on investment (ROI) with superior performance, flexibility and scalability.

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

## Mellanox showcases 100G QSFP solutions at OFC

At the Optical Fiber Communications event (OFC 2014) in San Francisco (11–13 March), Mellanox Technologies Ltd of Sunnyvale, CA, USA and Yokneam, Israel, a supplier of end-to-end InfiniBand and Ethernet interconnect solutions for servers and storage systems, demonstrated 100Gb/s technologies, including silicon photonics, that more than double the speed of existing 40Gb/s QSFP solutions.

Feature demonstrations included:

- 100Gb/s silicon photonics modules in the popular QSFP form factor, providing 300% more density than CFP2 or C-PAK footprint solutions;
- 100Gb/s vertical-cavity surface-emitting laser (VCSEL)-based solutions in the same QSFP package (the most popular pluggable form factor for

40G Ethernet applications); and

- multi-channel 28Gb/s VCSEL drivers and transimpedance amplifiers (TIAs) with integrated retiming.

"High-performance data centers, Web 2.0, cloud and storage infrastructures will need to scale their 40Gb/s and 56Gb/s interconnect to 100Gb/s to address the exponential growth in data," says chief operating officer Shai Cohen.

"The QSFP transceiver has provided excellent density for speeds up to 56Gb/s, but until now 100Gb/s technologies were only available in large form factors such as the CFP and CFP2. With silicon photonics, faster VCSELs and new electronics, we can squeeze multiple 100Gb/s technologies into the same QSFP form factor, supporting a wide

range of applications with the same physical port. Our LinkX interconnect family has QSFP options for any data-center reach — from less than 2m to more than 2km," he adds.

"When the industry settled on the QSFP form factor for 40Gb/s, the market increased dramatically," comments Dale Murray, principal analyst at LightCounting Market Research. "That is not happening as quickly for 100Gb/s links in part because of the large size and variety of form factors," he adds. "Data centers need low-cost, dense 100Gb/s ports in an industry-standard form factor. The emergence of 100Gb/s in the QSFP form factor is an important innovation that will accelerate large-scale data-center deployments."

## Finisar reports sixth quarter of growth to record \$294m Datacom product revenue up 42% year-on-year

For its fiscal third-quarter 2014 (ended 26 January), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported a sixth consecutive quarter of revenue growth, to a record \$294m. This is up 1.1% on \$290.7m last quarter and 23.4% on \$238.4m a year ago.

Revenue for datacom products was \$210.3m, up 3% on \$204.3m last quarter (driven primarily by sales of 40 Gigabit Ethernet transceivers) and up 42% on \$147.7m a year ago.

Revenue for telecom products was \$83.7m, down 7.7% on \$90.7m a year ago and 3.2% on \$86.5m last quarter, due mainly to the impact of one month of the annual price reductions for telecom products that typically take effect on 1 January.

On a non-GAAP basis, gross margin has risen further, from 30.7% a year ago and 37.1% last quarter to 37.2%, primarily as a result of favorable product mix, partially offset by the annual telecom price reductions.

Operating expenses were \$63.2m, level with last quarter but up from \$55.8m a year ago. Operating income has risen further, from \$17.4m (7.3% of revenue) a year ago and \$44.8m (15.4% of revenue) last quarter to \$46.3m (15.7% of revenue). Net income has risen from \$16.4m (\$0.17 per diluted share) a year ago and \$43.8m (\$0.43 per diluted share) last quarter to \$45m (\$0.44 per diluted share).

Capital expenditure was \$35.4m, above the expected \$32m and up from \$29.7m last quarter (which had low due to a delay in payments related to the new manufacturing facility being built in Wuxi, China).

During the quarter, cash, cash equivalents and short-term investments rose by \$238.2m, from \$316.5m to \$554.7m, reflecting net proceeds of \$255m from a convertible debt offering (of \$258.75m of principal amount of 0.5% convertible notes due in 2033).

"During the quarter, we continued to make significant strides in new

product development for both datacom and telecom products," says CEO Eitan Gertel.

"In the datacom, we have production released our 100G CFP2 LR4 product. Due to our vertical integration of lasers, receivers and optical subassemblies, our modules consume the lowest amount of power of any solution on the market," claims Gertel. "Our 100G CFP4 and our QSFP28 module developments are progressing very well. We continue to be designed into new applications with our parallel optical engine product that operates up to 28 gigabits per channel," he adds.

"In telecom, we are now shipping beta samples of our tunable SFP+ module, which utilizes our internal low-power tunable lasers and optical subassemblies, allowing a total power consumption of approximately 1.5W," continues Gertel.

In early January, Finisar announced that it had agreed to acquire u2t Photonics AG of Berlin, Germany for about \$20m in cash, subject to certain adjustments and that Finisar would also assume net debt of \$7m. The transaction closed on 31 January, one week into fiscal Q4/2014.

"With this transaction, Finisar added u2t indium phosphide-based, high-speed receivers and photodetectors, including their 100G and 200G coherent receivers that are used by multiple system manufacturers," says Gertel. "This acquisition consolidates Finisar's previously announced partnership with u2t on InP-based Mach-Zehnder modulators for 100G and 200G coherent applications. These receivers, photodiodes and modulator technologies and products, combined with Finisar's narrow-linewidth tunable lasers, provide a full suite of vertically integrated optical components that enables Finisar to offer its customers the very high-performance modules for the 100G and 200G coherent metro and long-haul markets," he adds.

"In addition to using these components for OIF discrete 100G and

200G applications, Finisar will utilize key components in our CFP2 coherent modules, as well as new form factors such as CFP4 and QSFP28 and SFP+, for next-generation telecom and datacom applications," says Gertel.

Without taking into account the acquisition of u2t, for fiscal fourth-quarter 2014 Finisar expects record revenue of \$290–305m (up for a seventh consecutive quarter). Gross margin should fall to about 36%, due to the impact of the full 3 weeks of the annual telecom price reductions since 1 January. Likewise, operating margin should fall to 13.8–14.8% and earnings per diluted share to \$0.38–0.42.

After taking into account the acquisition of u2t (including the elimination of any intercompany revenue or expense transactions), Finisar expects revenue up to \$296–311m, but gross margin down to about 35.5%, operating margin of 12.8–13.8%, and earnings per diluted share of \$0.36–0.40.

Capital expenditure is expected to be \$33m, driven primarily by construction on the shell of the second building of Finisar's new production site in Wuxi, China. "We expect the shell of the building to be completed by fall of 2015 and now plan to immediately start to fit out several floors of the building and then fit out additional floors over time, as needed," says chief financial officer Kurt Adzema.

Finisar expects the acquisition of u2t to be accretive to earnings per diluted share in about one year as it realizes cost and other synergies over time.

"We view the acquisition of u2t as strategically important in allowing Finisar to provide a differentiated vertically integrated solution to address the 100G coherent transceiver market," says executive chairman Jerry S. Rawls. "This market is forecasted by LightCounting to be over \$500m in calendar year 2017.

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

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# Finisar demos CFP4 modules for high-port-count 100G systems in carrier and data-center applications

At Optical Fiber Communication (OFC) in San Francisco (11–13 March), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA demonstrated several new products and technologies, including modules based on the new CFP4 MSA form factor for 100G systems within carrier and data-center environments, 40G serial vertical-cavity surface-emitting laser (VCSEL) link technology that increases per-lane data rates, a 16-channel x 25G CDFP active optical cable (AOC), and hybrid Raman erbium-doped fiber amplifier (EDFA) for extending reach without compromising performance. Finisar also showcased its new indium phosphide (InP)-based optical components, expanding its 100G coherent portfolio.

## CFP4 optical module ecosystem

Finisar demonstrated new products and technologies that enable the implementation of the new CFP4 MSA form factor in high-port-count 100G systems for carrier and data-center environments. Targeting single-mode fiber applications, a new 100GBASE-LR4 CFP4 optical transceiver module is being demonstrated on a 12km 100G link, interoperating error-free with a CFP transceiver. By using 4x28G distributed feedback (DFB) laser technology, the module supports a maximum power dissipation of less than 4.5W (4W typical), which is significantly lower than electro-absorption modulator laser (EML)-based solutions and enables much higher port density. It provides a re-timed 4x25G/28G electrical interface to the host board, meets IEEE 802.3, OIF and OTN standards, and interoperates with existing 100GBASE-LR4 CFP and CFP2 modules. Samples of the CFP4 LR4 module should be available later in 2014. Finisar's CFP2 LR4 and CFP LR4 modules are production released and available now.

Finisar also demonstrated the feasibility of a 40km error-free

100G link using 4x28G DFB lasers and 4x25G avalanche photodiode (APD) technologies. This 'ER4f' approach requires the use of forward error correction (FEC) in the data path (similar to 100GBASE-SR4) and is being standardized by the International Telecommunication Union (ITU-T), enabling low-power and high-density 40km 100G optical transceiver modules such as CFP4. For multimode applications, Finisar demonstrated its 100GBASE-SR4 CFP4 optical transceiver module at the European Conference on Optical Communications (ECOC 2013) in London, UK last September. Samples of the product are currently available.

## 40G serial VCSEL link technology and CDFP 16-channel x 25G AOC

Finisar also demonstrated the commercial viability of 40G serial NRZ VCSEL link technology. As the fastest directly modulated laser technology available today, VCSELs will also offer a highly attractive cost/performance combination for data-center interconnects at next-generation speeds, says Finisar. Currently, such links operate at multiples of 10–25Gb/s. In collaboration with IBM, which provided a prototype 40G VCSEL driver, Finisar demonstrated that the next generation of VCSELs can increase these links to multiples of 40Gb/s, leading to modules with aggregate data rates in excess of 160Gb/s.

As a new member of the CDFP MSA (multi-source agreement), Finisar is demonstrating a CDFP active optical cable. The CDFP-AOC is a 400Gb/s short-reach interconnect cable incorporating 16 channels of 25Gb/s VCSEL running over duplex, parallel-ribbon, multimode fiber (MMF). This form factor is under consideration for next-generation short-reach interconnects for routers, high-performance computers, and proprietary interconnects.

## Hybrid Raman EDFA product demo

Finisar's hybrid Raman EDFAs provide improved system optical

signal-to-noise ratio (OSNR) performance, enabling the service provider or operator to extend the reach of each span in a transport network. Current EDFAs are limited in reach to 80–100km with a high OSNR penalty. During this demonstration, hybrid Raman EDFAs achieve state-of-the-art optical performance with 44dB link loss over 220km at what is claimed to be the industry's lowest power consumption. The highly optimized and cost-effective design of the new hybrid Raman EDFAs offer eye-safety, a flexible modular/expandable design, and high reliability. Finisar's EDFA products are available as modules or network-interfaced 1RU rack-mountable units, and can be tailored to meet specific customer requirements across all network segments (long haul, regional, metro, and access) and applications including telecom, cable, and enterprise. Hybrid Raman EDFAs are in production.

## 100G high-speed components display

Finisar showcased its new portfolio of 100G high-speed components through its acquisition in January of u2t Photonics AG of Berlin, Germany. Via its InP-based Mach-Zehnder modulators and 100G high-speed receivers and photodetectors, Finisar now provides a full suite of optical components and vertically integrated modules for 100G coherent metro and long-haul applications. In addition, the technology has the potential to enable new telecom and datacom applications by helping to drive data rates higher than 100Gb/s and form factors smaller than CFP2.

Finisar also displayed equipment from its portfolio of optical products, including its latest optical transceivers, active cables, wavelength-selective switch (WSS) devices, advanced optical components, amplifiers, and passive devices.

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

## CDFP MSA releases mechanical specs for 400G interface

### Consortium issues draft design drawing and specifications for connector form factor in hot pluggable module

The CDFP MSA (multi-source agreement) consortium has released the draft mechanical specifications and a drawing for the new CDFP 400Gbps interface. Designed for resource-intensive applications in telecoms, networking and enterprise computing environments, the compact 400Gbps connector form factor aims to enable data rates of 25Gbps over 16 lanes with excellent signal integrity, thermal cooling properties, and EMI protection.

The CDFP MSA consortium has also issued a white paper examining industry trends, potential markets and in-depth specifications of the interoperable CDFP module. The complimentary white paper 'CDFP Delivers 400 Gbps Today' is available for download on the CDFP MSA homepage.

CDFP founder-promoters include: Avago Technologies, Brocade Communications, IBM Corp, JDSU, Juniper Networks, Molex Inc, and TE Connectivity. The CDFP roster has expanded to include the following

contributing member companies: FCI, Finisar, Huawei, Inphi, Mellanox Technologies, Oclaro, Semtech, and Yamaichi Electronics. The consortium is dedicated to defining specifications and promoting adoption of interoperable 400Gbps hot pluggable modules.

Building on OIF CEI-28G VSR and IEEE 802.3 electrical and optical interface standards, the CDFP mechanical specifications provide a standard connector and module with a pluggable form factor that supports signaling up to 26Gbps per lane with rates scalable up to 400Gbps. The 32mm-pitch CDFP interface enables OEMs to design systems of up to 5 terabytes capacity on one line-card. The connector features a straight, back-route footprint. A gasket provides EMI containment and suppression. Designed to accept a broad range of heat sinks, the press-fit design ensures a robust and simple board termination.

Providing a high level of integration, performance and long-term

reliability, the CDFP 400Gbps interface is available in short- and long-body versions. The specifications are compatible for use with direct attach cables, active optical cables (AOCs), and connectorized optical modules.

Enabling high port density, the compact module is suited to low-power applications using copper, vertical-cavity surface-emitting laser (VCSEL) or silicon photonics based technology. Designed for client-side interfaces inside the data center, the CDFP module will support up to 100m on MMF (multi-mode fiber) and 2km on SMF (single-mode fiber).

The CDFP 400Gbps draft interface mechanical drawings and specifications are available now. Mechanical samples are available from some respective member companies.

The CDFP consortium is working to complete the full specification, including memory mapping, within this calendar year.

[www.cdfp-msa.com](http://www.cdfp-msa.com)

## Finisar launches first wavelength-tunable RF-over-fiber transmitter in small-form-factor module

Fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has introduced what it says is the first 3GHz RF-modulated, wavelength-tunable optical transmitter in a small-form-factor module.

With its wide RF dynamic range, the transmitter is optimized for applications such as cellular backhaul, distributed antenna systems, and GPS signal distribution. It saves up to half the space and power consumption over existing non-tunable solutions, reckons the firm. The pluggable XFP-RF transmitter installs into Finisar's rack-mount system that hosts up to

10 transmitters in one rack-unit, and enables network equipment providers to design these ports into existing optical platforms. The transmitter complies with the interface specifications for XFP-RF transmitters (SCTE 195 2013) published by the Society of Cable Telecommunications Engineers (SCTE).

Optimized for dense wavelength-division multiplexing (DWDM) applications, Finisar's new XFP-RF optical transmitter module provides wide-band wavelength tuning up to 88 different wavelengths across the entire C-band. This eliminates inventory of transmitters at fixed

wavelengths and eases the provisioning of complex DWDM networks, adds the firm.

"Its pluggable small form factor and tunable wavelength capability provide increased flexibility for various applications such as backhaul for small cells and distribution of L-band satellite signals," says Shawn Esser, director of product marketing for RF-over-Fiber products.

Samples are available now for customer evaluation. Finisar displayed the wavelength-tunable 3GHz XFP-RF transmitter at the SATELLITE Conference and Exhibition in Washington DC (11-13 March).

[www.satellite2014.com](http://www.satellite2014.com)

# Emcore launches 1550nm DOCSIS 3.1 DWDM DFB laser module for CATV

Emcore has launched the 1752A 1550nm DOCSIS 3.1 dense wavelength division multiplexing (DWDM) distributed feedback (DFB) laser module for cable television (CATV) applications. The 1752A is the latest model in Emcore's 1550nm quadrature amplitude modulation (QAM) laser platform and is fully compliant with the new DOCSIS 3.1 standard, supporting operational bandwidth up to 1.2GHz.

DOCSIS (Data Over Cable Service Interface Specification) is the standard that facilitates the addition of high-speed data transfer over existing CATV systems for internet access through cable television services. DOCSIS 3.1 is the latest version and is designed to deliver several new benefits to cable companies, including greater capacity and speed. It allows for up to 50% more data throughput over the same spectrum to deliver up to

10Gbps downstream and 1–2Gbps upstream. DOCSIS 3.1 also decreases the cost-per-bit for data delivery by improving the efficiency of spectrum use, and it increases the energy efficiency of cable modems.

The 1752 laser platform has been designed specifically for CATV applications and the latest DOCSIS 3.1 standard. It features 1.2GHz operational bandwidth with low adiabatic chirp to maximize signal quality in short and long lengths of fiber.

The 1752A is available in a wide range of ITU grid wavelengths and operates over an industrial temperature

**The 1752A DOCSIS 3.1 laser is a key enabling component allowing our customers to provide fully DOCSIS 3.1 compliant systems**

range. The laser's inherent linearity minimizes degradation of broadcast signals caused by QAM channels.

"We are very pleased to introduce our first DOCSIS 3.1 laser module bringing Emcore's leading-edge highly linear DFB laser technology to the latest standard in the CATV industry," says Jaime Reloj, VP of business development. "The 1752A DOCSIS 3.1 laser is a key enabling component allowing our customers to provide fully DOCSIS 3.1 compliant systems."

All Emcore lasers use the highly linear, directly modulated DFB technology, which has become synonymous with high-speed photonics that drove the wide-scale deployment of fiber optics in CATV networks, satellite earth stations and mobile phone antenna sites. The new 1752A laser module extends that performance and reliability to the DOCSIS 3.1 standard.

## Emcore introduces EDFAs to extend reach of Optiva Platform

At the Satellite 2014 event in Washington DC (16–19 March), Emcore introduced the Optiva OTS-20 and OTS-20P Series of erbium-doped fiber amplifier (EDFA) and pre-amplifier modules, which are designed for a wide variety of extended long-haul signal transport applications.

The Optiva EDFA and pre-amplifier provide building blocks for system integrators to extend fiber-optic links beyond 100km. They are designed to meet the most demanding noise performance requirements of fiber-optic communications and control systems, while performing all the functions required of optical amplifiers for system integration, says Emcore. The new EDFA modules are available with optical output powers of 14, 17, 20 and 23dBm.

Applications for the new Optiva EDFA series include long-distance

RF and microwave fiber-optic communications links, CATV systems and FTTx networks, high-performance supertrunking links, high-power distribution networks, sensing and control systems, and redundant ring architectures.

The OTS-20 Series EDFA modules provide input and output optical isolation for stable, low-noise operation. The input and output optical signal power levels are detected for monitoring and control. The input optical signal is amplified with active gain control for a constant output power level, or with active output power control for constant gain mode operation. In the OTS-20P EDFA pre-amplifier, the very low-level input optical signal is initially pre-amplified, then amplified with active output power control for constant power mode operation, and the output optical signal power levels are

detected for monitoring and control.

"The integration of the Optiva OTS-20 and OTS-20P Series EDFA modules with the Optiva family of 1550nm fiber-optic transport equipment provides a complete solution that extends the reach of fiber links for a wide range of applications," says Frank Weiss, VP of Advanced Systems.

Key features of the OTS-20 and OTS-20P Series EDFA include low noise and low power consumption, standard and optional gain flatness (OTS-20), and local and remote monitors and alarms for all critical operating parameters via SNMP and EMCOREView GUI. In addition, the optical output can be split into multiple ports by optional external splitter. The OTS-20 and OTS-20P Series EDFA fit Optiva 16, 6- and 2-slot enclosures and are RoHS compliant.

[www.emcore.com/optiva-edfa](http://www.emcore.com/optiva-edfa)

## Emcore introduces second-generation 2804 fiber-optic transmitter and Medallion Series EDFAs for CATV

At the 2014 China Content Broadcasting Network (CCBN) show in Beijing (20–22 March), Emcore launched the 2804 Generation II 1310nm fiber-optic transmitter for cable television (CATV) applications. The second-generation 2804 is a fully redesigned version of the 2804 line of transmitters.

Featuring Emcore's linear analog distributed feedback (DFB) laser, the 2804 Generation II transmitter is packaged in an economical form-factor, making it a suitable fit for small and independent operators requiring a reliable, easy-to-install high-performance solution.

The 2804 Generation II is offered in a 19 inch, 1 RU rack-mount, fully contained enclosure and features output power up to 15dBm. Several different configurations can be requested, including single or dual power supplies. Also available is a dual transmitter option, allowing users to deploy two 1310nm transmitters in the same space traditionally used for one transmitter.

"The new 2804 Generation II transmitter makes Emcore's laser and RF technology accessible to small and independent operators," says Jaime Reloj, VP of business development. "The innovative design offers the operator flexibility to configure their system in a variety of ways."

Emcore expects to begin shipments

of the 2804 Generation II 1310nm transmitter in second-quarter 2014.

Also at CCBN, Emcore launched the Medallion 7000 Series erbium-doped fiber amplifiers (EDFA) for CATV applications. The new EDFAs extend Emcore's Medallion series rack-mount CATV transmitter portfolio and feature the low noise and output power stability demanded by CATV operators for modern hybrid fiber coax (HFC) topologies and FTTx networks, the firm claims.

The Medallion 7000 Series EDFAs are packaged in sturdy, lightweight 1RU (7100) and 2RU (7200) housings compatible with industry-standard 19" and 23" rack systems. The platform provides stable optical outputs over a wide operating temperature range. Internally, Medallion EDFAs are supported with input and output isolators for enhanced system stability and performance. Optical power is continuously monitored at the input and output for automatic power control during operation.

Based on existing Medallion transmitter system design, Medallion 7000 Series EDFAs offer a rich feature-set including remote management capability through SNMP (Simple Network Management Protocol) and Telnet, plus a wide set of configuration options including port count, automatic power and gain control, connector options and

integrated per channel WDM for FTTx PON or RFoG applications. They also support management information bases (MIBs) specified by the Society of Cable Television Engineers (SCTE) for this product class. The front panel's VFD (vacuum fluorescent display) and controls provide the operator with the option to both monitor the status and operate the amplifier locally.

"They will provide our customers with exceptional performance characteristics to expand the capabilities of their CATV distribution networks, while providing outstanding monitor and control functionality," claims Jaime Reloj, VP of business development. "The series offers a natural combination with Emcore's Medallion 6000 and 8000 series externally and directly modulated CATV transmitters, enabling the complete 1550nm transmission path."

Medallion 7000 Series EDFAs allow flexible configurations with up to 64 SC/APC output ports, high saturation output power up to 38dBm (pre-splitter), wide input dynamic range, front-panel optical input/output monitor ports, and dual redundant hot-swappable AC or DC power supplies.

Emcore will begin shipping the Medallion 7000 Series EDFAs in second-quarter 2014.

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

## ► Simultaneous 10MHz and L-band fiber-optic links for Optiva

At Satellite 2014, Emcore launched the Optiva OTS-2L10, 10MHz/L-band fiber-optic links for very small aperture antenna (VSAT) signal transport.

VSAT systems provide high-speed, broadband satellite communications for internet or private network communications and suit remote internet connectivity, video transmission, VoIP and emergency back-up communications. VSAT can connect remote offices, media vans or other remote locations.

OTS-2L10 fiber-optic links are

optimized to provide transparent, simultaneous 10MHz and L-band signal transport. They provides isolation of the 10MHz from L-band signals at the transmitter and receiver with low phase noise, facilitating greater flexibility to locate VSAT antennas for optimum performance. The connectivity features of coaxial cable are maximized without the penalty of RF loss, allowing the system to dictate equipment location and not the limitations of the coaxial cable.

The OTS-2L10 is designed with optically isolated uncooled DFB lasers that enable high-dynamic-range links with fixed gain up to 10km. Connection is via 50Ω SMA and the OTS-2L10 includes receiver DC output for the BUC upconverter with transmitter and receiver RF power monitoring via LED and SNMP.

OTS-2L10, 10MHz/L-band fiber links fit in Optiva 16, 6- and 2-slot enclosures which support Daisy Chain video, audio and data links.

[www.emcore.com/satcom](http://www.emcore.com/satcom)

# IQE's equity stake in Solar Junction acquired by strategic investor

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that its minor equity stake in the share capital of Solar Junction Corp (SJC) of San Jose, CA, USA, which makes III-V multi-junction solar cells for concentrated photovoltaics (CPV), has been acquired by a new strategic investor, as part of an acquisition of SJC. The new investor aims to accelerate the large-scale global adoption and commercialization of SJC's CPV technology.

The identity of the new investor, and specific terms of the acquisition, are not yet public and covered under non disclosure agreements. However, IQE says that its exclusive long-term wafer supply agreement using SJC's dilute nitride materials technology — agreed when IQE invested in SJC in 2012 — will be unaffected by the transaction. The

return to SJC equity shareholders, including IQE, will be deferred and contingent upon specific aspects of SJC's future business development. Further details will be provided in due course.

In February 2012, IQE invested \$5m in a 9.8% equity stake in order to obtain exclusive rights to supply SJC with high-efficiency CPV wafers using SJC's unique dilute nitride materials technology through a long-term supply agreement. The primary investors in SJC at that time were several US-based venture capitalists. The technology has subsequently been transferred to IQE's large-volume production tools, and record efficiencies of 44.1% have been achieved from this production platform for standard triple-junction cells. IQE has since been supplying wafers to SJC on a commercial basis under

the terms of the wafer supply agreement.

As anticipated at the time, SJC has required subsequent equity fundraisings, which were supported by its venture capital investors, but in which IQE did not participate. However, having obtained volume manufacturing credibility through the technology transfer and manufacturing agreements with IQE, the longer-term objective of SJC has always been to secure a major strategic investor to better facilitate and accelerate the commercialization and global adoption of its technology. IQE says that it has fully supported this initiative. Attracting the new strategic investor marks another milestone in accelerating SJC's growth and commercialization plan for its CPV technology, says IQE.

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

[www.sj-solar.com](http://www.sj-solar.com)

## South African Department of Energy grants preliminary approval to refinancing scheme for Soitec's 44MWp project

Concentrating photovoltaic (CPV) solar system maker Soitec of Bernin, France says that South Africa's Department of Energy has granted its preliminary approval to a refinancing scheme for Soitec's equity position in the 44MWp solar project developed in Touwsrivier.

The preliminary approval sets the path for finalizing the terms and conditions of the final transaction, pursuant to which the shareholding of the project company shall ultimately evolve to include an already-identified investor. Subject to final Department of Energy approval,

and in light of the anticipated schedule for finalizing the transaction, Soitec anticipates being in a position to disclose its 2013–2014 full-year sales report including actuals and/or pro-forma audited figures related to its South African solar project.

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

### Soitec announces full commissioning of first 22MWp

Soitec says that its Touwsrivier solar power plant has fulfilled milestones set for commissioning 50% of its total capacity of 44MWp, confirming that it performs in accordance with contractual specifications and validates the power purchase agreements applied to the 44MWp plant.

As anticipated, the milestone will trigger refinancing of the project

through availability of proceeds of the bond issued on the Johannesburg stock exchange in April last year.

Soitec says that, thanks to its local partners and suppliers, it is confident of completing what will be South Africa's largest solar power plant in the coming months. Currently, more than 60% of the power plant has been installed.

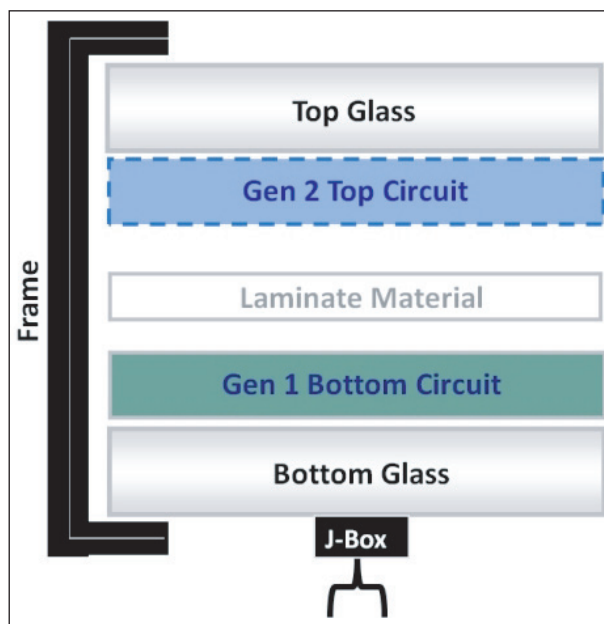
Soitec reckons that achievement of the performance testing milestone demonstrates that its CPV technology is best suited for large utility-scale power plants in high-irradiance areas, which is one of the largest markets for solar power, confirming the bankability of the firm's CP system for its announced pipeline of large-scale solar projects.

# Stion demos 23.2%-efficient CIGS tandem cell

## High-bandgap top device added to low-bandgap 'Gen 1' bottom device

Stion Corp of San Jose, CA, USA, which makes nanostructure-based CIGS (copper indium gallium sulphur-diselenide) thin-film photovoltaic panels, has produced a 23.2%-efficiency thin-film cell based on its proprietary tandem junction technology. Stion has already scaled the technology at or above 20.0% efficiency on a prototype module (20cm x 20cm) and expects to soon scale to monolithic modules (65cm x 165cm) in the 20–22% efficiency range.

As a developer of tandem module technology, Stion claims to be first to demonstrate fully integrated thin-film devices at such high conversion efficiencies using scalable commercial processes. The firm aims to continue to implement the key technical innovations behind the 23.2% cell on its pilot-production line in San Jose, in preparation for the commercialization of thin-film



**Stion's tandem device has a high-bandgap top device and a low-bandgap bottom device (same device as is used for Stion's current Gen 1 panels) to deliver increased efficiency and light capture.**

modules with >20% efficiency.

"Achieving 23.2% cell efficiency and 20% mini-module efficiency on this state-of-the-art technology clearly demonstrates Stion's commitment to technology differentiation and its deep IP portfolio," says Howard Lee, chief technology officer, founder & senior VP of technology. "We expect the technology to keep improving with production experience," he adds.

Stion says that its unique approach to CIGS leverages proprietary materials and device expertise along with a robust, high-volume manufacturing process based on readily available, standardized equipment.

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

## Centrosolar to distribute TSMC modules in North America

TSMC Solar Ltd of Taichung, Taiwan, which was founded in May 2009 as a subsidiary of the world's biggest silicon wafer foundry Taiwan Semiconductor Manufacturing Co Inc (TSMC), has agreed for specialty PV distributor Centrosolar America Inc of Scottsdale, AZ, USA to be the exclusive provider of its copper indium gallium diselenide (CIGS) solar modules in residential and commercial solar markets across North America, including the USA, Canada, Mexico, Virgin Islands and Puerto Rico. TSMC Solar and Centrosolar America may also collaborate on utility-scale projects.

TSMC says that, as well as being cost competitive with silicon-based solar modules, its CIGS modules yield more kWh per Watt installed over the life of the system due to a lower temperature coefficient, increased power rating due to the 'light soaking effect' once exposed

to light, and less power loss in shaded conditions due to the cell configuration. Such high-performance attributes are especially important in high-temperature regions, such as the Sun Belt in the USA and in Mexico and the Caribbean, says the firm. Also, the sleek, all-black appearance of the CIGS modules is reckoned to be aesthetically pleasing to homeowners.

"Our robust network of installers and distributors today delivers the most cutting-edge, turn-key solutions on the market and is ideally positioned to bring TSMC Solar's new high-performance CIGS technology to homeowners and commercial projects on a broad scale," claims Centrosolar America's managing director Ram Akella.

As a subsidiary of TSMC (an NYSE-listed, publicly traded company with a market capitalization exceeding \$90bn), TSMC Solar reckons that it

brings unparalleled financial stability and 'bankability' to integrators, owners and investors.

"This partnership with TSMC Solar means expanded opportunities in serving the larger-scale commercial and utility-scale markets and new ways to provide our installers with the latest technology, products and service for their customers," says Akella. "It means more choices in solar for the end-users and it challenges the mainstream industry to take solar to the next level," he adds.

"With its great relationships with installers and widely recognized excellence in customer service, Centrosolar America is a natural fit for us as we bring our high-performance CIGS solar technology to North American markets," comments Steve McKenery, VP & general manager of TSMC Solar North America.

[www.tsmc-solar.com](http://www.tsmc-solar.com)

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

# First Solar raises CdTe total area module efficiency record from 16.1% to 17%, highest of any thin film

## Year-end lead-line production target raised to 15.6–15.8% for 2015, 17.7–18.4% for 2016, and 18.1–18.9% for 2017

First Solar Inc of Tempe, AZ, USA has raised the record for cadmium telluride (CdTe) thin-film photovoltaic total area module efficiency from 16.1% (which it set in April 2013) to 17%, as confirmed in tests performed by the US Department of Energy's National Renewable Energy Laboratory (NREL). Just in late February, First Solar announced it set a record in CdTe research cell efficiency of 20.4%.

The record module was created at First Solar's Research and Development Center in Perrysburg, OH using production-scale processes and materials, and included several recent technology enhancements that are incrementally being implemented on the firm's commercial production lines.

Notably, First Solar's research module also has a confirmed 'aperture area' conversion efficiency of

17.5%. The firm says that many manufacturers often quote this aperture area efficiency when claiming record performance, particularly for small mini-modules custom-built in R&D labs. First Solar says that its record significant because it is full production size.

"This achievement demonstrates our ability to rapidly and reliably transfer research results to full-size modules," says chief technology officer Raffi Garabedian. "We can take CdTe innovation from the lab to production faster and more reliably than other technologies due to our robust, adaptable manufacturing processes and the accommodating nature of CdTe material technology," he reckons. "Our R&D efforts are delivering technology that will quickly be scaled to real-world application as part of our integrated power plant systems."

Garabedian reckons that the efficiency record is also a signal that First Solar's CdTe modules are becoming a more attractive option for application in constrained-space projects and commercial/industrial installations. "With the highest demonstrated thin-film module performance, we are positioned to pursue new deployment opportunities around the world."

Based on the firm's sustained rapid technology development, Garabedian says that First Solar has accelerated its production module conversion efficiency roadmap, raising its year-end lead-line production nameplate efficiency target to 15.6–15.8% for 2015, 17.7–18.4% for 2016 (up from the prior target of 16.2–16.9%), and 18.1–18.9% for 2017 (up from 16.4–17.1%).

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

## Shams Ma'an secure 20-year PPA for Jordan's largest PV project

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar and Shams Ma'an Power Generation have signed a power purchase agreement (PPA) for a planned 52.5MW<sub>AC</sub> solar power plant in the Hashemite Kingdom of Jordan. The PPA was signed with the National Electric Power Company (NEPCO), the country's regulatory authority for power generation and distribution, and is valid for 20 years.

Shams Ma'an Power Generation PSC — which counts First Solar GmbH of Mainz, Germany as a shareholder — was established to pursue solar energy opportunities in the country. In addition to supplying solar modules, First Solar will also provide engineering, procurement & construction (EPC) and operations & maintenance

(O&M) services for the project.

"The Shams Ma'an solar power plant represents the future of Jordan's energy independence," says Shams Ma'an's CEO Hanna Zaghloul. "By bringing together industry-leading capabilities, international financing and advanced thin-film technology that is ideally suited to local conditions, we will establish a regional benchmark for the independent production of power," he adds. "Adding PV capacity to the country's energy generation portfolio offers Jordan and its people a winning value proposition."

The power plant (the largest facility of its kind in Jordan, representing 1% of the country's overall generation capacity) will supply 160 million kilowatt hours (kWh) of electricity per year, sufficient to power more than 35,000 average

homes in the country. The project, which is part of the Ma'an Development Area (MDA) initiative in southern Jordan, will generate an estimated 500 jobs during construction. The plant will also help the country reduce its carbon footprint by displacing about 90,000 metric tons of carbon dioxide (CO<sub>2</sub>) per year, equivalent to removing about 20,000 cars from its roads.

"This agreement marks a significant step towards fulfilling Jordan's energy security goals," believes Ahmed S. Nada, VP of business development for First Solar in the Middle East. "Shams Ma'an will help power sustainable growth and development with clean, affordable and reliable solar electricity," he adds.

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

# First Solar expects 2014 sales to rise to \$3.7–4bn, with operating cash flow of \$250–450m

**Sales to rise to \$3.8–4.3bn and \$3.8–4.5bn in 2015 and 2016; operating cash flow to grow to \$300–600m then \$800–1300m**

First Solar has announced full-year 2014 guidance as well as summary financial targets through 2016.

For 2014, First Solar expects net sales of \$3.7–4bn, up from \$3.31bn in 2013. Gross margin should be 16–18%. Operating income is expected to be \$270–320m (down from \$368m in 2013), and diluted earnings per

share \$2.20–2.60 (down from \$4.35). Operating cash flow should be \$250–450m (down from \$856m). The firm plans \$300–350m of capital expenditures (up from \$282.6m in 2013).

Also, for 2015 and 2016 respectively, First Solar expects net sales to rise to \$3.8–4.3bn and \$3.8–4.5bn, and operating cash

flow to rise to \$300–600m then \$800–1300m. Diluted earnings per share should rise to \$4.50–6.00 in 2015 but then fall to \$3.50–5.00 in 2016.

Chief financial officer Mark Widmar provided the guidance and outlook during the company's 2014 Analyst Day event in New York.

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

## First Solar completes 1.3MW PV plant at Kitakyushu-shi in Japan

First Solar has announced completion of the 1.3MW<sub>DC</sub> solar PV power plant at Kitakyushu-shi.

Powered by First Solar's FS Series 3 Black PV modules, the plant will generate about 1400MWh of electricity per year. Power from the project will be purchased by Kyushu Electric Power Company.

"Japan has ambitious solar power development goals to help mitigate

the dependency on nuclear energy," says First Solar's chief commercial officer Joe Kishkill.

"Completion of the Kitakyushu-shi project supports that commitment along with providing electricity users with a fuel alternative that is safe, can be rapidly deployed, and has the smallest carbon footprint."

Begun last November, the project had a workforce of about 65 con-

struction jobs at its peak, building local capability to construct similar solar power projects in the future.

First Solar holds 100% equity in the project. Obayashi Corp (based in Tokyo) and Yaskawa Electric Corp (based in Kitakyushu) constructed the project. Tokyo-based Nippon Sheet Glass Co Ltd (NSG Group) supplied the glass used in the PV modules.

## First Solar optimizes CdTe PV modules for GE's new 4MW ProSolar 1500V inverter/transformer system

GE's Power Conversion business and First Solar are utilizing their technology and commercial partnership (announced last August) to develop a more cost-effective and productive utility-scale PV power plant design that combines First Solar's thin-film cadmium telluride (CdTe) photovoltaic modules with GE's new ProSolar 1500V inverter/transformer system.

First Solar has integrated new technology into its modules and optimized them for 1500V<sub>DC</sub> applications. Combined with GE's 4MW ProSolar 1500V inverter/transformer stations, the development enables power plant engineering design that significantly increases the size of the solar array served by each inverter and reduces the number of

inverter/transformer stations required for each plant to convert the power from direct current (DC) to alternating current (AC) and feed electricity to a commercial electrical grid, says First Solar. The resulting plant design maintains high power delivery while lowering installation and maintenance costs, it is claimed.

Future generations of First Solar modules will increase optimization, benefiting from advances gained in part from the acquisition last fall of GE thin-film PV technology, notes Mahesh Morjaria, First Solar's VP of product management.

"With our ProSolar inverters, we were able to draw from our experience developing and manufacturing technology for traditional power plants to create a highly efficient

solution with industry-leading capabilities," claims GE Power Conversion's CEO Joe Mastrangelo.

"The inverters' design enable our customers to apply engineering design that significantly increases efficiency of energy production."

First Solar has already identified projects under construction for initial deployment of the 1500V system, says Morjaria. The 4MW ProSolar 1500V station is the largest inverter in the industry capable of accommodating 1500V DC solar arrays, which is a major factor in utilizing economies of scale by significantly increasing the array size and reducing the number of inverters required by a solar power plant, reckons First Solar.

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

# Moapa Paiute Tribe, LADWP and First Solar break ground on 250MW project

US Senate Majority Leader Harry Reid (NV) joined representatives from the Moapa Band of Paiutes, executives from cadmium telluride (CdTe) thin-film photovoltaic modules First Solar Inc of Tempe, AZ, USA and the Los Angeles Department of Water and Power (LADWP), as well as other community, government and energy industry leaders to celebrate the start of construction of the 250MW<sub>AC</sub> Moapa Southern Paiute Solar Project. The project is located on the Moapa River Indian Reservation just north of Las Vegas, and has a power purchase agreement (PPA) with the LADWP to deliver solar energy for 25 years to the City of Los Angeles.

"The Moapa Southern Paiute Solar project is the first utility-scale solar project on tribal land and will deliver much needed economic benefits to the Tribe and Nevada," says Reid. "It will also create about 400 construction jobs."

The power plant, anticipated to be fully operational by the end of 2015, is expected to generate enough energy to serve the needs of more than 93,000 homes, displacing about 313,000 metric tons of carbon dioxide (CO<sub>2</sub>) annually (equivalent to taking about 60,000 cars off the road).

The project will play a key role in LADWP's efforts to expand renewable energy to 33% of its total power supply and to eliminate coal power. The Moapa plant will contribute 2.4% toward LADWP's renewable energy portfolio. This transformational goal also includes reducing energy use by at least 10% through energy-efficiency measures; expanding local solar and other forms of distributed generation; initiating a robust demand-response program; and rebuilding local power plants to better integrate renewable energy and be more flexible to meet peak demand.



**(From right to left) US Senate Majority Leader Harry Reid joins Moapa Band of Paiutes chairwoman Aletha Tom, First Solar's CEO James Hughes, LADWP's director of power system planning and development Randy Howard, and the Moapa Band of Paiutes Tribal Council to break ground on the 250MW Moapa Southern Paiute Solar Project.**

"The Moapa Southern Paiute Solar Project is a significant step toward the Los Angeles Department of Water and Power's effort to achieve a major transformation of the city's power supply — one that has greater reliance on renewable energy resources and zero coal power," says LADWP's general manager Marcie L. Edwards.

For the Moapa Band of Paiutes, the utility-scale solar project is an opportunity for the Tribe to create economic opportunities while preserving the land and their cultural heritage. "This will help to create a model for other Tribes to follow," reckons Aletha Tom, chairwoman of the Moapa Paiute Tribal Council. "Tribes across the nation have the available land on which to build them."

Moapa Southern Paiute Solar LLC (a subsidiary of First Solar Electric LLC) is the project owner and will construct the project using First Solar's modules. It will be built on 2000 acres of land on the Moapa

River Indian Reservation and include an onsite substation and a new 5.5 mile 500kV transmission line that will connect the project to the existing Crystal Substation, serving energy users in California.

Once the Moapa Southern Paiute Solar facility becomes fully operational, LADWP will be able to repurpose existing transmission systems that currently bring high-carbon coal power from Navajo Generating Station. The Moapa plant, along with a second utility-scale solar power plant in that region of Nevada, will enable LADWP to stop receiving coal power from the Navajo plant by the end of 2015, four years before it is required by California state law — reducing greenhouse-gas emissions by 8.4 million metric tons (MMT) between 2014 and 2019 cumulatively. The energy from the two solar power projects in Nevada will contribute over 4% to LADWP's goal of 33% renewable energy by 2020.

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

# Xenics strengthens direct sales force for XenicsCores SWIR & LWIR OEM modules, targeting security markets

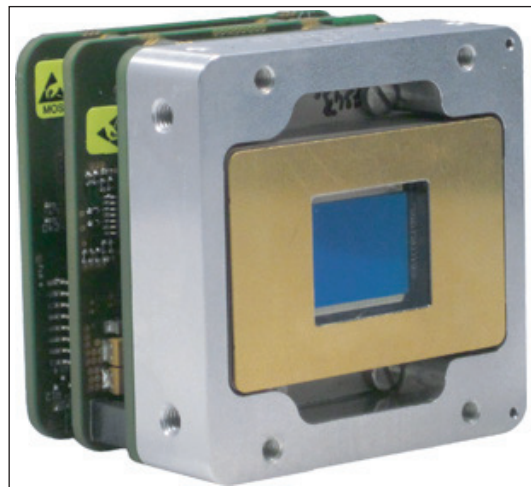
Xenics nv of Leuven, Belgium — a manufacturer of infrared detectors, cameras and customized IR imaging solutions covering the spectrum from long-wavelength infrared (LWIR) to the visible (0.4–14μm) — is expanding its reach to the government and security systems community by strengthening its direct sales force for the XenicsCores product line of short-wave infrared (SWIR) and long-wave infrared (LWIR) OEM modules. Xenics has recently appointed a new European sales manager and added another staff position to cover the OEM security market.

After more than ten years of building and expanding its position in the R&D and industrial automation markets for its uniquely qualified IR detectors and camera systems, Xenics is focusing on targeting the demanding and rapidly growing segment of government and security applications, such as active and passive day/night-vision for enhanced vision systems, situational awareness, UAV (defense, surveillance and fire-fighting), homeland security and SAR (search and rescue) missions.

Based on its in-house indium gallium arsenide (InGaAs) development and vertically integrated manufacturing capacity, Xenics is now directly marketing its proven XenicsCores product family of high-resolution OEM modules to the demanding security markets in Europe and worldwide. The XenicsCores family was announced in 2012, and is now available worldwide.

## Reaching out to government and security systems integrators

"Customers frequently state there is an important piece missing in the government and public security market for highly qualified and rugged OEM modules," says European sales manager Guido Deutz, who joined Xenics in 2012 from previous positions at Isra Vision,



**Xenics' XSW-640 short-wave IR module.**

Parsytec, FLIR, and LumaSense. "Especially the European security community is looking for an alternative supplier like us — who is not a potential competitor but close technology-wise to help build product value and accelerate time to market," he adds. "We support our customers as partners."

In this vein, the XenicsCores product family of high-resolution IR OEM modules offers easy integration and high image quality. The first two members on the market are the short-wave module XSW-640 and thermal imaging module XTM-640. These uncooled OEM modules are compact and light-weight, and offer low power consumption. Due to their easy integration via the universal QTE interconnect or standard interfaces (e.g. analog video, CameraLink or Gigabit Ethernet), they can substantially accelerate time to market for users' products, claims Xenics. Longer detection, recognition and identification distances are feasible due to the detector's small pixel size. With their powerful integrated readout electronics, their use of advanced non-uniformity compensation and image processing algorithms, the OEM modules deliver crisp IR images covering a broad range of defense and security applications under all weather conditions, says the firm.

## Unique combination of SWIR and LWIR

"Extensive use of the SWIR realm for superior day/night-vision and other security applications is being evaluated by major government system integrators," says Xenics' founder & CEO Bob Grietens. Compared with their LWIR counterparts, SWIR imagers allow the penetration of fog, haze and high humidity for camouflage detection, long-range identification and detection of lasers and other markers. "We regard the

LWIR module as a volume driver, while the SWIR version will open up new territories for extreme day- and night-vision tasks," Grietens adds.

The XSW-640 and XTM-640 modules can be combined in one imaging system, boosting detection and recognition to what are claimed to be previously unseen levels. Both modules are based on the same on-board image processing platform, featuring multiple interfaces and multiple wavelength specs. Depending on the application, the SWIR/LWIR combination is performed either through independent imaging devices or as fused imaging.

"The emerging security market is very important to us," Grietens says. "Thus, we are moving into direct sales to be closer to the system designer and manufacturer," he adds. "Last December, we have hired an extra person as sales manager XenicsCores based in Paris, France, to handle the many inquiries destined for Southern Europe."

With its European location and ITAR-free delivery, Xenics reckons it is set to gain market share in the evolving OEM security segment. In terms of quality control, Xenics is certified to ISO-9001:2008.

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

# Caltech develops high-coherence laser based on integral high-Q resonators in hybrid Si/III-V platform

**Single-mode high-Q silicon resonator yields spectral linewidth of 18kHz in telecom band**

**A** research group at California Institute of Technology (Caltech) has developed a new laser that is reckoned to have the potential to increase optical-fiber network data transmission rates by orders of magnitude ('High-coherence semiconductor lasers based on integral high-Q resonators in hybrid Si/III-V platforms', Proceedings of the National Academy of Sciences, published online 10 February).

The work is the result of a five-year effort by researchers in the laboratory of Amnon Yariv (the Martin and Eileen Summerfield Professor of Applied Physics and professor of electrical engineering). The project was led by post-doctoral scholar Christos Santis and graduate student Scott Steger.

In long-distance communications, light can carry about 10,000 times more bandwidth than microwaves. But, to utilize this potential, the laser light needs to be as spectrally pure as possible. For decades researchers have been trying to develop a laser that comes as close as possible to emitting just one frequency.

Optical-fiber networks are currently still powered by distributed-feedback semiconductor (S-DFB) lasers, developed in the mid 1970s in Yariv's research group. The S-DFB laser's unusual longevity in optical communications stemmed from its, at the time, unparalleled spectral purity. The laser's increased spectral purity directly translated into greater information bandwidth of the laser beam and longer possible transmission distances in the optical fiber, hence more information could be carried further and faster than before.

At the time, this unprecedented spectral purity was a direct consequence of the incorporation of a nanoscale corrugation within the laser's multilayered structure. The surface acts as an internal filter, discriminating against spurious 'noisy' waves contaminating the ideal wave frequency. Although the S-DFB laser has had a 40-year run in optical communications — and was cited as the main reason for Yariv receiving the 2010 National Medal of Science — the spectral purity

(coherence) of the laser no longer satisfies the ever-increasing demand for bandwidth, says Caltech.

"Present-day laser designs — even our S-DFB laser — have an internal architecture which is unfavorable for high-spectral-purity operation," says Yariv. "This is because they allow a large and theoretically unavoidable optical noise to commingle with the coherent laser and thus degrade its spectral purity," he adds.

The S-DFB laser consists of continuous crystalline layers of III-V semiconductor materials — typically gallium arsenide and indium phosphide — that convert into light the applied electrical current flowing through the structure. Once generated, the light is stored within the same material. Since III-Vs are also strong light absorbers (leading to a degradation of spectral purity), the researchers sought a different solution to lossy III-V material for storing the optical energy.

Their new high-coherence laser still uses III-V materials for light generation but, in a fundamental departure from the S-DFB laser, it stores the light in a layer of silicon, which does not absorb light. Spatial patterning of this optically passive, low-loss silicon layer — a variant of the corrugated surface of the S-DFB laser — causes it to act as a light concentrator, pulling the newly generated light away from the light-absorbing III-V material and into the near-absorption-free silicon. A very high-Q resonator is hence incorporated as an integral (rather than externally coupled) part of the laser cavity.

The resultant high spectral purity — a 20 times narrower range of frequencies than possible with the S-DFB laser — could be especially important for the future of fiber-optic communications, it is reckoned. Originally, laser beams in optic fibers carried information in pulses of light; data signals were impressed on the beam by rapidly turning the laser on and off, and the resulting light pulses were carried through the optic fibers. However, to meet the increasing demand for bandwidth, communications system engineers are adopting the coherent phase communication method

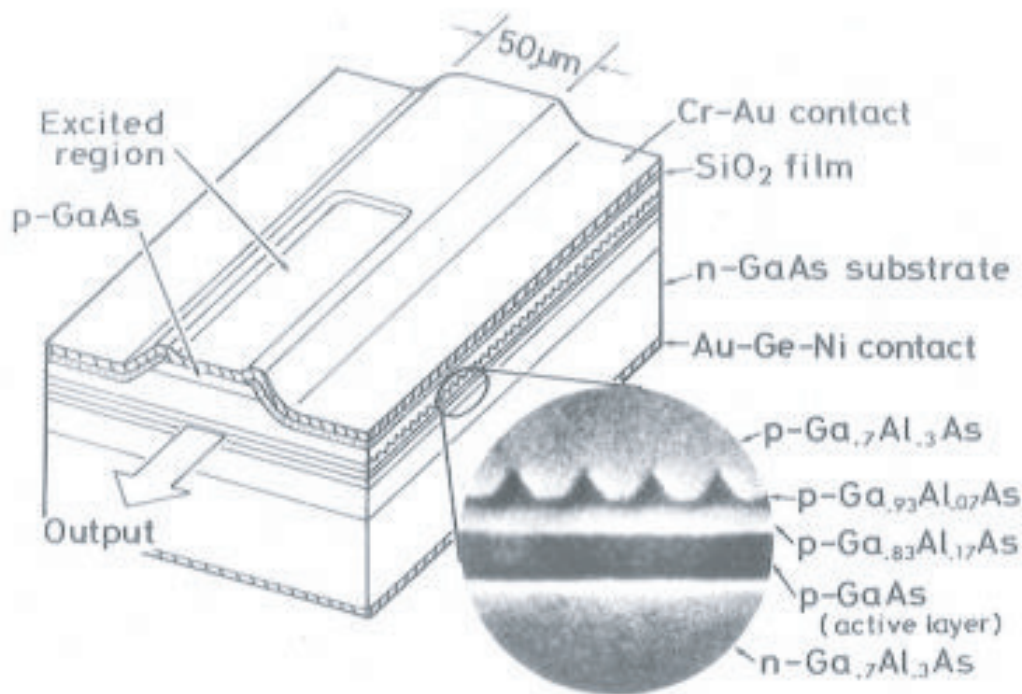
of impressing data on laser beams, which no longer requires an 'on-off' technique.

In coherent phase communications, the data resides in small delays (about  $10^{-16}$  of a second in duration) in the arrival time of the waves, which can then accurately relay the information even over thousands of miles. Digital electronic bits (carrying video, data, or other information) are converted at the laser into these small delays in the otherwise steady light wave. But the number of possible delays, and thus the data-carrying capacity of the channel, is fundamentally limited by the degree of spectral purity of the laser beam. This purity can never be absolute — a limitation of the laws of physics — but with the new laser, Yariv and his team have tried to come as close to absolute purity as is possible.

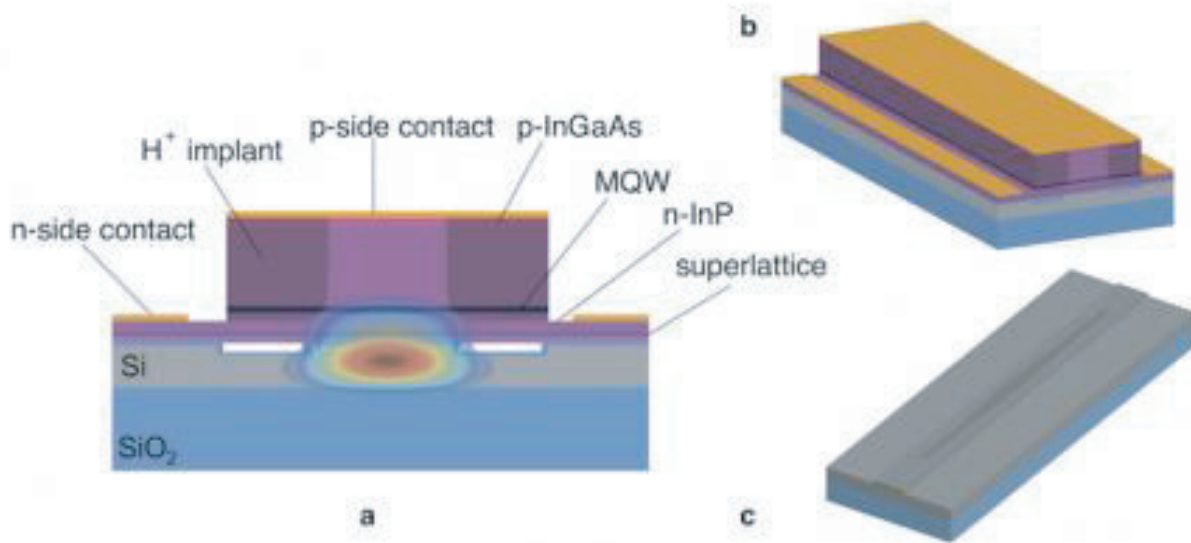
Consequently, using a single-mode silicon resonator with a Q value of 106, the team has demonstrated a laser with a spectral linewidth of 18kHz in the telecom band (around  $1.55\mu\text{m}$ ).

In addition to Yariv, Santis, and Steger, other Caltech co-authors include graduate student Yaakov Vilenchik, and former graduate student Arseny Vasilyev. The lasers

## S-DFB Laser (1975)



## High-coherence Laser (2014)



**Caltech's high-coherence laser includes a layer of non-light-absorbing silicon. Credit: Amnon Yariv/Caltech.**

were fabricated at the Kavli Nanoscience Institute at Caltech. The work was funded by the US Army Research Office, the National Science Foundation (NSF), and the Defense Advanced Research Projects Agency (DARPA). ■

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[www.its.caltech.edu/~aphyariv](http://www.its.caltech.edu/~aphyariv)

# PLD/MBE m-plane gallium nitride on lithium gallate

**An InGaN/GaN MQW structure on a GaN/LiGaO<sub>2</sub> buffer gives photoluminescence performance comparable to commercially available LEDs and semi-polar LEDs.**

**S**outh China University of Technology has improved the quality of non-polar m-plane nitride semiconductor layers on lithium gallate (LiGaO<sub>2</sub>) by combining pulsed laser (PLD) and molecular beam epitaxy (MBE) deposition techniques [Weijia Yang et al, J. Mater. Chem. C, vol2, p801, 2014].

Non-polar nitride semiconductors are of interest for producing higher internal quantum efficiency (IQE) and hence more efficient light-emitting devices. However, the growth of non-polar material is difficult to achieve with sufficient quality or at low cost.

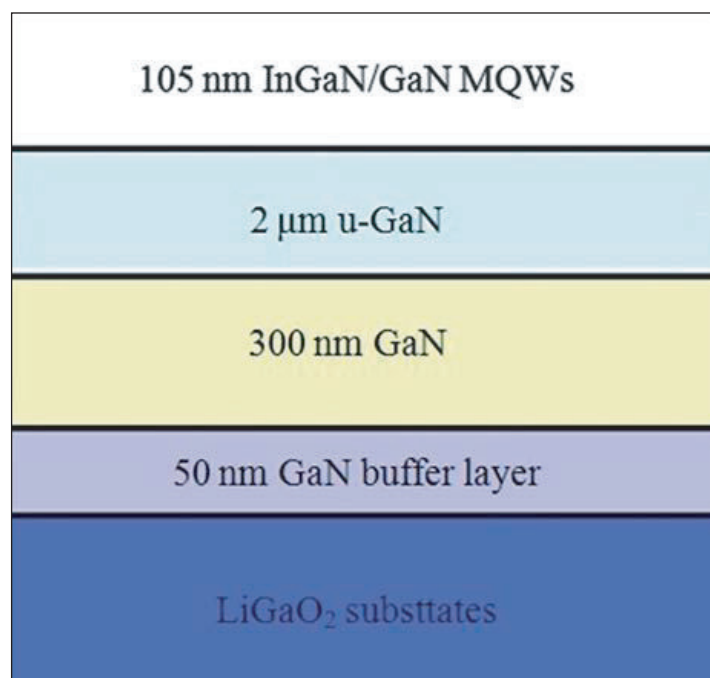
LiGaO<sub>2</sub> (100) is an attractive substrate for m-plane gallium nitride (GaN) deposition because it has a lattice mismatch as small as 0.1%. Also, the thermal expansion coefficient is more nearly matching, compared with alternatives. Thermal expansion mismatch creates problems in processes involving temperatures up to 1000°C.

One drawback with LiGaO<sub>2</sub> is that the lithium component tends to evaporate at raised temperature, as needed for MBE or metal-organic chemical vapor deposition (MOCVD).

PLD has been used to grow m-plane GaN at relatively low temperature, avoiding lithium evaporation, but the quality of the resulting material has not been sufficient for applications such as light-emitting diodes (LEDs) or laser diodes (LDs).

The researchers have designed a tool that allowed both PLD and MBE to be carried out in one ultrahigh-vacuum chamber. The system had access to gallium and indium MBE sources, along with a liquid gallium PLD target. The laser source was an external 248nm-wavelength krypton fluoride excimer laser focused through optical lenses on the target.

The LiGaO<sub>2</sub> wafer was first annealed at 1000°C for 4 hours and cleaned to give an atomically flat surface free of contamination. After putting the wafer in the vacuum chamber and pumped down to 5x10<sup>-11</sup>Torr, the laser was used to ablate Ga with 220mJ pulses at 20Hz frequency. The substrate was positioned 5cm away and heated to 200°C. For the nitrogen source, N<sub>2</sub> gas was pumped in at 6x10<sup>-3</sup>Torr pressure and put through a purifier and a 500W radio-frequency plasma radical generator.



**Figure 1. Schematic structure of InGaN/GaN MQWs grown on LiGaO<sub>2</sub>(100) substrates.**

The PLD was used to grown 50nm of m-plane GaN as a template for further GaN layers: 300nm through 500°C MBE, and 2μm through 750°C MBE.

The GaN(1100) x-ray rocking curves show improved crystallinity in the upper layers, as indicated by narrower full-width at half maximum (FWHM) values: 0.55° for the PLD layer, 0.14° for the 500°C MBE, and 0.098° for the final 2μm layer. These values compare very favorably with the 0.25° previously achieved in a PLD-only approach.

The PLD/MBE layers are estimated to have dislocation densities of 1.6x10<sup>10</sup>/cm<sup>2</sup>, 1.1x10<sup>9</sup>/cm<sup>2</sup>, and 5.1x10<sup>8</sup>/cm<sup>2</sup>, respectively.

The researchers checked that no lithium diffused from the substrate into the overlying GaN layer with x-ray photo-electron spectroscopy (XPS) that showed the initial low-temperature m-plane GaN buffer had suppressed Li diffusion from the substrate.

To demonstrate the possibilities for LED production, the researchers added a 7-period InGaN/GaN (3nm/12nm) multiple quantum well (MQW) structure with 700°C

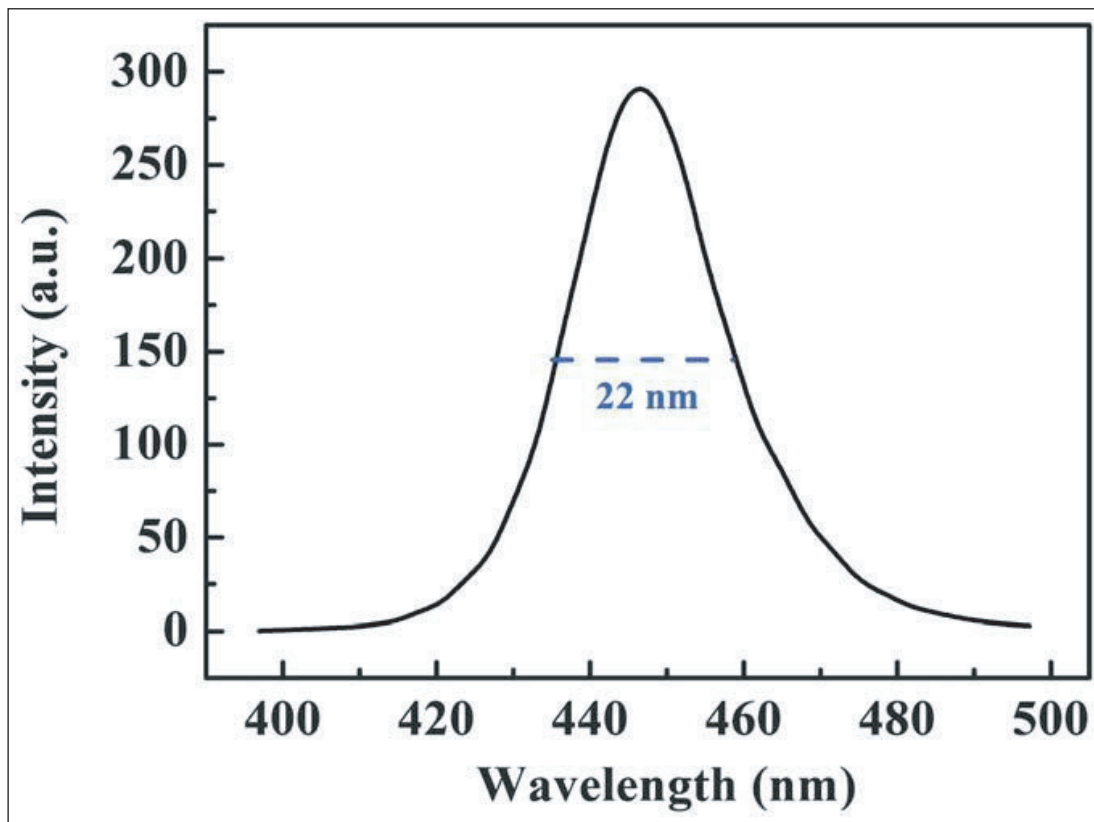
**Figure 2. Room-temperature photoluminescence spectrum of non-polar m-plane InGaN/GaN MQWs on LiGaO<sub>2</sub> substrate.**

MBE (Figure 1). The indium composition of the wells was 0.156. The InGaN layers were estimated to have a dislocation density of  $6.6 \times 10^8/\text{cm}^2$ , on the basis of an x-ray rocking curve FWHM of  $0.11^\circ$ .

Photoluminescence measurements gave a peak at 445nm and a FWHM of 22nm (Figure 2), "comparable to the commercially available LEDs and semi-polar InGaN/GaN LEDs", according to the researchers. ■

<http://dx.doi.org/10.1039/C3TC31935K>

Author: Mike Cooke



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# Gallium nitride quantum dots and deep UV light emission

**University of Notre Dame produces LEDs with wavelengths as short as 243nm.**

**U**niversity of Notre Dame is developing gallium nitride (GaN) quantum dots in aluminium nitride (AlN) as a route to deep ultraviolet (UV) light-emitting diodes (LEDs) [Jai Verma et al, Appl. Phys. Lett., v104, p021105, 2014].

Aluminium gallium nitride deep-UV LEDs are being widely developed for water purification, sterilization, integrated biosensors, solid-state lighting, and lithography. "The availability of low-power, lightweight, and robust deep-UV light sources are expected to seed several unforeseeable applications," the University of Notre Dame (UND) researchers add.

The leader of the research team, Debdeep Jena, also sees potential for low-threshold lasers: "Quantum-dot lasers require much lower threshold injection currents than quantum well or double-heterostructure lasers due to the reduced dimensionality. In extremely wide-bandgap semiconductors, free carriers do not come about easily because of doping problems. Thus a quantum dot active region is highly attractive for electrically injected deep-UV lasers. That is really the long-term goal driving this work."

Presently the external quantum efficiency (EQE) of AlGaIn quantum well LEDs is low (a few percent at most in the 250nm wavelength region) due to a number of challenges. A leading problem is the difficulty in injecting sufficient numbers of electrons and holes into the active region.

An additional (and related) problem is that the hole source tends to be restricted to GaN or very low Al-content AlGaIn with a bandgap narrower than the emitted radiation. This means that the emitted photons are strongly absorbed by the p-contact.

The researchers see two advantages for GaN QDs over AlGaIn QWs: "Three-dimensional confinement prevents electrons and holes from thermally diffusing to dislocations and recombining nonradiatively. The monolayer thickness makes the emission process robust to quantum-confined Stark effect (QCSE)."

The confinement of the electron and hole energy levels in quantum dot devices increases the bandgap, allowing higher-energy, shorter-wavelength photons to be produced. The electron injection and hole injection operate by tunneling enabled by alignment of the conduction and valence bands with the electron and hole energy levels of the confined GaN QDs, rather than the

drift/diffusion of traditional devices. Tunnel injection avoids problems from self-heating effects.

To tackle the problem with the p-type hole injecting contact, the UND researchers used "polarization doping" to allow the use of wider-bandgap AlGaIn rather than GaN. The technique uses changes in polarization given by grading the Al-content of the AlGaIn layer to enhance the activation of the magnesium doping. Normally, high-Al-content AlGaIn has a prohibitively high activation energy that kills hole densities and hence conductivity.

Growth of the semiconductor material was through plasma-enhanced molecular beam epitaxy on thick AlN-on-sapphire templates. The AlN nucleation and buffer layers were grown at 730°C. The active layers of compressively strained GaN quantum dots were formed due to the 2.4% lattice mismatch with AlN.

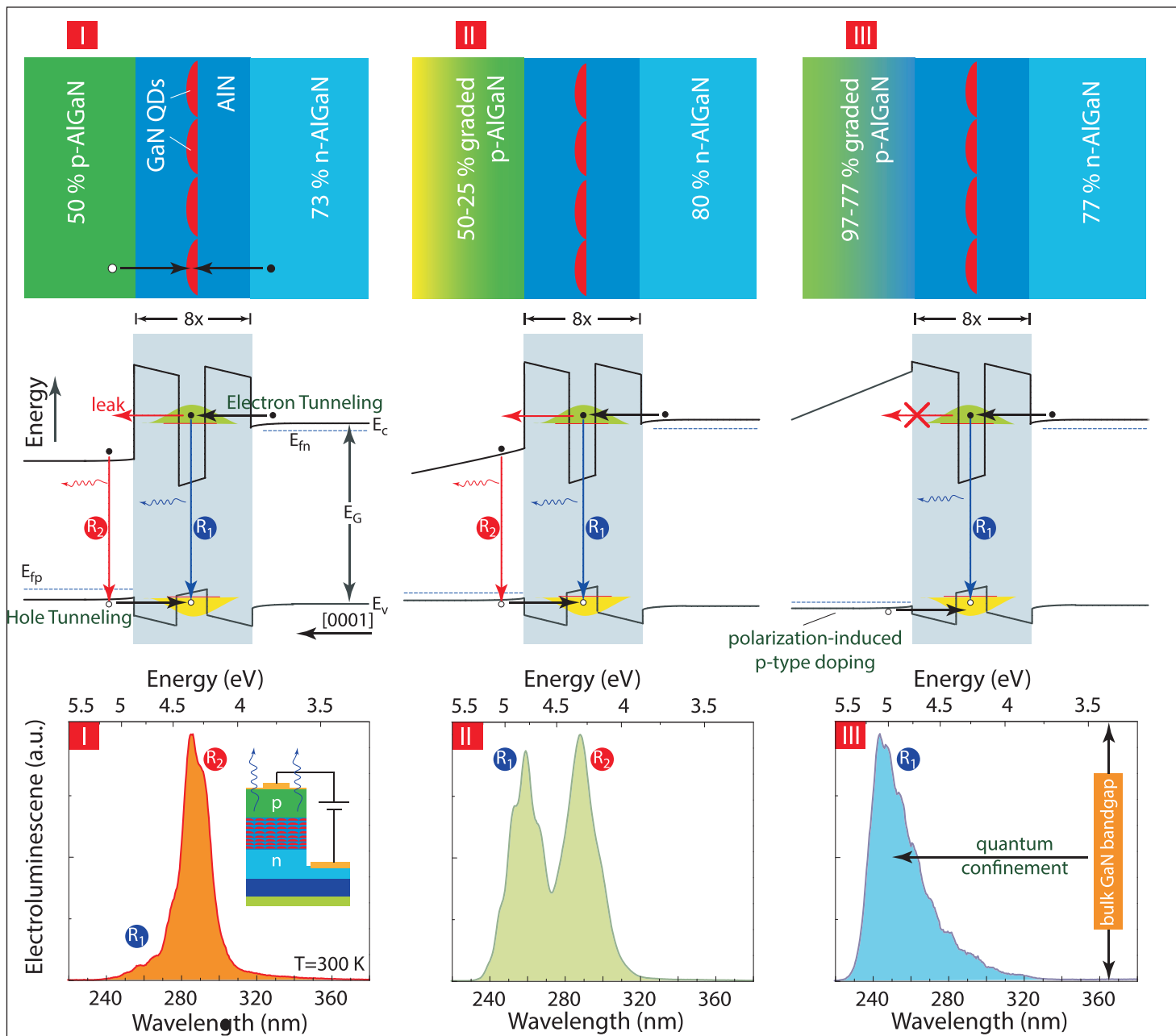
The photoluminescence of the GaN quantum dots can be varied by altering the growth time or Ga flux. A reduction in growth time from 35 to 25 seconds with  $6.2 \times 10^{-8}$  Torr Ga flux reduces the peak wavelength from 270nm to 246nm. Also, in the longer-wavelength case, there is a secondary peak, which is much reduced in the shorter-wavelength QDs. Reducing the Ga flux to  $5.6 \times 10^{-8}$  Torr with 25 second growth blue-shifts the wavelength further to 238nm.

An alternative technique with a Ga-rich flux of  $2.6 \times 10^{-7}$  Torr, but interrupting the growth after 12 seconds for up to 45 seconds, gave a PL peak wavelength as short as 234nm, corresponding to a photon energy of 5.3eV. Bulk GaN has a bandgap of 3.4eV in the near UV (~365nm).

The researchers attribute the shorter wavelength from the interrupt process as being due to smaller, more confined dots as a result of Ga desorption. The QD heights were 0.58nm in 2.7nm AlN barriers, as determined in transmission electron micrograph (TEM) and x-ray diffraction analysis.

The LED active regions consisted of 8 layers of QDs. Two of the devices used the 25-second growth method, and one used the interrupted technique with 12-second growth followed by 25-second "ripening".

The n-type electron injection region consisted of 225nm silicon-doped AlGaIn. A 117nm p-type hole injection region was achieved by different techniques. One of the 25-second growth devices used a traditional



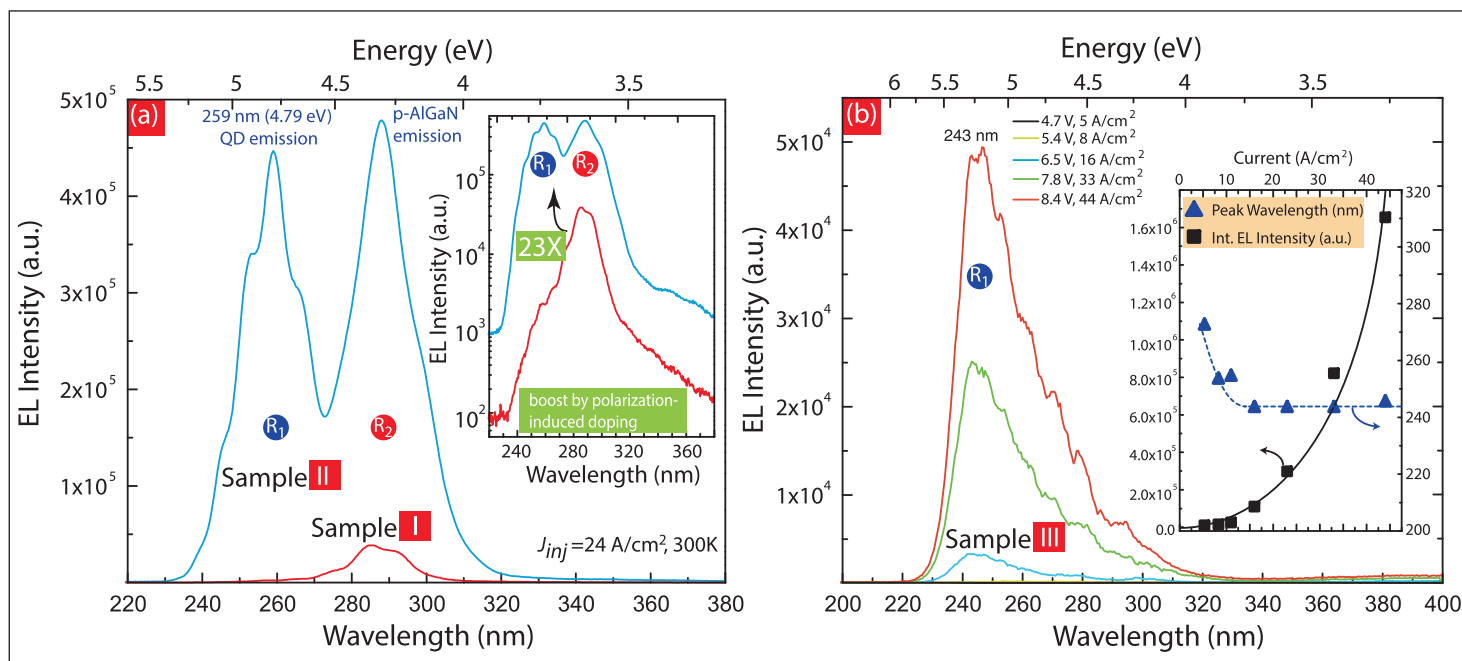
**Figure 1. Schematic cross-section of GaN/AlN QD UV LEDs. Sample I: 73% n-AlGaN, 50% p-AlGaN; sample II: 80% n-AlGaN, 50%-25% p-AlGaN; sample III: 77% n-AlGaN, 97%-77% p-AlGaN. Corresponding schematic band diagrams at forward bias, showing tunneling transport and recombination mechanisms in QDs (R<sub>1</sub>) and AlGaIn cladding layer (R<sub>2</sub>). Individual electroluminescence (EL) spectra for structures show short- and long-wavelength emissions.**

uniform magnesium-doped Al<sub>0.5</sub>Ga<sub>0.5</sub>N layer (sample I). The two other samples used 'polarization doping' that consisted of grading the x-value of magnesium-doped Al<sub>x</sub>Ga<sub>1-x</sub>N by varying the Al flux during growth. For the second 25-second growth device the grading was from 0.5 to 0.25 (sample II). The third interrupted growth device used a 0.97-0.77 grading (sample III).

The 300µm x 300µm LEDs were fabricated by etching mesas, applying titanium/aluminium/nickel/gold to the exposed n-type surface and a thin nickel/gold transparent current-spreading electrode to the p-type surface, and then depositing titanium/gold p-contact pads.

The sample III device also blocks electron overflow (Figures 1 and 2). In fact, the sample I device has most of its emission emanating from the p-type injection region rather than the QDs. The sample II device has improved emission from the QDs, but some of this radiation is converted in the p-type region into the longer wavelength of transitions in the p-type region (down-conversion), along with emissions from electron leakage.

The sample III devices solve both the leakage and down-conversion problems, giving a single deep-UV peak at 243nm (5.1eV). The electron leakage is blocked by the thicker barrier to leakage and down-



**Figure 2. (a) EL spectra for graded AlGaIn layer LED (sample II) showing emission from QDs (259nm) and p-AlGaIn layer (290nm). Non-graded AlGaIn layer LED (sample I) shows weak QD emission. EL intensity from sample II is 23 times larger than from sample I, implying better hole concentration due to polarization-induced doping. Inset: log scale EL spectra. (b) EL spectra for 97%–77% graded AlGaIn layer LED (sample III) showing 243nm emission from GaN QDs grown in interrupted growth mode. Inset: EL peak wavelength and intensity variation with injection current density.**

conversion by the wider bandgap, preventing re-absorption of QD photons.

The researchers believe further improvements could come from examining the effect of the number of periods in the active region and improving the ohmic contacts to the p-type layer, along with incorporating

polarization-induced doping in the n-type AlGaIn layer as well. The team is also working on fully calibrated characterization of the devices using an integrating sphere. ■

<http://dx.doi.org/10.1063/1.4862064>

Author: Mike Cooke

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# New 'universal' method for transparent conduction on nitride semiconductors

Transparency of 95% has been maintained in some candidate materials to a deep ultraviolet wavelength of 250nm.

**R**esearchers based in Korea and USA believe they have developed "a universal method of producing transparent electrodes with high conductivity and high optical transmittance in the UV regimes using electrical breakdown (EBD) to form conducting filaments (CFs) providing a current path between the transparent conducting electrodes (TCEs) and the semiconductor, which leads to a large reduction in their contact resistance." [Hee-Dong Kim et al, Adv. Funct. Mater., published online 11 November 2013].

The team from Korea University, LG Advanced Research Institute, and Rensselaer Polytechnic Institute (RPI) comment: "We highly expect that the proposed CF-based TCEs can be immediately applied to many types of optoelectronic devices (and systems), including LEDs, organic LEDs, solar cells, and even large-area display panels that require TCEs with high conductivity and high transmittance in the UV-to-IR wavelength regimes."

In particular, the researchers see applications in the deep ultraviolet (DUV), where traditional TCEs such as indium tin oxide (ITO) cut-off. DUV LEDs are being developed as light sources for killing microbes — an application that needs wavelengths shorter than 254nm. Such devices presently have external quantum efficiencies (EQE) of less than 11%.

A further factor reducing EQE in these short-wavelength LEDs is that the p-contact is usually made from p-type gallium nitride (p-GaN), which also absorbs DUV strongly. Ideally one would use an aluminium gallium nitride (AlGaN) layer that has a suitably wide bandgap, transmitting DUV radiation. Unfortunately, AlGaN is difficult to dope in a p-type direction and there has been no work thus far in creating suitable ohmic TCEs.

The researchers used the method to create ohmic or near-ohmic contacts between a range of TCE candidates and p-GaN and p-AlGaN layers. The ohmic connection between the TCE material and underlying p-AlGaN was created using the EBD forming process through applying a relatively large bias of around 17.5V between two

nickel electrodes that were placed on the TCE (Figure 1a). The increased conductivity is attributed to the formation of CFs of oxygen or nitrogen vacancies in the material. The technique seems to work with a wide variety of oxides and nitrides.

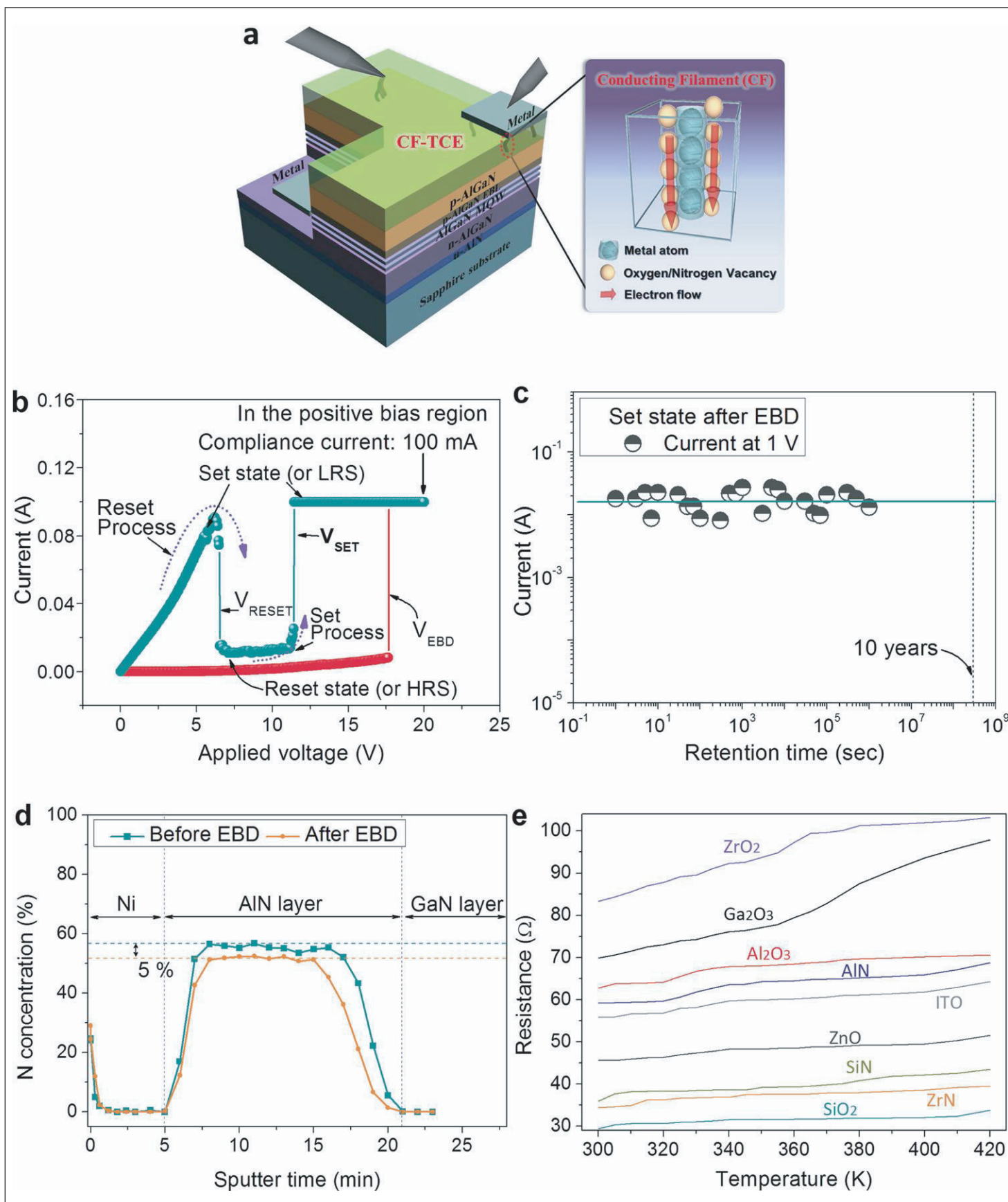
With aluminium nitride (AlN) on p-type gallium nitride (Figure 1b), a soft breakdown is seen, with the material switching between high- and low-resistance states (HRS/LRS). After a first sweep between 0V and 20V, which switched to the LRS at 17.5V ( $V_{\text{EBD}}$ ), a second sweep showed increased current up to 6.5V ( $V_{\text{RESET}}$ ) and then switched back to the HRS. The LRS was regained by a switch at 12V ( $V_{\text{SET}}$ ).

Of course, with a soft breakdown such as this, one is concerned about retention of the low-resistance state (Figure 1c). The researchers estimate that a bias of 1V giving a current of 18mA could be stably maintained at room temperature for  $3 \times 10^8$  seconds (a period of time better known as 10 years). Stability in the LRS was maintained even with 1–1000 second pulses up to 5V.

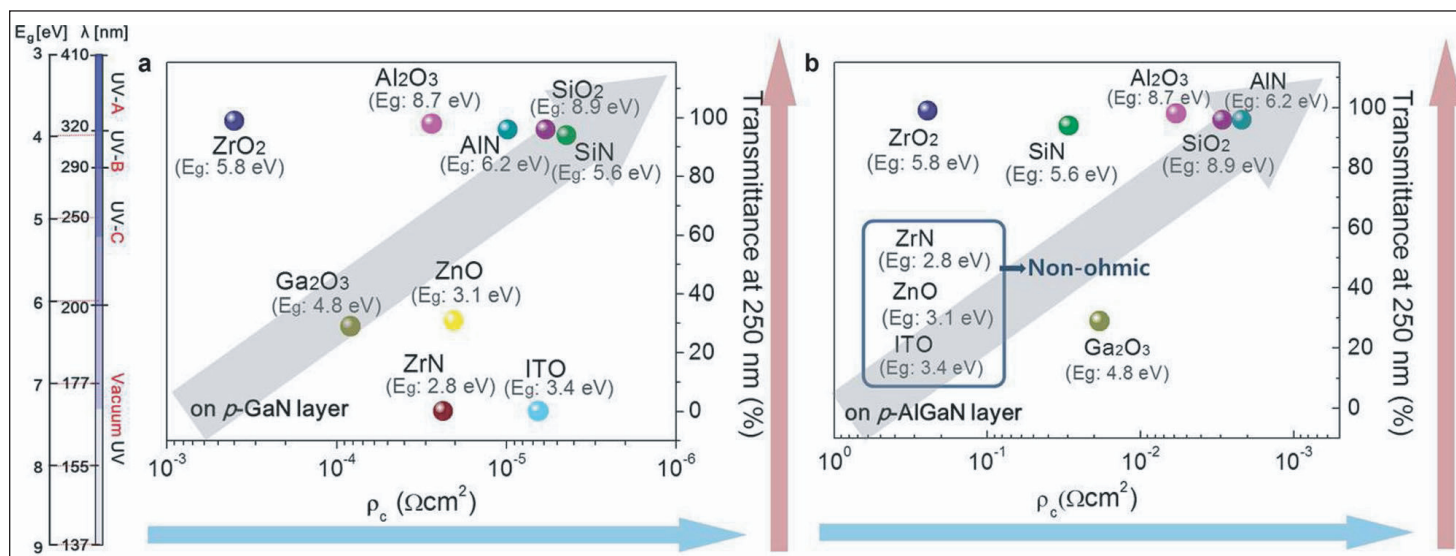
Auger electron spectroscopy (AES) confirms a depleted nitrogen fraction by about 5%, as would be expected from the formation of CFs after EBD (Figure 1d). Near the GaN layer the depletion is even more apparent, "which facilitated the formation of Ohmic contact between the TCEs and the p-GaN layers."

The EBD process results in a metallic-like conduction that shows increased resistance at higher temperatures (Figure 1e). The other materials tested showed a similar transition from a non-linear HRS to a 'perfect' linear/ohmic LRS after EBD with a similar voltage

**The researchers see applications in the deep UV, where traditional TCEs such as ITO cut-off. DUV LEDs are being developed as light sources for killing microbes — an application that needs wavelengths shorter than 254nm. Such devices presently have external quantum efficiencies of less than 11%**



**Figure 1.** (a) AlGaIn-based UV LED schematic after EBD and atomic-level view of CF within TCE. (b) Current-voltage characteristics for 80nm AlN TCE on p-GaN before and after EBD through nickel. (c) Retention characteristics of set state at 1V as function of time. (d) Nitrogen concentration of AlN film and the interface between AlN TCE and the p-GaN layer before and after EBD, analyzed by AES. (e) Temperature-dependent resistance characteristics of ITO, Al<sub>2</sub>O<sub>3</sub>, ZnO, Ga<sub>2</sub>O<sub>3</sub>, ZrO<sub>2</sub>, SiO<sub>2</sub>, ZrN, SiN, and AlN TCEs on p-GaN after EBD in 300–420K temperature range.



**Figure 2. Correlation between contact resistance ( $\rho_c$ ) for TCEs on (a) p-GaN and (b) p-Al<sub>0.5</sub>Ga<sub>0.5</sub>N after EBD and transmittances at 250nm.**

**Table 1. Average specific contact resistance, between TCEs and the p-GaN/AlGa layers.**

Material [bandgap]	Average specific contact resistance [ $\Omega\text{-cm}^2$ ]			
	on p-GaN		on p-AlGa	
	Before EBD	After EBD	Before EBD	After EBD
ZrN [2.8 eV]	Non-Ohmic	$4.91 \times 10^{-5}$	Non-Ohmic	Non-Ohmic
ZnO [3.1 eV]	Non-Ohmic	$2.81 \times 10^{-5}$	Non-Ohmic	Non-Ohmic
ITO [3.8 eV]	Non-Ohmic	$8.68 \times 10^{-5}$	Non-Ohmic	Non-Ohmic
Ga <sub>2</sub> O <sub>3</sub> [4.8 eV]	Non-Ohmic	$7.56 \times 10^{-5}$	Non-Ohmic	$2.42 \times 10^{-2}$
SiN [5.6 eV]	Non-Ohmic	$1.01 \times 10^{-5}$	Non-Ohmic	$2.55 \times 10^{-2}$
ZrO <sub>2</sub> [5.8 eV]	Non-Ohmic	$4.79 \times 10^{-4}$	Non-Ohmic	$2.75 \times 10^{-1}$
AlN [6.2 eV]	Non-Ohmic	$2.41 \times 10^{-5}$	Non-Ohmic	$4.55 \times 10^{-3}$
Al <sub>2</sub> O <sub>3</sub> [7 eV]	Non-Ohmic	$5.67 \times 10^{-5}$	Non-Ohmic	$7.10 \times 10^{-3}$
SiO <sub>2</sub> [8.9 eV]	Non-Ohmic	$1.99 \times 10^{-5}$	Non-Ohmic	$4.55 \times 10^{-3}$

sweep. Before EBD the 1V current is around  $10^{-9}$ A (1nA), while after EBD the ohmic behavior leads to  $\sim 10$ mA ( $\sim 10^{-2}$ A) at the same voltage. The transfer length method (TLM) metal pads for the resistance measurement were separated by  $2\mu\text{m}$ .

The same set of materials was also deposited on p-Al<sub>0.5</sub>Ga<sub>0.5</sub>N and subjected to EBD. In this case some of the materials were non-ohmic after EBD. Also, for those that became ohmic, the specific contact resistance was not as low as in the case of p-GaN (Table 1). Even so, the production of ohmic contacts on p-AlGa has not been tried before because of the challenges of the material such as surface oxidation, poor doping ability for p-type conduction by magnesium, and large workfunction. The 1V current was  $\sim 5$ nA before EBD and  $\sim 0.1$ mA after.

In structures with an AlGa top layer, a GaN cap is usually applied to protect against oxidation. However, in deep UV devices such cap layers absorb radiation, reducing device efficiency severely.

Another factor is that the 'ohmic' behavior on p-AlGa is not 'perfect'. The researchers write: "Although a

perfect Ohmic behavior similar to that observed in the p-GaN layers has not been obtained yet for the p-AlGa contact layers (probably because of the still immature technology of heavily doped p-AlGa layers), the obtained result is not only a first-time demonstration of the direct Ohmic contacts in p-Al<sub>0.5</sub>Ga<sub>0.5</sub>N layers but also a critical turning point in delivering a technical breakthrough in deep UV LEDs."

The measured specific contact resistances on GaN are of the order  $10^{-5}\Omega\text{-cm}^2$ . The researchers comment "These values are comparable with (or lower than) the best result reported from the metal-based p-GaN electrodes, with the additional benefit of high transmittance of over 95% at 365nm."

Transmittance characteristics were obtained by depositing the materials on quartz substrates (Figure 2). The transmittance of most of the materials was  $\sim 95\%$ , including substrate, across the deep UV to infrared (220nm–800nm) range. The exceptions were bandgap-limited ITO, ZnO, and ZrN. ■

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Author: Mike Cooke

# Increasing $f_{\text{MAX}}$ for InP/GaInAsSb transistors

ETH-Zurich fabricates GaInAsSb DHBTs with record  $f_{\text{MAX}}$  of 636GHz.

**R**esearchers at ETH-Zurich have used quaternary gallium indium arsenide antimonide (GaInAsSb) in the p-type base region of a double heterostructure bipolar transistor (DHBT) to improve performance over devices using GaAsSb or graded GaAsSb/GaInAsSb [Ralf Flückiger et al, IEEE Electron Device Letters, v35, p166, 2014].

Radio-frequency measurements gave a maximum oscillation frequency ( $f_{\text{MAX}}$ ) of 636GHz and cut-off ( $f_T$ ) of 424GHz at a collector current density of 8.8mA/cm<sup>2</sup> and collector emitter voltage of 1.6V. The researchers comment: "The present transistors offer the highest  $f_{\text{MAX}}$  to date for GaInAsSb DHBTs and match the highest  $f_{\text{MAX}}$  of any Sb-based DHBT."

DHBTs with graded bases have achieved balanced  $f_T/f_{\text{MAX}}$  performance of 480/420GHz and unbalanced performance of 670/185GHz. ETH-Zurich has previously produced GaAsSb devices with  $f_T/f_{\text{MAX}}$  of 428/621GHz (2013) and 365/501GHz (2011).

The addition of indium to GaAsSb is expected to increase minority electron mobility, reducing base transit time and thus improving the frequency response.

The epitaxial structure (Table 1) was produced on semi-insulating indium phosphide (InP) using metal-organic vapor phase epitaxy (MOVPE). The 20nm Ga<sub>0.94</sub>In<sub>0.06</sub>As<sub>0.59</sub>Sb<sub>0.41</sub> base layer had a sheet resistance of 1070Ω/square.

The sheet resistance value is considered relatively low considering the low doping concentration. Part of the explanation is given by the high hole mobility of 40cm<sup>2</sup>/V-s. A similarly doped GaAsSb layer with ~0.6 As fraction had a sheet resistance of 1140Ω/square and hole mobility of 31cm<sup>2</sup>/V-s.

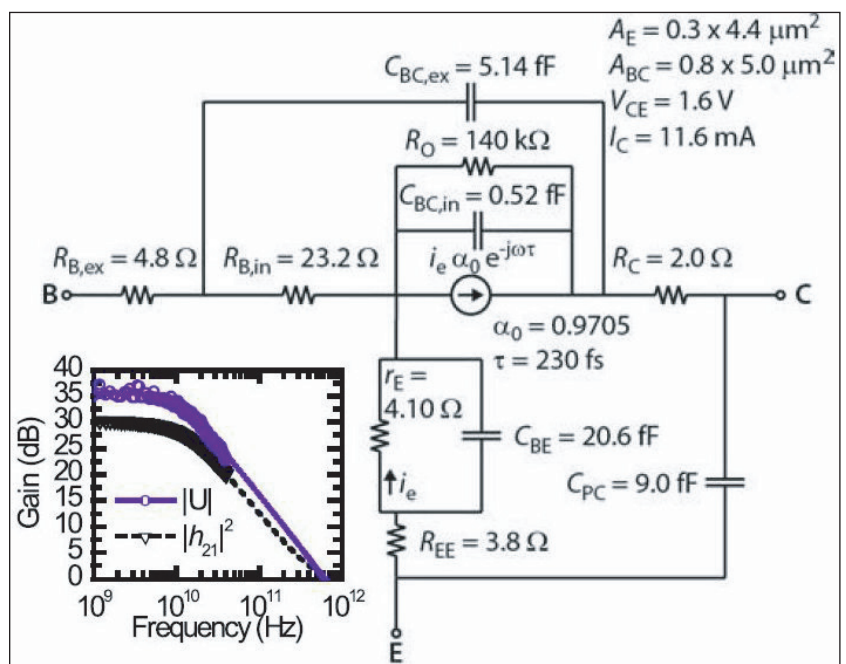
The DHBTs were fabricated using a triple-mesa process. The emitter area was 4.4μm x 0.3μm. Base/collector contact area was 5.0μm x 0.8μm.

With 0V bias across the base-collector junction, peak DC gain was 23. The researchers estimate that a GaAsSb base device with similar sheet resistance would have a gain of about half of this. The open base common emitter breakdown voltage was 4.75V.

The small-signal model for the optimum RF bias point (Figure 1) has total base resistance of 123Ω-μm (10% lower than ETH-Zurich's 2013 GaAsSb-base DHBT). ■

Material	Doping (cm <sup>-3</sup> )	Thickness
Ga <sub>0.25</sub> In <sub>0.75</sub> As	Si : 3.8×10 <sup>19</sup>	5 nm
Ga <sub>0.47</sub> In <sub>0.53</sub> As → Ga <sub>0.25</sub> In <sub>0.75</sub> As	Si : 3.8×10 <sup>19</sup>	10 nm
Ga <sub>0.47</sub> In <sub>0.53</sub> As	Si : 3.8×10 <sup>19</sup>	20 nm
InP	S : 3.0×10 <sup>19</sup>	130 nm
InP	Si : 4.3×10 <sup>16</sup>	5 nm
Ga <sub>0.10</sub> In <sub>0.9</sub> P → InP	Si : 4.3×10 <sup>16</sup>	10 nm
Ga <sub>0.10</sub> In <sub>0.9</sub> P	Si : 4.3×10 <sup>16</sup>	5 nm
Ga <sub>0.94</sub> In <sub>0.06</sub> As <sub>0.59</sub> Sb <sub>0.41</sub>	C : 7.3×10 <sup>19</sup>	20 nm
InP	S : 1.3×10 <sup>17</sup>	125 nm
InP	S : 2.2×10 <sup>19</sup>	50 nm
Ga <sub>0.40</sub> In <sub>0.60</sub> As	Si : 3.0×10 <sup>19</sup>	20 nm
InP	S : 2.2×10 <sup>19</sup>	300 nm
InP semi-insulating 2-inch substrate		350 μm

**Table 1. Epitaxial layer structure for ETH-Zurich DHBT with InP collector, GaInAsSb base, and GaInP/InP emitter.**



**Figure 1. Small-signal equivalent circuit with component values extracted from S-parameter measurements at  $V_{\text{CE}}$  bias of 1.6V and  $I_C$  at 11.6mA. Inset: measured  $|h_{21}|^2$  and U (symbols) with corresponding simulated small-signal data (lines).**

<http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=6709773>

Author: Mike Cooke

# Embedded Schottky diode for unidirectional GaN HFET

Korean researchers have developed a device that demonstrates both forward and reverse breakdown drain voltages greater than 600V.

Korea's Hongik University has demonstrated a unidirectional nitride semiconductor hetero-structure field-effect transistor (HFET) that embeds a reverse current block Schottky diode into the drain contact [Jae-Gil Lee et al, Appl. Phys. Express, vol7, p014101, 2014]. Hongik has previously worked with Cornell University on embedding Schottky diodes to block reverse currents in AlGaIn/GaN metal-oxide-semiconductor HFETs [www.semiconductor-today.com/news\_items/2013/NOV/HONGIK\_141113.shtml].

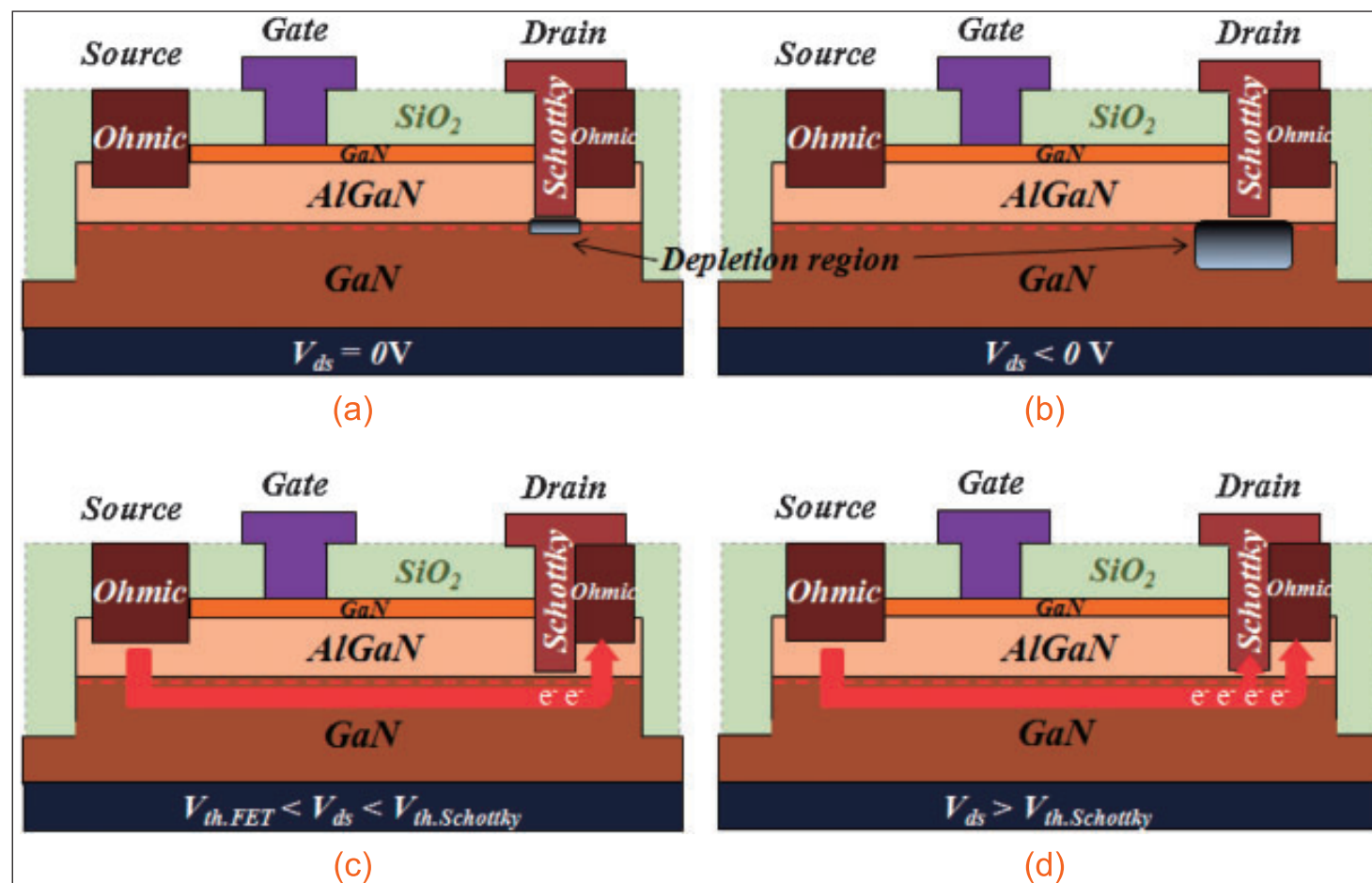
Hongik is seeking to develop devices that could compete with silicon-based power devices such as insulated-gate bipolar transistors (IGBTs) and power metal-oxide-semiconductor field-effect transistors (MOSFETs). Aluminium gallium nitride (AlGaIn) compound alloys have higher critical fields, high carrier

**Table 1. Epitaxial structure used in unidirectional HFET.**

Cap	GaN	4nm
Barrier	$\text{Al}_{0.23}\text{Ga}_{0.77}\text{N}$	20nm
Spacer	AlN	1nm
Buffer	GaN	1.7 $\mu\text{m}$
Multilayer	GaN/AlN	3.7 $\mu\text{m}$
Transition	AlN-rich	0.4 $\mu\text{m}$
Substrate	(111) n-Si	

concentration and high mobility, making these materials attractive for power applications.

Such devices are designed to have high breakdown in the forward direction. Typically, the gate-drain distance is much longer than the source-gate distance.



**Figure 1. Operation mechanism of unidirectional AlGaIn/GaN-on-Si HFET: (a) zero drain bias, (b) reverse drain bias, (c) small forward drain bias (less than Schottky turn-on voltage), and (d) large forward drain bias.**

Long gate-drain distances are used to reduce peak electric fields and hence delay break-down. A negative drain bias would reverse the roles of source and drain, leading to premature break-down and potential damage of the device, hence the need for a diode to block reverse currents through the device.

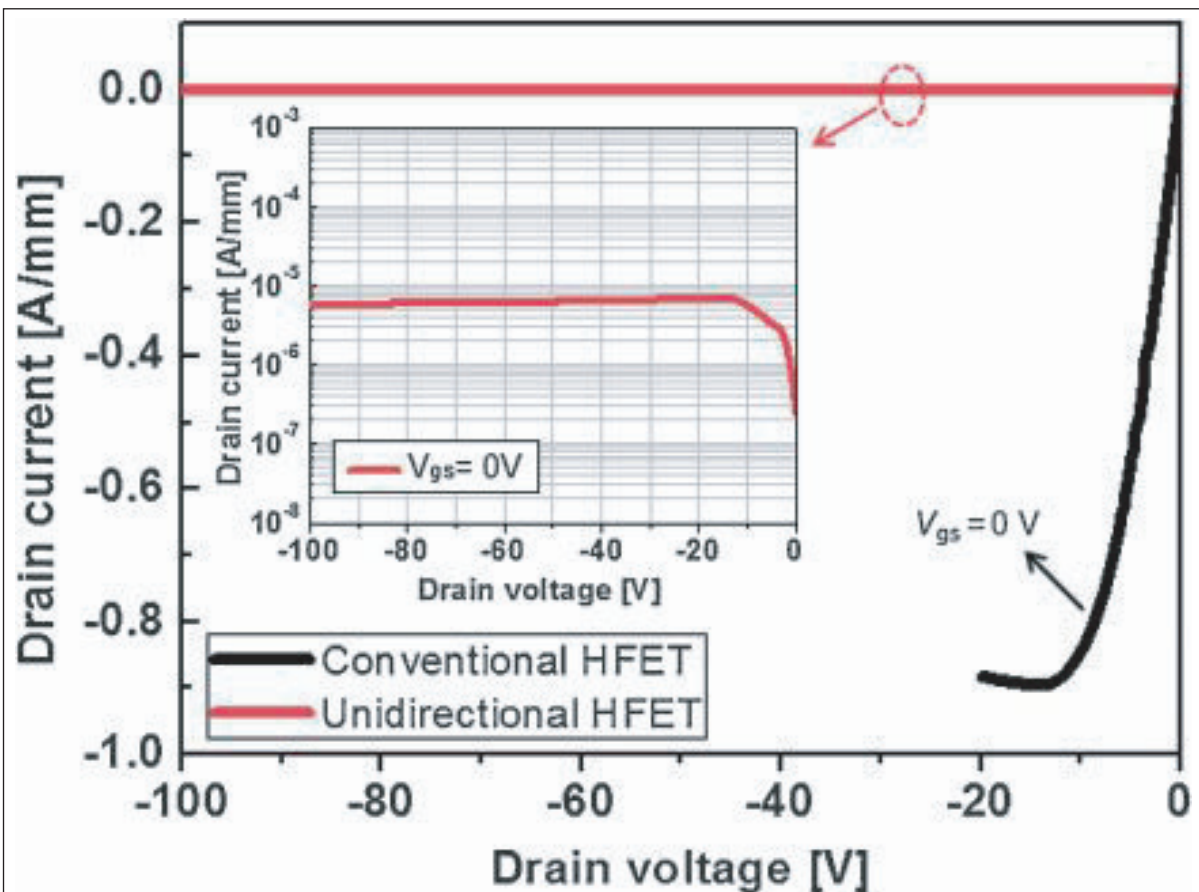
The new Hongik device used an epitaxial structure on n-type silicon (n-Si) with AlGaIn alloy barrier layer (Table 1).

The fabrication of HFETs with a Schottky contact (Figure 1) included mesa etch for isolation, silicon/titanium/aluminium/molybdenum/gold ohmic metal deposition and annealing for the source/drain contacts, silicon dioxide surface passivation, and gate formation by buffered oxide etch and nickel/gold deposition.

The Schottky recessing was achieved using buffer oxide etch for the silicon dioxide removal and inductively coupled plasma (ICP) reactive-ion etch (RIE) to drill into the nitride semiconductor layers. The Schottky contact of the drain electrode was deeply recessed 17nm into the AlGaIn barrier "to achieve a low forward turn-on voltage while blocking the reverse current flow". The researchers explain: "To block the reverse current flow, the recessed AlGaIn barrier must be thin enough to completely deplete the 2DEG channel underneath." The length of the Schottky contact was 3µm.

The gate-drain distance was 12µm, while the gate length was 3µm and the gate-source distance was 2µm. The device also included field-plates on the gate (2µm) and drain (1.5µm) contacts to further massage the electric fields so as to achieve high voltage breakdown performance.

The forward 1mA/mm turn-on voltage of the embedded Schottky diode was 0.4V. The forward voltage performance of the device is comparable with that of a



**Figure 2. Comparison of reverse characteristics between conventional and unidirectional AlGaIn/GaN-on-Si HFETs. Inset: reverse drain leakage current of unidirectional device under on-state (0V gate) condition.**

conventional HFET without Schottky diode produced for comparison. While the conventional HFET was bi-directional, the embedded Schottky device limited reverse currents to less than  $10^{-5}$  A/mm (0.01mA/mm), indicating a completely depleted channel (Figure 2).

The forward 'off' (gate potential -10V) and reverse 'on' (0V gate) catastrophic breakdown drain voltages for the unidirectional HFET were +615V and -685V, respectively. The conventional device suffered forward breakdown at +585V. The researchers believe the reduced breakdown in the conventional device can be mainly attributed to that device not having a drain field-plate, although it did have a gate field-plate.

The researchers carried out simulations in support of their belief. The need for the drain field-plate arises from the long gate-drain distance. In conventional AlGaIn/GaN HFETs designed for RF operation rather than lower-frequency power switching, shorter gate-drain distances are used and then the field tends to peak near the gate rather than the drain. Also, if an optimum gate field-plate is employed to reduce the field peak near the gate edge, one has then to consider the peak near the drain edge to achieve further breakdown improvements. ■

<http://dx.doi.org/10.7567/APEX.7.014101>

Author: Mike Cooke

# Enhancing SiC epitaxy with high-speed rotation

**By spinning 150mm wafers at 1000rpm, growth rate has been boosted to 50µm/hour while also improving doping uniformity.**

**R**esearchers in Japan have developed a single-wafer-type 150mm vertical 4H polytype silicon carbide (SiC) epitaxial reactor with high-speed wafer rotation [Hiroaki Fujibayashi et al, Appl. Phys. Express, vol7, p015502, 2014]. The team comments on the results: "The obtained growth rates and doping uniformity for 150mm-diameter wafers are much superior to those reported previously."

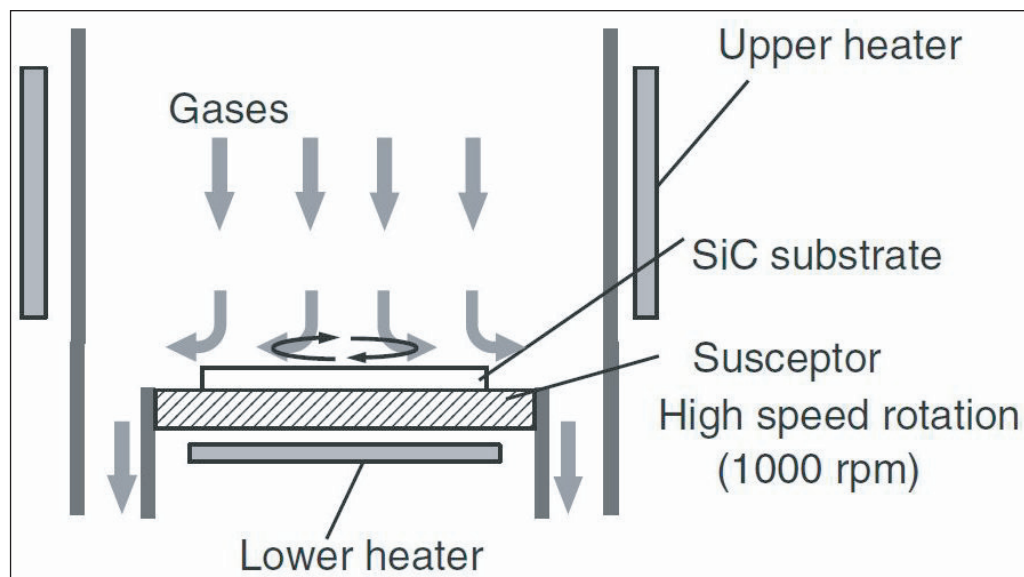
The research team involved collaboration between Central Research Institute of Electric Power Industry, DENSO Corp, NuFlare Technology Inc, Toyota Motor Corp, and Toyota Central R&D Labs.

Although SiC has been developed for high-voltage and low-loss power devices for many years, the commercial impact of the material has been slow because it is expensive and difficult to work. In particular, epitaxial process temperatures are very high, at around 1600°C, compared with 1000°C for gallium nitride and silicon, and 700°C for gallium arsenide and other III-V materials.

SiC-based Schottky diodes have been available commercially since 2001 but, to compete with silicon production, processes need to be higher throughput and need to result in higher-quality epilayers.

The researchers developed a reactor (Figure 1) based on the silicon epitaxy HT-2000 system developed by Toshiba and NuFlare in the 1990s. For SiC, the researchers added extra upper heaters with respect to the lower heaters of the silicon tool.

The lower heaters were divided into inner and outer zones, allowing temperature control in the radial direction. The upper heaters were designed for rapid heating of the hot zone to the 1600–1650°C needed for SiC growth. These upper heaters were placed outside a cylindrical wall, which was designed to also heat the source gases that enter from the top before they reached the epitaxy region below.



**Figure 1. Schematic cross section of epitaxial reactor.**

The electric-power-controlled resistance heaters were arranged to give intra-temperature variation of less than 2°C across a 150mm wafer. A pyrometer on the top of the reactor was used to gauge the wafer temperature.

The wafer was rotated at up to 1000 revolutions per minute (rpm) to improve growth rates and uniformity.

The system allows temperature ramp up and down in 15 minutes, allowing a short cycle time of 30 minutes to achieve a 10µm layer at a growth rate 40–50µm/hour.

The source gases consisted of hydrogen, silane, propane, and hydrogen chloride ( $H_2 + SiH_4 + C_3H_8 + HCl$ ). Nitrogen was used for n-type doping. The substrate was 4° offcut 4H SiC.

The high rotation speed was found to improve the growth rate, particularly at higher pressures. The effect of fast rotation was to thin the boundary layer, leading to higher growth rates. "The thinning of the boundary layer is explained by pumping out and pulling down gases on a disk with high-speed rotation," the researchers write.

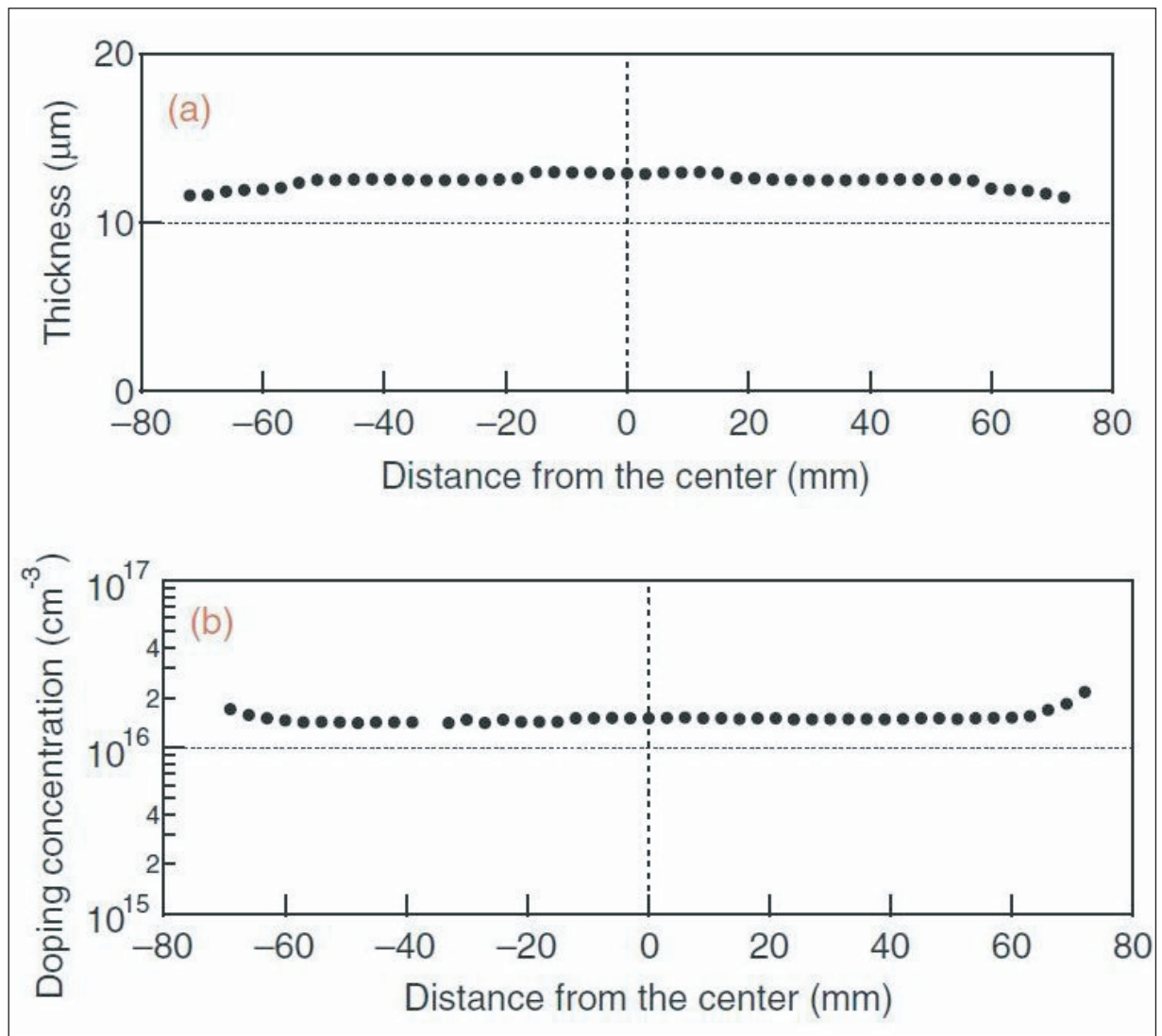
The growth enhancement came without the need to increase flow rates of the source gases. The consequent reduced formation of byproducts is seen as beneficial in terms of high throughput. If many byproducts are generated, chamber cleaning needs to be more frequent, reducing productivity.

Another benefit of fast rotation was greater uniformity of growth rate across the wafer. While 50rpm growth on a 3-inch substrate leads to 1.5% relative standard deviation in growth uniformity with respect to the mean ( $\sigma/\text{mean}$ ) at 500mbar pressure, 1000rpm growth sees the variation reduced to around 0.25%. The slow rotation worsens uniformity as the pressure increases. By contrast, the 1000rpm growth reduced from 1%  $\sigma/\text{mean}$  at low pressures to a relatively steady 0.25%  $\sigma/\text{mean}$  beyond 500mbar system pressure.

The researchers comment: "when the boundary layer formation is dominated by high-speed rotation at a relatively high system pressure, the growth rate is not dependent on gas-flow velocities in the hot zone of the reactor."

Although the results at high pressure were promising, the researchers were concerned about the possible generation of byproducts away from the wafer due to swirling effects predicted in simulations. They therefore put aside investigation at higher system pressures for later work and decided to focus on 267mbar for closer study.

Evaluation based on Nomarski optical microscopy (NOM) on a 3-inch wafer grown at  $37\mu\text{m}/\text{hour}$  gave  $0.2/\text{cm}^2$  total epi-induced morphological defects, including particle-induced, triangular, carrot, etc. The NOM inspection area was  $9\text{cm}^2$ . Atomic force microscopy (AFM) showed that there was no macrostep bunching and gave a root-mean-square (RMS) roughness of 0.18% for a  $10\mu\text{m} \times 10\mu\text{m}$  scan. Higher growth rates up to  $50\mu\text{m}/\text{hour}$  showed a surface morphology free of macrostep bunching. At  $40\mu\text{m}/\text{hour}$ , the defect level was still only  $0.2/\text{cm}^2$ .



**Figure 2. Radial direction distribution of (a) thickness and (b) n-type doping concentration for a 150mm-diameter 4° off 4H-SiC epilayer. Average growth rate  $50\mu\text{m}/\text{hour}$ .**

For growth on 150mm wafers (6-inch), the researchers modified the radial distribution of the source gas inlet. With  $50\mu\text{m}/\text{hour}$  growth of nitrogen-doped n-type SiC, the uniformities were 2.8%  $\sigma/\text{mean}$  for thickness (6mm edge exclusion) and 5.2%  $\sigma/\text{mean}$  for n-type doping (6mm edge exclusion) at a central concentration of  $1.5 \times 10^{16}/\text{cm}^3$  (Figure 2).

Without doping (background n-type  $\sim 10^{13}/\text{cm}^3$  carrier density), thickness uniformity of 1.6%  $\sigma/\text{mean}$  (6mm edge exclusion) was achieved with  $42\mu\text{m}/\text{hour}$  growth rate with fine tuning of the radial gas-flow pattern. The doping uniformity was 2.6%  $\sigma/\text{mean}$  with a "peculiar increase in doping concentration near the wafer periphery". The researchers say that this may be due to "turbulence or temperature variation near the wafer edge, although a very flat distribution of doping concentration is obtained except for the periphery area" (i.e. 11mm edge exclusion). ■

<http://dx.doi.org/10.7567/APEX.7.015502>

[www.nuflare.co.jp/english/index.html](http://www.nuflare.co.jp/english/index.html)

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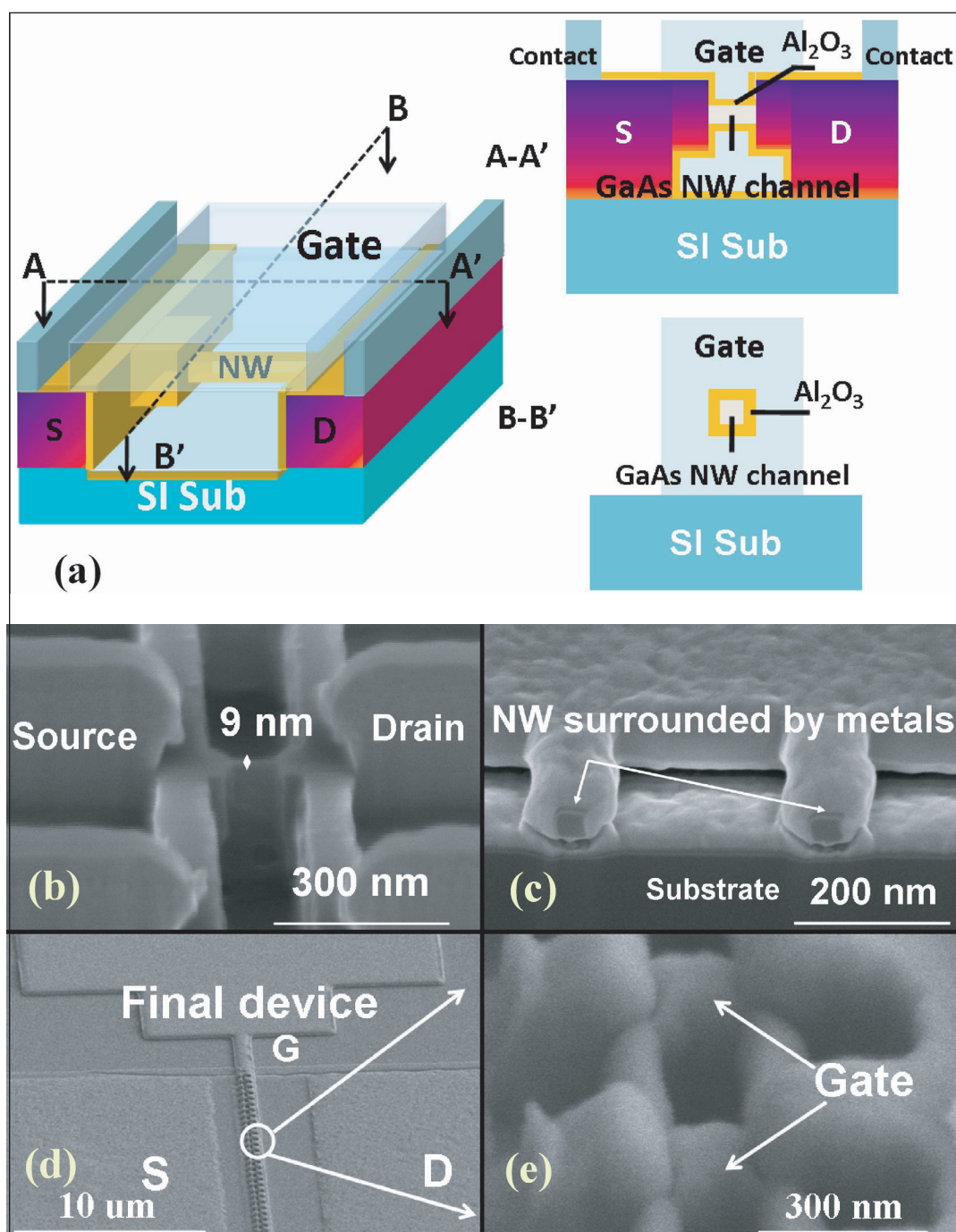
# Improving nanowire transistor linearity with regrowth

Third intercept point values “significant improvement over those achieved from other approaches”.

University of Illinois at Urbana-Champaign has realized junction-less (JL) gallium arsenide (GaAs) nanowire field-effect transistors (NWFETs) “for the first time” by implantation-free source/drain metal-organic chemical vapour deposition (MOCVD) regrowth combined with gate-all-around (GAA) metal sputtering [Yi Song et al, IEEE Electron Device Letters, published online 9 January 2014]

The researchers were particularly keen to develop devices with better linearity to minimize distortion being added between input and output signals. Radio-frequency amplification is putting greater demands on linearity than before — for example, some 4G mobile phone standards are very exacting in this respect. The usual technique to achieve this is through more complex circuitry. Apart from the increased circuit footprint, such complexity increases power demand.

The Urbana-Champaign team hopes that a better solution could come from using more linear basic transistors. “However,” the researchers point out, “non-linearity is an inherent property of conventional transistors and the trans-conductance ( $g_m$ ) non-linearity is the main contribution at



**Figure 1. (a) Schematic structure of GaAs JL GAA NWFET and two cross-sectional views across (AA') and parallel to (BB') S/D; (b) SEM image of suspended NWs and raised S/D; (c) focused ion-beam cross section of NW surrounded by gate metal; (d) top-view SEM of fully fabricated JL GAA NWFET and (e) zoomed-in view of gate region.**

high frequencies. For short-channel devices,  $g_m$  linearity is especially degraded because of mobility degradation and severe source/drain (S/D) resistance. High linearity is even more difficult to achieve at low bias, which is crucial for portable RF applications."

The researchers believe that JL GAA NWFETs are a promising route to improved linearity in scaled devices. Such devices can suffer from high parasitic S/D resistance, and the regrowth technique is a way to tackle this.

The epitaxial nanowire and sacrificial aluminium gallium arsenide (AlGaAs) layers

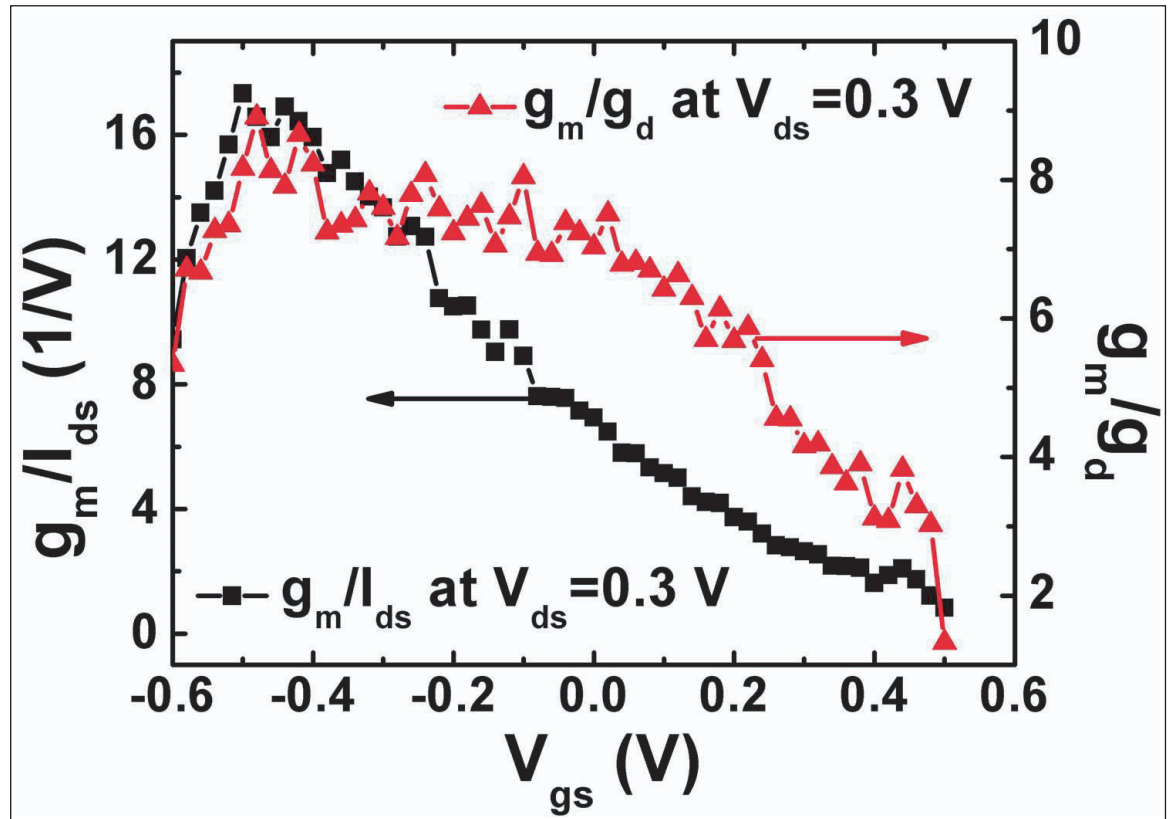
were grown on semi-insulating (SI) GaAs, also using MOCVD. The layers were 100nm lattice-matched undoped  $\text{Al}_{0.6}\text{Ga}_{0.4}\text{As}$  and 40nm n-type Si-doped GaAs.

Source/drain regions were recessed into the epitaxial layers using wet chemical etching to avoid the surface damage caused by plasma processes. Selective MOCVD regrowth of the source/drain regions added 200nm of n-GaAs.

The nanowires were created by sculpting 140nm-high fins in the AlGaAs/GaAs epitaxial layers with dry plasma etching and then removing the sacrificial AlGaAs and silicon dioxide mask using hydrofluoric acid solution. The process resulted in 9nm x 40nm cross-section suspended nanowires of n-GaAs between the source/drain electrodes.

Further processing consisted of ammonium sulfide passivation, atomic layer deposition (ALD) of 9nm aluminium oxide gate dielectric, and 90-second 650°C annealing. The source/drain electrodes were annealed germanium/gold/nickel/gold. The chromium/gold gate metal was applied using sputtering from two directions to ensure full all-around coverage.

A device with 80nm gate length achieved a sub-threshold swing (SS) of 110 mV/dec, "reasonable for such short channels and attributed to the good GAA electrostatic control", according to the researchers. The drain voltage was kept low (0.1–0.5V) to explore low power linearity behavior. The drain current was thus relatively low at less than 300 $\mu\text{A}/\mu\text{m}$ . Similarly,



**Figure 2.** Power efficiency ( $g_m/I_{ds}$ , black squares) and intrinsic gain ( $g_m/g_d$ , red triangles) curves of a JL GaAs GAA NWFET.

the peak transconductance was less than 400 $\mu\text{S}/\mu\text{m}$  for 0.4V drain.

The transconductance performance is relatively broad, with values near maximum for 0.2–0.5V gate potentials. The linearity, as described by the third intercept point (IP3), was 3.8dBm for 0.4V drain and 2.6dBm for 0.3V. Even at 0.1V, IP3 is 1.5dBm, allowing use in low-bias conditions. "These values represent significant improvement over those achieved from other approaches," the researchers comment.

The broad transconductance performance benefits power efficiency (Figure 2), as measured by the ratio of transconductance ( $g_m$ ) and drain current ( $I_{ds}$ ). Also the intrinsic gain of the device (transconductance/drain conductance) is greater than 4 for a large range of gate potentials.

The researchers attributed the improved linearity to reduced surface scattering and less mobility degradation at high bias. They add: "The reduced degradation of mobility leads to a much slower drop of transconductance when gate voltage is increased." Another factor was reduced source/drain resistance due to the use of MOCVD regrown regions. Ion implantation of dopants is an alternative technique for reducing source/drain resistance, but it results in activation problems and crystal structure damage. ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6705581>

Author: Mike Cooke

# Peregrine challenging GaAs power amplifier market with UltraCMOS Global 1

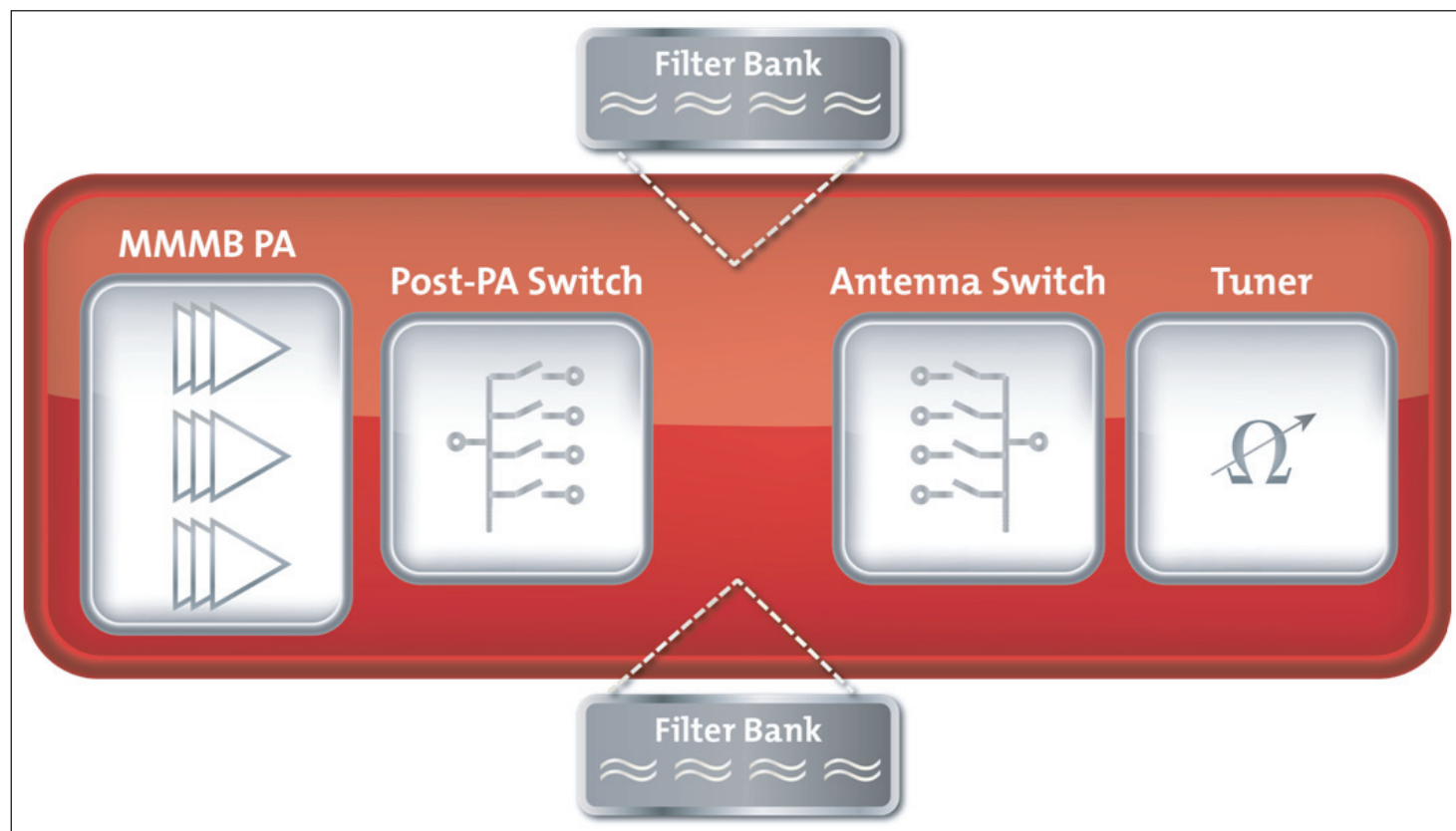
**Performance achieved without envelope tracking or other enhancements.**

**P**eregrine Semiconductor Corp of San Diego, CA, USA, a fabless provider of radio-frequency integrated circuits (RFICs), has claimed the world's first reconfigurable RF front end (RFFE) using silicon-on-insulator (SOI) complementary metal-oxide-semiconductor (CMOS) technology. The company sees the 'UltraCMOS Global 1' device as allowing "for the first time" 4G LTE mobile phone platform providers and OEMs to save time and money through a single design adaptable for global markets that need facilities to tackle 40 frequency bands and a 5000-fold increase in potential operating states.

The use of a CMOS process enables Peregrine to integrate a 3-path multimode, multiband (MMMB) power amplifier (PA), post-PA switch, antenna switch, and antenna tuner into the Global 1 IC (Figure 1). The

device also supports envelope tracking – a technique to tune power consumption to usage. The interface with the mobile phone system is through the common RFFE MIPI interface.

Peregrine's ultra-thin silicon (UTSi) UltraCMOS process on insulating substrates – sapphire or enhanced silicon-on-insulator – has been developed over a period of 25 years. The latest version – UltraCMOS 10 – was announced in 2013 and features Peregrine's design expertise, SOITEC substrates, and GLOBALFOUNDRIES' fabrication flow. The measured 37% reduction in the on-resistance, off-capacitance product of 133 femtoseconds ( $R_{on} \times C_{off}$ , Figure 2) is expected to feed through to related improvements in linearity, reduced insertion loss and better isolation on a 130nm chip. Competitor SOI CMOS processes tend



**Figure 1. Block diagram of Peregrine's reconfigurable RF front end.**

to have  $R_{on} \times C_{off}$  in the range 200–250 femtoseconds.

The company has already deployed UltraCMOS to grab a large share of the RF switch market that was previously mainly the preserve of gallium arsenide (GaAs) device makers. Now the Global 1 CMOS power amplifier challenges the performance of GaAs-based modules, even without envelope tracking, or digital pre-distortion or other enhancement.

The device was tested using a WCDMA (voice) waveform at an ACLR (adjacent channel leakage ratio) of  $-38\text{dBc}$  and was found to have a power-added efficiency (PAE) of almost 50% (Figure 3). The company comments: "This is on par with the leading gallium arsenide power amplifiers and exceeds the performance of other CMOS power amplifiers by 10 percentage points, which represents a 33% efficiency increase."

Peregrine also points out that the benefits of envelope tracking can be very band specific, but typically the system efficiency of Global 1 increases a further 10 percentage points with tracking.

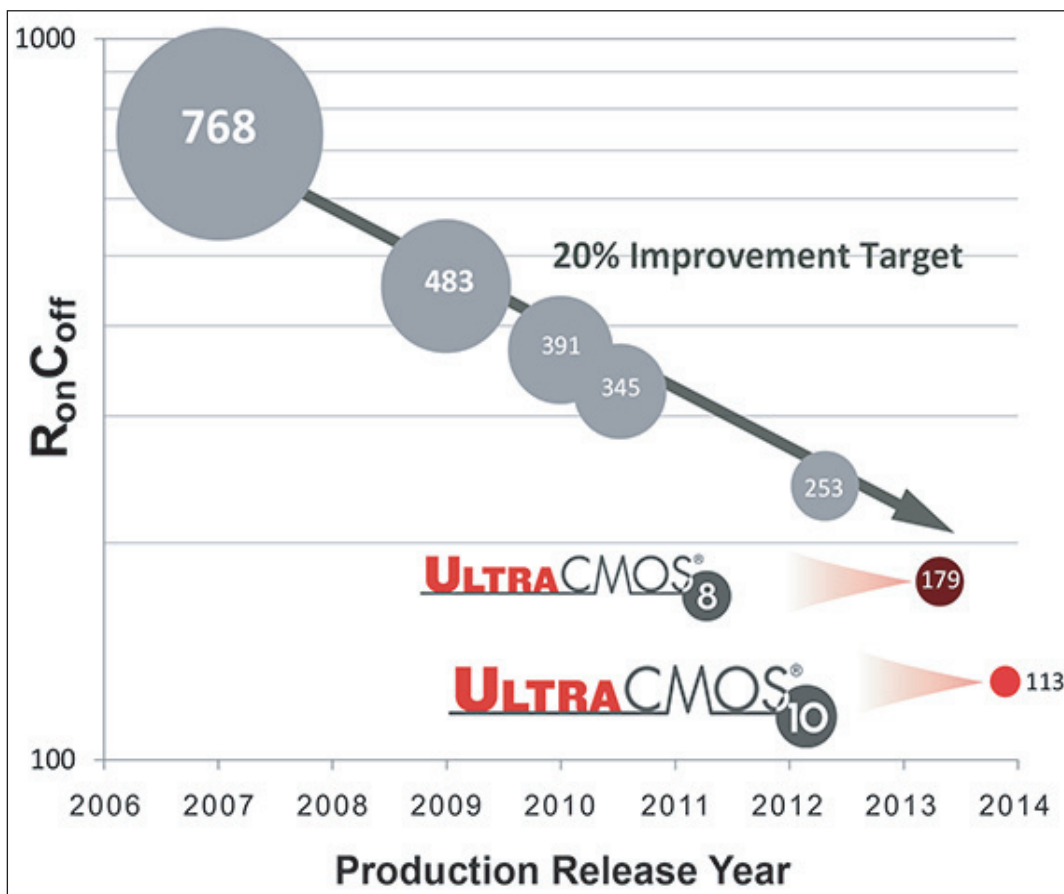
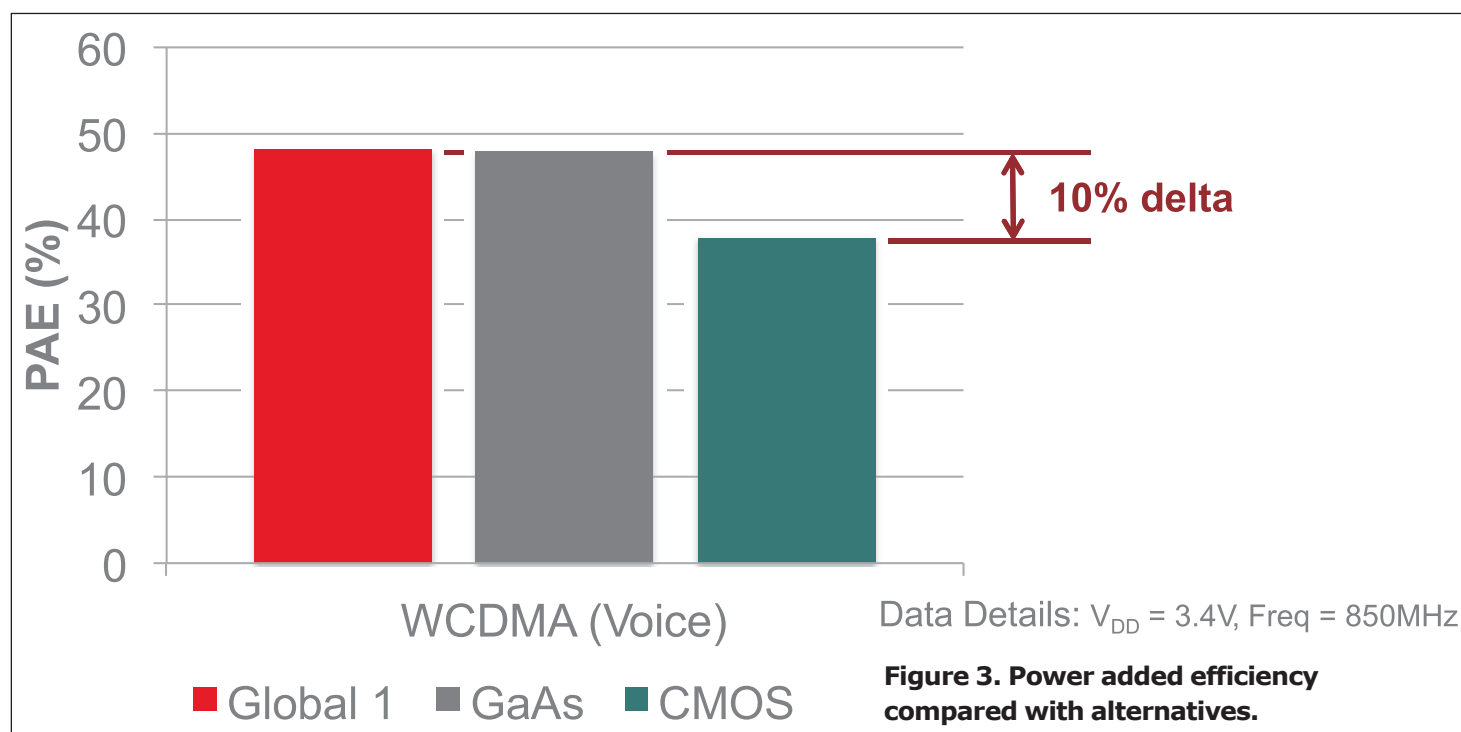


Figure 2. UltraCMOS  $R_{on} \times C_{off}$  delay (femtosecond) improvement over time.

The firm demonstrated the product, at late February's Mobile World Congress (MWC 2014) in Barcelona, Spain. Platform integration is due to be completed this year, for volume production in late 2015. ■

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Author: Mike Cooke



# Meeting the challenge of integrating III-Vs with deep submicron silicon

High-mobility devices based on indium gallium arsenide (InGaAs) channels could benefit the performance of mainstream silicon integrated circuits. Researchers are working to meet the challenges of bringing the different device traditions together. **Mike Cooke** reports on contributions at December's IEEE International Electron Devices Meeting (IEDM) in Washington DC.

**I**n principle, the high mobilities of InGaAs and related III-V compound semiconductors should lead to faster switching speeds with larger drive currents. These benefits could be used to replace silicon channels altogether or the critical parts of a complementary metal-oxide-semiconductor (CMOS) integrated circuit (IC).

Such developments are not simple drop-in replacements, however. While the cut-off frequencies can be much higher than silicon, other factors such as high on/off ratios and device dimension scaling (shrinks) are more difficult to achieve with III-Vs. Many III-V production processes are incompatible with silicon processing.

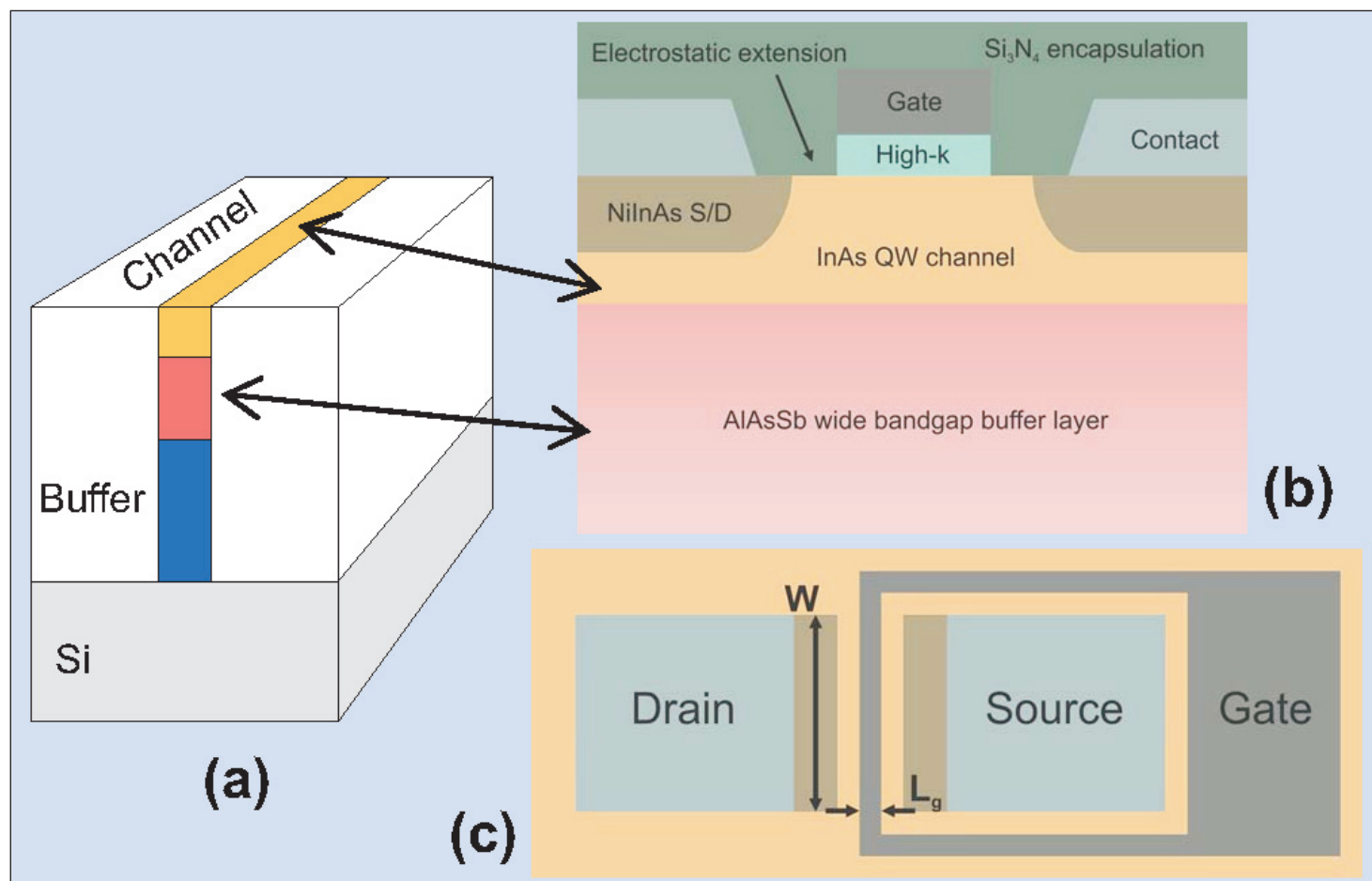


Figure 1. (a) The STI ART technique to introduce high-mobility channels into a silicon CMOS platform. (b) Representative 6.1Å III-V quantum well (QW) n-MOSFET architecture for implementation in CMOS. (c) Schematic of device layout used in S.W. Chang et al, showing active device width W and gate length  $L_g$ .

Here we look at some attempts to tackle these issues and others as reported at IEDM.

### Beating HEMTs

Record-setting III-V n-type MOS field-effect transistors (FETs) were claimed by TSMC (Belgium and Taiwan), University of Glasgow (UK), Texas State University (USA), and Lund University (Sweden) [S.W. Chang et al, 16.1]. The team comments: "For the first time performance better than state-of-the-art HEMTs is demonstrated."

The process used is compatible with shallow-trench isolation (STI) aspect-ratio trapping (ART) growth techniques (Figure 1) and with antimony (Sb)-based p-FETs for a full III-V CMOS structure.

The MOSFET consisted of a 10nm surface channel of unstrained InAs with a 130nm gate length. The channel layer was molecular beam epitaxy (MBE) grown on a lattice-matched aluminium arsenide antimonide (AlAsSb) barrier on InAs substrate. Metal-organic chemical vapor deposition (MOCVD) growth has also recently been demonstrated.

The device structure had a gate that surrounds the gate contact. "This alleviates the need for isolation by, for example, mesa etch, which is not straightforward to implement due to the conductive nature of exposed InAs surfaces," the researchers explain. The gate stack consisted of ALD high-k dielectric and palladium metal electrode.

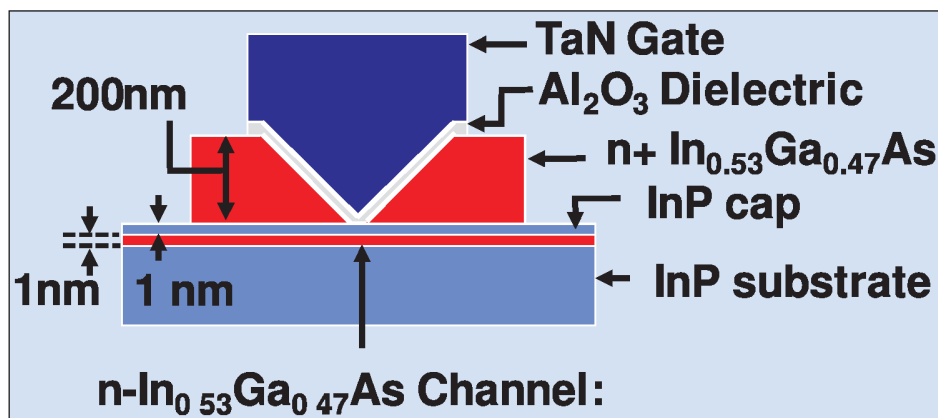
The source/drain regions consisted of titanium-nickel InAs, followed by titanium/gold contacts. Low-sheet-resistance electrostatic extensions and encapsulation were achieved using silicon nitride. The extensions induce carriers by pinning the Fermi surface above the conduction band minimum.

At 0.5V drain bias, the on current was 601 $\mu$ A/ $\mu$ m and the off current was 100nA/ $\mu$ m. The extrinsic transconductance was 2.72mS/ $\mu$ m (5.5mS/ $\mu$ m, intrinsic), exceeding the best reported data for state-of-the-art planar III-V n-FETs. The researchers point out that this performance is higher than aggressively scaled devices, despite the relatively long gate length.

Subthreshold swing (SS) and drain-induced barrier lowering (DIBL) were 85mV/dec and 40mV/V, respectively. The mobility was 7100cm<sup>2</sup>/V-s and the carrier density was 6.7x10<sup>12</sup>/cm<sup>2</sup>.

### Shrink to 6nm

National University of Singapore (NUS) reported the realization of In<sub>0.53</sub>Ga<sub>0.47</sub>As junctionless FETs (JLFETs) with the shortest channel length for any III-V transistor of 6nm [K.H. Goh et al, 16.5]. The 1nm-thick channel was sandwiched between a 1nm InP cap/etch stop and



**Figure 2. Structure of National University of Singapore device with ultra-thin (1nm) and ultra-short (~6nm) channel.**

the InP substrate. Etched raised source/drain structures consisted of n<sup>+</sup>-In<sub>0.53</sub>Ga<sub>0.47</sub>As, giving a contact resistance of 165 $\Omega$ - $\mu$ m. The gate stack consisted of tantalum nitride electrode on aluminium oxide (Al<sub>2</sub>O<sub>3</sub>) dielectric with an equivalent oxide thickness (EOT) of 2.5nm (Figure 2).

The peak transconductance of 1480 $\mu$ S/ $\mu$ m was achieved at 0.7V drain bias. The device achieved a ballistic transport efficiency of 0.82. The on-off current ratio was  $\sim 10^4$  at 0.1V drain. A drive current of 480 $\mu$ A/ $\mu$ m was achieved at 0.7V drain and 0.7V gate potential over threshold. Short-channel effects were quite severe, however, although these were considered "well controlled down to 16nm" channel length.

NUS has also developed a passivation process for germanium FETs using high-quality In<sub>0.48</sub>Al<sub>0.52</sub>P. The large band offset between the materials enabled record high mobility values in electron transport in n-FET inversion layers of  $\sim 958$ cm<sup>2</sup>/V-s. The carrier density was 6x10<sup>11</sup>/cm<sup>2</sup>. Hole transport mobility in p-FETs was also high, at  $\sim 390$ cm<sup>2</sup>/V-s.

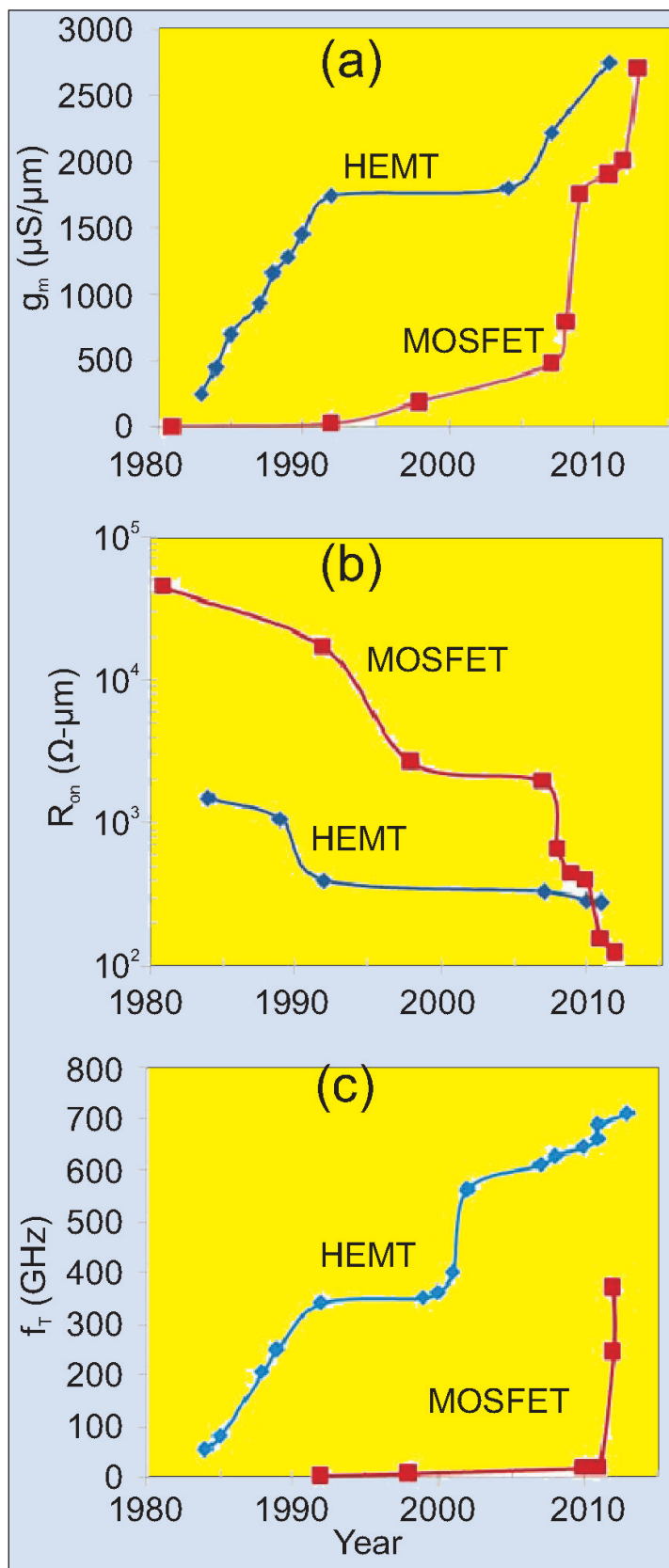
The researchers comment: "The InAlP-capped Ge CMOS technology could enable a common gate stack, common channel material option for sub-10nm technology nodes."

### Results and prospects

The Massachusetts Institute of Technology (MIT) group led by Jesús del Alamo contributed three papers on InGaAs transistor technology [2.1, 16.2, 28.4] (along with one on GaN MISHEMTs [6.2], see Mike Cooke, Semiconductor Today 2014 February, page 83).

One presentation [J. A. del Alamo et al, 2.1] gave a progress report comparing MOSFET technology with the more established HEMT technology (Figure 3). Global Foundries and SEMATECH were also involved in the work. Recent MOSFET work has managed to beat HEMTs in terms of low on-resistance and has come close to HEMT transconductance performance.

Although there is a gap in current-gain cut-off frequency ( $f_T$ ) performance, the researchers comment: "It is only



**Figure 3. Performance comparison of inversion-type InGaAs MOSFETs and HEMTs (with InAs composition between 0 and 1) vs year: (a) transconductance, (b) ON resistance, (c) current-gain cut-off frequency,  $f_T$ .**

a matter of time before low-parasitic-capacitance MOSFET designs are developed and improved high-frequency characteristics are demonstrated."

However, for integration into 10nm-scale mainstream manufacture these devices need to be shrunk to an ultra-small footprint. Further, the process needs to be 'self-aligned' to lower complexity and cost. Present research devices tend to have micron-scale contacts that need to be reduced by orders of magnitude. Finally, the transistors need to be inserted into a production environment where three-dimensional (3D) stacking of devices is an increasing trend.

Also, for consistency with mainstream silicon device processing, traditional III-V methodologies such as gold-based metallization, wet etch, and lift-off must be replaced with their silicon-compatible counterparts.

The team has developed molybdenum contacts that give a low contact resistivity of  $0.67\Omega\text{-}\mu\text{m}^2$ , but this value is not maintained below 110nm contact lengths. Alternative materials such as nickel, cobalt or palladium give inferior results.

The team has also worked on the gate dielectric, seeking EOTs smaller than 1nm for adequate electrostatic control of channel current by the gate. Sub-1nm EOTs have been achieved with a buried channel under an InP layer on which hafnium dioxide ( $\text{HfO}_2$ ) is deposited. The direct deposition of  $\text{HfO}_2$  on InP has been found to give lower interface trap densities, compared with  $\text{Al}_2\text{O}_3$ .

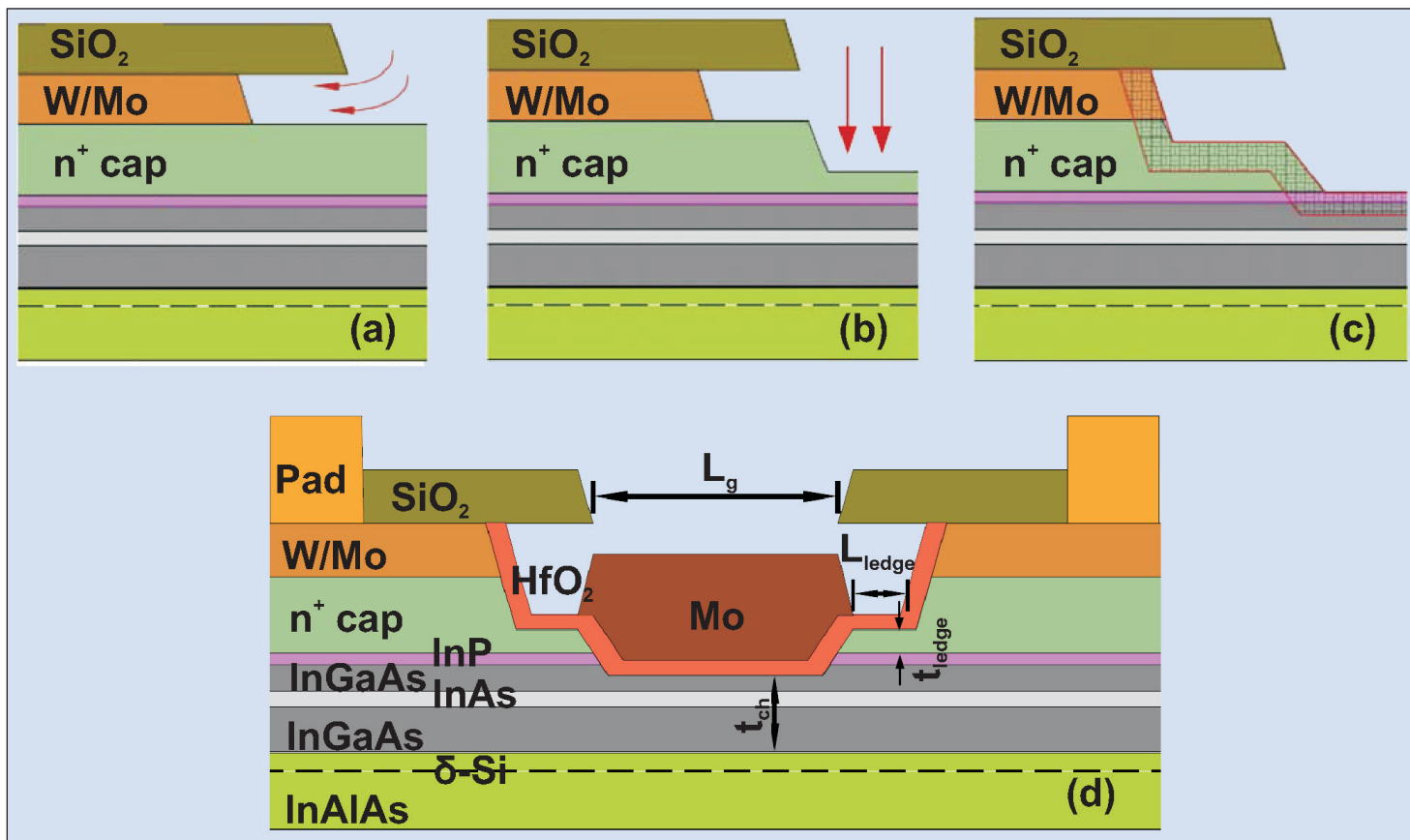
MOSFETs with 50nm gates and  $\text{HfO}_2/\text{InP}$  gate barriers have been produced with SS of 95mV/dec in 0.5V operation. "This nearly matches the characteristics of InGaAs trigate FETs of identical gate length, even though the trigate MOSFET has intrinsically better short-channel effects," the team writes.

For tackling the problems of dry/plasma etch of indium-containing materials, the team has developed an inductively coupled plasma reactive-ion process using boron trichloride, silicon tetrachloride and argon. The researchers report: "When combined with digital etching, we have realized 20nm fins and pillars on InGaAs/InAlAs/InP heterostructures without notching and minimum footing and trenching."

Some of these techniques were demonstrated in the two device presentations from MIT. Jianqiang Lin et al [16.2] reported on a "new self-aligned quantum-well MOSFET architecture fabricated by a scalable tight-pitch process". The device was produced using a three-step gate recess process (Figure 4).

A 70nm gate length InAs MOSFET with 5nm ledge length achieved a record transconductance of  $2.7\text{mS}/\mu\text{m}$ . A different device with a 70nm ledge achieved a record  $410\mu\text{A}/\mu\text{m}$  on-current. The latter MOSFET also demonstrated SS of 90mV/dec at 50mV and 94mV/dec at 0.5V. "This is the lowest S demonstrated to date at this gate length among III-V MOSFETs," the researchers claim.

The short-ledge device also has low source-drain resistance. To combine the positive features of the two types of device would require improvements in access resistance.



**Figure 4. MIT's 3-step gate recess process: (a) W/Mo pull in, (b) time-controlled  $\text{Cl}_2$  dry etch, (c) cap and barrier digital etch. (d) Cross section schematic of complete device structure.**

The process was also used to create working 20nm gate-length devices with "very tight metal contact spacing". The researchers comment: "To our knowledge, this is the smallest III-V MOSFET demonstrated so far."

The second MIT device report was "Vertical nanowire InGaAs MOSFETs fabricated by a top-down approach" from Xin Zhao et al [28.4]. The nanowire (NW) device fabrication included digital etch — effectively atomic-layer deposition in reverse — that increased the transconductance by 20%.

The researchers involved in this project comment: "A vertical NW device structure uncouples gate length scaling and footprint scaling. As a result, device density goals can be reached with far better short-channel effects and performance than in planar MOSFETs, FinFETs or lateral NW-FETs."

The vertical nanowires were carved out of InGaAs on InP substrates with the ICP-RIE described above and digital etch to smooth out surface roughness. The use of 'top-down' etching, rather than a 'bottom-up' process, to create nanowires is rare because of the difficulty in obtaining smooth sidewalls. Bottom-up processes use a gold seed, which is not compatible with mainstream silicon processing.

The InGaAs layers consisted of an undoped intrinsic region sandwiched between heavily doped n-type material. A device with 80nm channel (the intrinsic InGaAs layer) length, 50nm diameter wires and EOT of

2.2nm for the gate dielectric (spin-on glass) achieved  $720\mu\text{S}/\mu\text{m}$  transconductance at 0.5V.

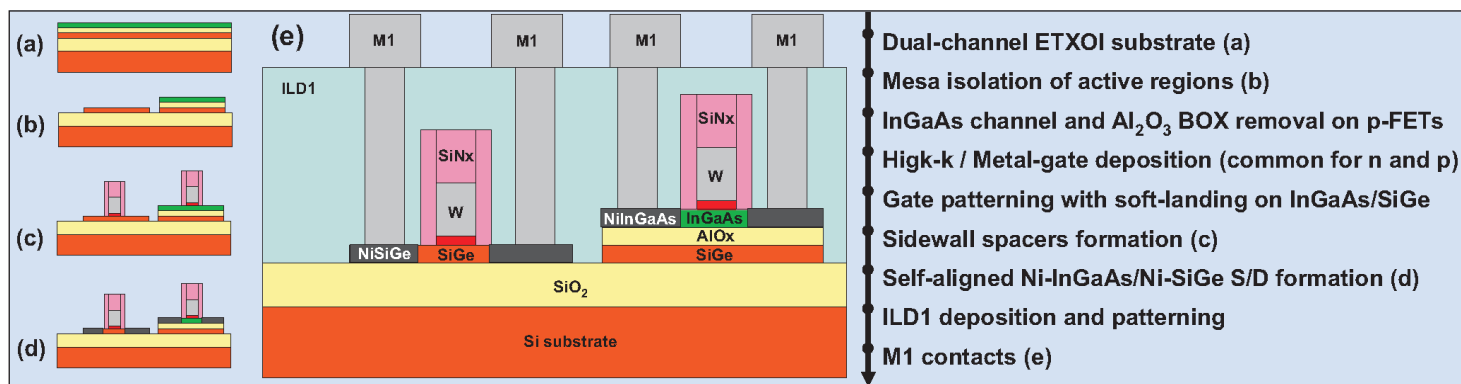
Subthreshold swing and drain-induced barrier lowering characteristics are improved by using smaller-diameter NWs, at the cost of reduced transconductance. The researchers add: "Our devices demonstrate a performance in terms of the balance between short-channel effects and transport that matches that of the best vertical NW III-V MOSFETs fabricated by bottom-up techniques."

### Self-alignment and co-integration

IBM researchers at the T. J. Watson Research Center have developed "self-aligned fully-depleted III-V MOSFETs using CMOS-compatible device structures and manufacturable process flows" [Y. Sun et al, 2.7]. Devices with gate lengths as short as 30nm were produced. The peak saturation transconductance was  $1140\mu\text{S}/\mu\text{m}$  for a 60nm gate-length transistor at 0.5V operation.

The process involved "gate definition and spacer formation using RIE, and formation of self-aligned source/drain extensions (SDE) and self-aligned raised source/drain ( $R_{SD}$ )".

The IBM team chose to work with  $\text{In}_{0.53}\text{Ga}_{0.47}\text{As}$  channels since it expected this to lead to lower leakage at 10nm gate length due to "reduced direct source-to-drain tunneling and band-to-band tunneling, even when quantization is taken into account". Also, the material



**Figure 5. Process flow description for the co-planar co-integration of InGaAs n-FETs and SiGe p-FETs with a common front-end (a, b, c, d, e).**

is likely to optimize on-current at shorter gate lengths.

The device layers were grown on p-type InP substrates using metal-organic chemical vapor deposition. An InAlAs buffer layer with wider bandgap than the channel provided back-barrier insulation similar to that achieved with silicon-on-insulator technologies. The researchers believe that replacing the InAlAs with a true insulator such as silicon dioxide ( $\text{SiO}_2$ ) or  $\text{Al}_2\text{O}_3$  could help them to better tackle short-channel effects. Channels thinner than 20nm could also be beneficial.

A peak mobility at  $1550\text{cm}^2/\text{V}\cdot\text{s}$  for the device was 4–5x that achieved for silicon-based NFETs. The researchers believe that “exploring methods to impart uniaxial tensile stress is more fruitful than trying to simply integrate high-In-content channels”. They project that with gate lengths of less than 20nm, such MOSFETs would operate within 5% of the ballistic limit (i.e. where

carrier transport occurs without scattering losses).

A team mainly based at IBM Zurich Research Laboratory presented the first demonstration of “dense co-integration of co-planar nano-scaled SiGe p-FETs and InGaAs n-FETs” [L. Czonomaz et al, 2.8]. Direct wafer bonding techniques were used to create “hybrid substrates containing extremely-thin SiGe and InGaAs layers” on an insulating layer of  $\text{SiO}_2$  on silicon. The stacked high-mobility III-V semiconductor layers were about 6nm thick. The silicon germanium (SiGe) layer was 8nm. A 10nm aluminium oxide layer was used for bonding the SiGe-on-insulator and III-V layers.

The hybrid substrates enabled the creation of n- and p-channel FETs with ultra-thin bodies on a buried oxide, similar in design to extremely thin body silicon-on-insulator technology (Figure 5). The researchers comment: “Working CMOS inverters are obtained using a common front-end which

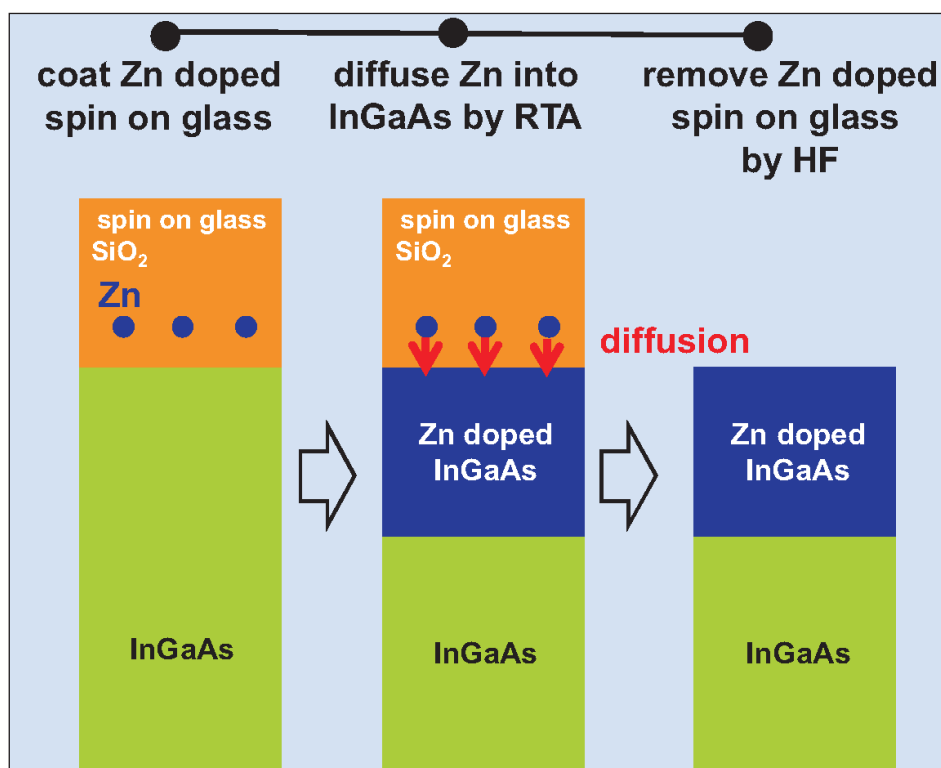
confirms the viability of this integration scheme for hybrid high-mobility dual-channel CMOS.” However, it was not possible to produce ring oscillators since the output from one inverter was not sufficient to trigger another.

### Tunneling

University of Tokyo and Sumitomo have developed planar InGaAs tunneling FETs (TFETs) using solid-phase zinc diffusion (Figure 6) to achieve steep  $p^+/n$  source junctions without defects [Munetaka Noguchi et al, 28.1]. The structure achieved a low SS of 64mV/dec and high on/off current ratio of  $10^6$ . The SS and on/ratio values are records for planar-type III-V TFETs.

TFETs achieve a steep switching slope by using bandgap filtering of carriers in the source from the tail of the Fermi distribution.

Vertical TFETs have achieved 60mV/dec, the theoretical limit for traditional

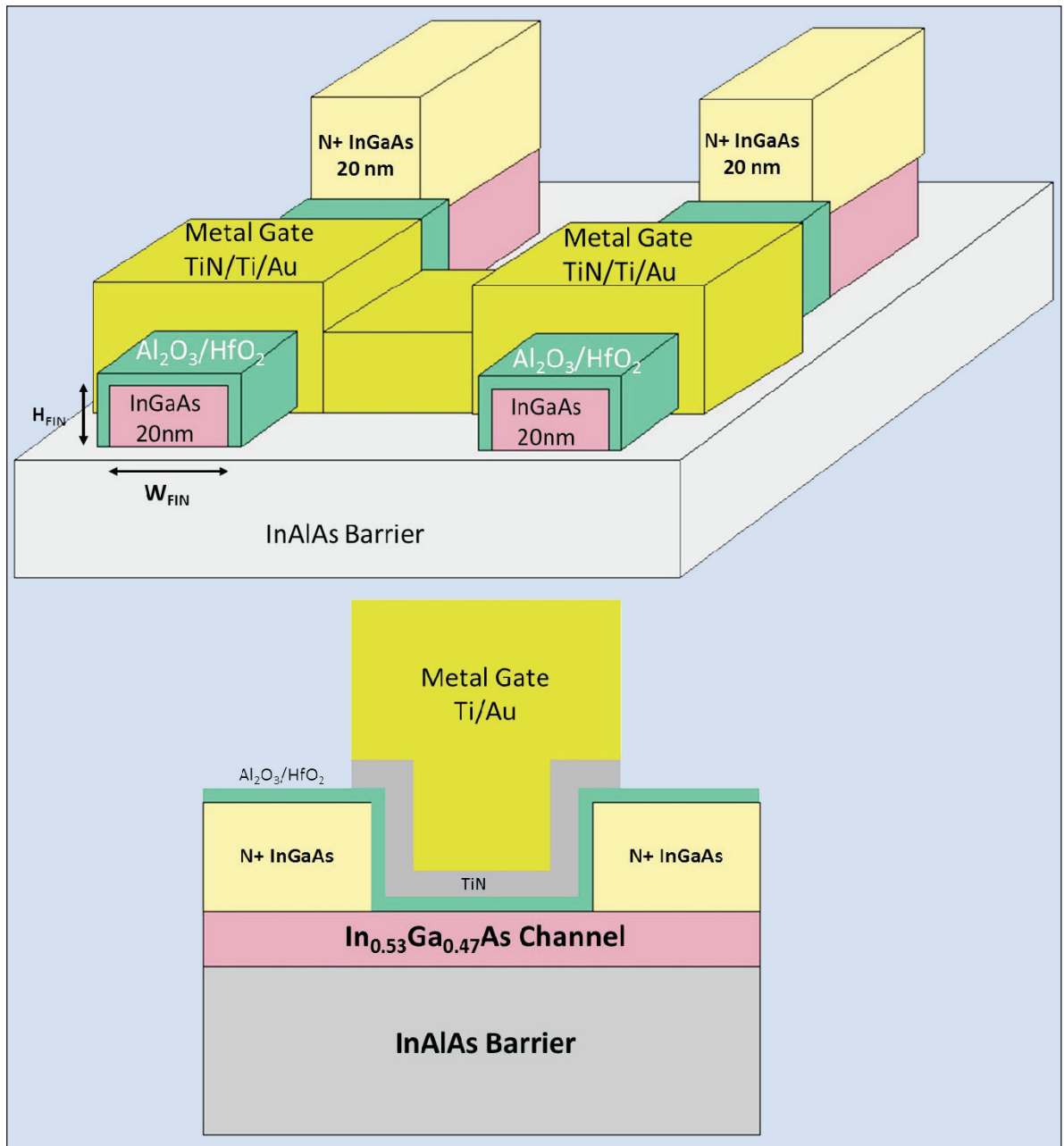


**Figure 6. Schematic process flow of Zn diffusion into InGaAs by using Zn-doped spin-on-glass.**

planar MOSFETs. However, planar TFETs would be preferable in terms of integration with mainstream silicon processing technologies. Planar InGaAs TFETs with beryllium doped source junctions have only achieved 230mV/dec SS. Besides the poorer performance, one should probably avoid exposure to beryllium since it is poisonous when inhaled and classified as a group 1 carcinogen by the International Agency for Research on Cancer.

Penn State University, US National Institute of Standards and Technology, and IQE Inc. reported on high switching speeds attained by  $\text{In}_{0.9}\text{Ga}_{0.1}\text{As}/\text{GaAs}_{0.18}\text{Sb}_{0.82}$  tunneling FETs with 200nm channel length. The devices use a near-broken gap structure to achieve record drive current of  $740\mu\text{A}/\mu\text{m}$  at 0.5V drain bias. The peak intrinsic RF transconductance was  $700\mu\text{S}/\mu\text{m}$ . These values were, respectively, 2.3x and 2.6x the characteristics reported by Penn State in 2012. The  $f_T$  cut-off frequency was 19GHz. At 0.3V drain,  $f_T$  was 10GHz.

The device used heterojunction technology to boost on-currents without increasing off-currents at the same time. This was achieved by decreasing the effective barrier height to 0.02eV, compared with  $\sim 0.25\text{eV}$  in 2012. The researchers used an internal photoemission spectroscopy (IPE) technique involving a graphene electrode to determine the heterojunction band alignments in the process of tuning the epitaxial metamorphic growth on lattice mismatched InP substrate using solid source MBE.



**Figure 7. Top: InGaAs quantum-well (QW) tri-gate MOSFET architecture. Bottom: cross-sectional schematic of each fin along gate-length direction.**

### Contact and gate stack developments

SEMATECH was involved in two pieces of research towards promoting InGaAs technology: in one, a self-aligned nickel source/drain contact process module was developed using wet etch [Rinus T.P. Lee et al, 2.6]; in the other, trigate MOSFETs were produced with a gate stack EOT of less than 1nm aimed at low-power logic [T.-W. Kim et al, 16.9].

The nickel process module work also involved New York State's College of Nanoscale Science and Engineering (CNSE), along with assignees from TSMC and GLOBALFOUNDRIES. The contacts helped the researchers achieve a 25% increase in saturated drain current over non-self-aligned molybdenum contact devices. The reduction in parasitic resistance was 27%. The thermal stability of the nickel contacts was also

increased over previous reports to 500°C by the use of a 'novel interlayer', enabling compatibility with standard very large scale integration (VLSI) back-end-of-line metallization processes.

The researchers comment: "Reduced parasitic resistance with a thermally stable, single contact scheme is significant to achieve a manufacturable path for III-V on Si."

The trigate MOSFET development involved University of Texas Austin, CNSE, Tokyo Electron Ltd, Yonsei University, and GLOBALFOUNDRIES. The transistor achieved SS as low as 77mV/dec, and DIBL of 10mV/V. The peak transconductance was 1.5mS/μm at 0.5V drain. The researchers write: "This result is the best balance of  $g_{m,max}$  and SS in any reported III-V MOSFETs."

The measured device (Figure 7) had a 60nm gate length with a fin width x height cross-section of 30nm x 20nm. Simulations suggest that the technology could be used for sub-10nm devices.

The sub-1nm EOT was achieved by using two layers of high-k dielectric: 0.7nm of Al<sub>2</sub>O<sub>3</sub> and 1.6nm of HfO<sub>2</sub>. The InGaAs channel was 20nm thick. The gate electrode metal was titanium nitride applied using atomic-layer deposition. In addition, on-resistance was 253Ω-μm, "the lowest reported in any non-planar III-V MOSFET", according to the team.

### Channel thickness and nanowires

The IMEC research center in Belgium has been studying the effect of InGaAs channel thickness on transistor performance [Alireza Alian, 16.6]. The team found that thinner channels improved electrostatic control, but at the cost of degraded mobility. A 3nm channel had a low mobility of 110cm<sup>2</sup>/V-s, resulting in loss of drive current. A 10nm channel was able to maintain mobility above 1000cm<sup>2</sup>/V-s while still delivering reasonable electrostatic control, as indicated by the SS of 77mV/dec with 10μm gate length. The on/off current ratio was 50,000.

The mobility droop in thin channels is attributed to increased scattering effects from oxide interface roughness/defects, border traps, and InP/InGaAs

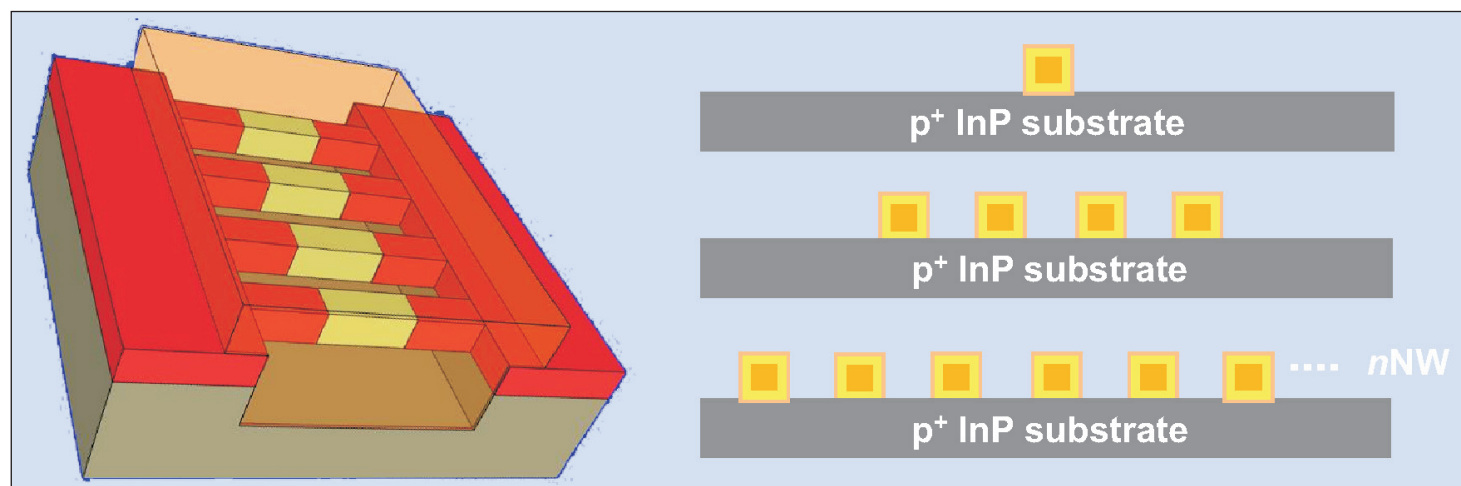
interface dipoles. A further problem suggested by simulations is that the carriers are effectively heavier. Heavy carriers tend to have lower mobility. IMEC also sees its work as having implications for nanowire devices with small cross-section parameters.

Purdue University reported "for the first time" on the variability and reliability of gate-all-around transistors (Figure 8) using multiple InGaAs nanowires [S. H. Shin et al, 7.5]. Two particular problems are: self-heating with high densities of nanowires to achieve high on-current that also increases the off-state leakage current, degrading the on/off ratio; and, variability in threshold voltage and subthreshold swing of individual nanowires negatively impacts the overall subthreshold performance. With 19 parallel nanowires, the researchers found the self-heating led to a temperature of 420K (~150°C).

The researchers conclude: "Such variability and heat dissipation must be carefully optimized to fully realize the dramatic scaling potential promised by surrounding-gate transistors."

Finally, researchers in Japan (AIST, Sumitomo Chemical Ltd., and Tokyo Institute of Technology) successfully fabricated triangular InGaAs-on-insulator (InGaAs-OI) n-type MOSFETs with smooth (111)B side surfaces on Si [E Moriyama et al, 2.2]. The triangular-shaped channels were formed by MOVPE growth on narrow InGaAs-OI fins. The bottom widths of the triangles were as small as 30nm. The use of (111)B surfaces for the transistor channel improved device mobility over reference InGaAs-OI tri-gate (by 1.9x) as well as bulk (100) InGaAs nMOSFETs (1.6x). The researchers suggest the new devices have lower interface trap density in the conduction band, suppressing carrier trapping at the MOS interface. The current reached 930μA/μm with 0.3μm gate length. ■

*The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.*



**Figure 8. InGaAs GAA NW MOSFET.**



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## 3 Substrates

### AXT Inc

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Fremont,  
CA 94538,  
USA

Tel: +1 510 438 4700  
Fax: +1 510 683 5901

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

Supplies GaAs, InP, and Ge wafers using VGF technology with manufacturing facilities in Beijing and five joint ventures in China producing raw materials, including Ga, As, Ge, pBN, B<sub>2</sub>O<sub>3</sub>.



### CrystAl-N GmbH

Dr.-Mack-Straße 77,  
D-90762  
Fürth,  
Germany

Tel: +49 (0)911 650 78 650 90  
Fax: +49 (0)911 650 78 650 93  
E-mail: [info@crystal-n.com](mailto:info@crystal-n.com)

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

### Crystal IS Inc

70 Cohoes Avenue  
Green Island, NY 12183, USA

Tel: +1 518 271 7375  
Fax: +1 518 271 7394

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

### Freiberger Compound Materials

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Freiberg, 09599, Germany

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Fax: +49 3731 280 106

[www.fcm-germany.com](http://www.fcm-germany.com)

### Kyma Technologies Inc

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Raleigh, NC, USA

Tel: +1 919 789 8880  
Fax: +1 919 789 8881

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

**sp3 Diamond Technologies**

2220 Martin Avenue,  
Santa Clara, CA 95050,  
USA

Tel: +1 877 773 9940

Fax: +1 408 492 0633

[www.sp3inc.com](http://www.sp3inc.com)

**Sumitomo Electric  
Semiconductor Materials Inc**

7230 NW Evergreen Parkway,  
Hillsboro, OR 97124,  
USA

Tel: +1 503 693 3100 x207

Fax: +1 503 693 8275

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

**III/V-Reclaim** 

Wald 10,  
84568 Pleiskirchen,  
Germany

Tel: +49 8728 911 093

Fax: +49 8728 911 156

[www.35reclaim.de](http://www.35reclaim.de)

III/V-Reclaim offers reclaim  
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structures from customers' wafers.  
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handled. The firm offers single-side  
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ready-to-use surface treatment.

**Umicore Electro-Optic Materials**

Watertorenstraat 33,  
B-2250 Olen, Belgium

Tel: +32-14 24 53 67

Fax: +32-14 24 58 00

[www.substrates.umicore.com](http://www.substrates.umicore.com)

**Wafer Technology Ltd**

34 Maryland Road, Tongwell,  
Milton Keynes, Bucks, MK15 8HJ,  
UK

Tel: +44 (0)1908 210444

Fax: +44 (0)1908 210443

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

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Fax: +1-561-842-2677

E-mail: [sales@waferworld.com](mailto:sales@waferworld.com)

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

**4 Epiwafer foundry****Spire Semiconductor LLC**

25 Sagamore Park Drive,  
Hudson, NH 03051, USA

Tel: +1 603 595 8900

Fax: +1 603 595 0975

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

**Cambridge Chemical Company Ltd**

Unit 5 Chesterton Mills,  
French's Road, Cambridge CB4 3NP,  
UK

Tel: +44 (0)1223 352244

Fax: +44 (0)1223 352444

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

**Intelligent Epitaxy Technology Inc**

1250 E Collins Blvd, Richardson,  
TX 75081-2401, USA

Tel: +1 972 234 0068

Fax: +1 972 234 0069

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

**IQE**

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

**Soitec**

Place Marcel Rebuffat, Parc de  
Villejust, 91971 Courtabouef, France

Tel: +33 (0)1 69 31 61 30

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**5 Deposition  
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[metalorganicsAP@akzonobel.com](mailto:metalorganicsAP@akzonobel.com)

**Americas:**

AkzoNobel Functional Chemicals,  
Chicago, USA

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Tel: +1 312 544 7000

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[metalorganicsNA@akzonobel.com](mailto:metalorganicsNA@akzonobel.com)

**Europe, Middle East and Africa:**

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Fax: +31 33 467 6101

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**Cambridge Chemical Company Ltd**

Unit 5 Chesterton Mills,  
French's Road,  
Cambridge CB4 3NP,  
UK

Tel: +44 (0)1223 352244

Fax: +44 (0)1223 352444

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

**Dow Electronic Materials**

60 Willow Street,  
North Andover, MA 01845,  
USA

Tel: +1 978 557 1700

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

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Newark, CA 94560,  
USA

Tel: +1 510 793 2559

Fax: +1 510 790 6241

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

**Mining & Chemical Products Ltd**

(see section 1 for full contact details)

**Power + Energy Inc**

(see section 10 for full contact details)

## Praxair Electronics

542 Route 303, Orangeburg,  
NY 10962,  
USA

Tel: +1 845 398 8242

Fax: +1 845 398 8304

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

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Wirral, Merseyside CH62 3QF, UK

Tel: +44 151 334 2774

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

## Williams Advanced Materials

2978 Main Street,  
Buffalo, NY 14214,  
USA

Tel: +1 716 837 1000

Fax: +1 716 833 2926

[www.williams-adv.com](http://www.williams-adv.com)

## 6 Deposition equipment

### AIXTRON SE

Kaiserstrasse 98,  
52134 Herzogenrath,  
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### Oxford Instruments Plasma Technology

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Fax: +43 5672 600 500

E-mail [info@plansee.com](mailto:info@plansee.com)

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

**PLANSEE**

### Plasma-Therm LLC

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### Temescal, a part of Ferrotec

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### MicroChem Corp

1254 Chestnut St. Newton,  
MA 02464, USA

Tel: +1 617 965 5511

Fax: +1 617 965 5818

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

**Power + Energy Inc**  
(see section 10 for full contact details)

**Praxair Electronics**  
(see section 5 for full contact details)

## 8 Wafer processing equipment

### EV Group

DI Erich Thallner Strasse 1,  
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Austria  
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Plasma Technology**  
(see section 6 for full contact details)

**Plasma-Therm LLC**  
(see section 6 for full contact details)

**Power + Energy Inc**  
(see section 10 for full contact details)

### SAMCO International Inc

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USA  
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Fax: +1 408 734 0961  
[www.samcointl.com](http://www.samcointl.com)

### SPTS Technology Ltd

Ringland Way,  
Newport NP18 2TA, UK  
Tel: +44 (0)1633 414000  
Fax: +44 (0)1633 414141  
[www.spts.com](http://www.spts.com)

**Veeco Instruments Inc**  
(see section 6 for full contact details)

## 9 Materials & metals

### Goodfellow Cambridge Ltd

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## 10 Gas and liquid handling equipment

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Cambridge CB3 8SQ,  
UK  
Tel: +44 (0)1954 786800  
Fax: +44 (0)1954 786818  
[www.cambridge-fluid.com](http://www.cambridge-fluid.com)

### CS CLEAN SYSTEMS AG

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Ismaning, 85737,  
Germany  
Tel: +49 89 96 24 00 0  
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[www.cscleansystems.com](http://www.cscleansystems.com)

### Power + Energy Inc

106 Railroad Drive,  
Ivyland, PA 18974,  
USA  
Tel: +1 215 942-4600  
Fax: +1 215 942-9300  
[www.powerandenergy.com](http://www.powerandenergy.com)

### SAES Pure Gas Inc

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San Luis Obispo,  
CA 93401,  
USA  
Tel: +1 805 541 9299  
Fax: +1 805 541 9399  
[www.saesgetters.com](http://www.saesgetters.com)

## 11 Process monitoring and control

### k-Space Associates Inc

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East, Dexter,  
MI 48130, USA  
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Fax: +1 734 426 7955

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

k-Space Associates Inc specializes in  
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### KLA-Tencor

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CA 95035,  
USA  
Tel: +1 408 875 3000  
Fax: +1 408 875 4144  
[www.kla-tencor.com](http://www.kla-tencor.com)

### LayTec AG

Seesener Str.  
10-13,  
10709 Berlin,  
Germany  
Tel: +49 30 89 00 55 0  
Fax: +49 30 89 00 180  
[www.laytec.de](http://www.laytec.de)  
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[www.wepcontrol.com](http://www.wepcontrol.com)

## **12 Inspection equipment**

### **Bruker AXS GmbH**

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Karlsruhe, 76187,  
Germany  
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Fax: +49 (0)721 595 4587  
[www.bruker-axs.de](http://www.bruker-axs.de)

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USA  
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Fax: +1 402 477 8214  
[www.jawoollam.com](http://www.jawoollam.com)

### **Lake Shore Cryotronics Inc**

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## **14 Chip test equipment**

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Cleveland, OH 44139,  
USA  
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Fax: +1 440.248.6168  
[www.keithley.com](http://www.keithley.com)

### **SUSS MicroTec Test Systems**

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Waterbury Center, VT 05677,  
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[www.suss.com](http://www.suss.com)

## **15 Assembly/packaging materials**

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Fax: +1 512 231 8183  
[www.epak.com](http://www.epak.com)

### **Gel-Pak**

31398 Huntwood Avenue,  
Hayward, CA 94544,  
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Tel: +1 510 576 2220  
Fax: +1 510 576 2282  
[www.gelpak.com](http://www.gelpak.com)

### **Wafer World Inc**

(see section 3 for full contact details)

### **Williams Advanced Materials**

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Buffalo, NY 14214, USA  
Tel: +1 716 837 1000  
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[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  
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Fax: +41 329257115  
[www.ismeca.com](http://www.ismeca.com)

### **Kulicke & Soffa Industries**

1005 Virginia Drive,  
Fort Washington,  
PA 19034,  
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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,  
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Fax: +1 408 748 0111  
[www.tecdia.com](http://www.tecdia.com)

## **17 Assembly/packaging foundry**

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USA  
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Fax: +1 858 674 4681  
[www.quikcpak.com](http://www.quikcpak.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

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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

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Fax: +43 5672 600 500  
E-mail [info@plansee.com](mailto:info@plansee.com)

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

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## 21 Computer hardware & software

### Ansoft Corp

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Pittsburgh, PA 15219, USA

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

### Crosslight Software Inc

121-3989 Henning Dr.,  
Burnaby, BC, V5C 6P8,  
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Fax: +1 604 320 1734

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

### Semiconductor Technology Research Inc

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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

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

### M+W Zander Holding AG

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Stuttgart,  
Germany

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Fax: +49 711 8804 1950

[www.mw-zander.com](http://www.mw-zander.com)

## 24 Consulting

### Fishbone Consulting SARL

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## 25 Resources

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San Jose, CA 95134, USA

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**E-mail:** [semiconsingapore@semi.org](mailto:semiconsingapore@semi.org)

**www.semiconsingapore.org**

**5–9 May 2014**

## **SPIE DSS 2014, incorporating: SPIE Security + Defence 2014 SPIE Sensing Technology + Applications 2014**

Baltimore Convention Center, MD, USA

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)

**http://spie.org/defense-security-sensing.xml**

**11–15 May 2014**

## **Compound Semiconductor Week 2014, inc: 41st International Symposium on Compound Semiconductors (ISCS 2014)**

## **26th International Conference on Indium Phosphide and Related Materials (IPRM 2014)**

Montpellier, France

**E-mail:** [csw2014@csw2014.org](mailto:csw2014@csw2014.org)

**www.csw2014.org**

**11–16 May 2014**

## **225th Electrochemical Society (ECS) Meeting**

Orlando, FL, USA

**E-mail:** [meetings@electrochem.org](mailto:meetings@electrochem.org)

**www.electrochem.org/meetings/biannual/fut\_mtgs.htm**

**14–15 May 2014**

## **SEMICON Russia**

Moscow, Russia

**E-mail:** [yulia.solovieva@businessmediarussia.ru](mailto:yulia.solovieva@businessmediarussia.ru)

**www.semiconrussia.org**

**19–21 May 2014**

## **25th annual SEMI Advanced Semiconductor Manufacturing Conference (ASMC 2014)**

Saratoga Springs, NY, USA

**E-mail:** [mkindling@semi.org](mailto:mkindling@semi.org)

**www.semi.org/asmc2014**

**19–22 May 2014**

## **2014 International Conference on Compound Semiconductor Manufacturing Technology (CS MANTECH)**

Sheraton Denver Downtown Hotel, CO, USA

**E-mail:** [conferencechairman@gaasmantech.org](mailto:conferencechairman@gaasmantech.org)

**www.csmantech.org**

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**1-6 June 2014****Microwave Week 2014:**

**IEEE Microwave Theory and Techniques Society's (MTT-S) 2014 International Microwave Symposium (IMS 2014)**  
**2014 IEEE Radio Frequency Integrated Circuits (RFIC) Symposium**  
**15th annual IEEE Wireless and Microwave Technology Conference (WAMICON 2014)**  
**Automatic RF Techniques Group (ARFTG)**  
**83rd Microwave Measurement Conference**

Tampa Bay, FL, USA

**E-mail:** tpc\_chairs@ims2014.org**www.ims2014.org****9-13 June 2014****2014 Symposia on VLSI Technology and Circuits**

Hilton Hawaiian Village, Honolulu, Hawaii

**E-mail:** vlsi@vlsisymposium.org**www.vlsisymposium.org****15-19 June 2014****6th International Workshop on Crystal Growth Technology (IWC GT-6)**

Berlin, Germany

**E-mail:** iwcgt-6@ikz-berlin.de**https://iwcgt-6.ikz-berlin.de****22-25 June 2014****The ConFab 2014**

Encore at the Wynn Resort, Las Vegas, NV, USA

**E-mail:** psinger@extensionmedia.com**www.theconfab.com****8-10 July 2014****SEMICON West**

Moscone Center, San Francisco, CA, USA

**E-mail:** semiconwest@semi.org**www.semiconwest.org****9-10 July 2014****UK Semiconductors 2014**

Sheffield UK

**E-mail:** info@uksemiconductors.com**www.uksemiconductors.com****13-18 July 2014****17th International Conference on Metalorganic Vapor Phase Epitaxy (ICMOVPE XVII)**

Lausanne, Switzerland

**E-mail:** icmovpe2014@epfl.ch**http://icmovpe2014.epfl.ch****14-16 July 2014****2014 IEEE Photonics Society Summer Topical Meeting Series**

Delta Montreal Hotel, Montreal, Quebec, Canada

**E-mail:** i.donnelly@ieee.org**www.sum-ieee.org****17-21 August 2014****SPIE Optics + Photonics 2014**

San Diego Convention Center, CA, USA

**E-mail:** customerservice@spie.org**http://spie.org/optics-photonics.xml****27-29 August 2014****IEEE Photonics Society's 11th International Conference on Group IV Photonics (GFP-2014)**

Cit  Internationale Universitaire de Paris, France

**E-mail:** m.figueroa@ieee.org**www.gfp-ieee.org****3-5 September 2014****SEMICON Taiwan**

TWTC Nangang Exhibition Hall, Taipei, Taiwan

**E-mail:** nsun@semi.org**www.semicontaiwan.org****22-25 September 2014****SPIE Security+Defence 2014**

Amsterdam RAI Exhibition and Convention Centre, The Netherlands

**E-mail:** info@spieeurope.org**http://spie.org/security-defence-europe.xml****5-10 October 2014****226th Electrochemical Society (ECS) Meeting**

Moon Palace Resort, Cancun, Mexico

**E-mail:** meetings@electrochem.org**www.electrochem.org/meetings/biannual/fut\_mtgs.htm****7-9 October 2014****SEMICON Europa**

Alpexpo, Grenoble, France

**E-mail:** eweller@semi.org**www.semiconeuropa.org****7-9 October 2014****Solar Power International (SPI '14)**

Las Vegas Convention Center

**E-mail:** plangdon@solarenergytradeshows.com**www.solarpowerinternational.com****12-16 October 2014****IEEE Photonics Conference (IPC) 2014**

Hyatt Regency La Jolla, San Diego, CA, USA

**E-mail:** i.donnelly@ieee.org**www.ipc-ieee.org**

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