

# semiconductor TODAY

COMPOUNDS & ADVANCED SILICON

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## Power semiconductors News from IMS and PCIM Europe

Rohm & GaN Systems collaborate • BluGlass raises funds  
Osram acquires Vixar • Hexatech launches 2" AlN substrates



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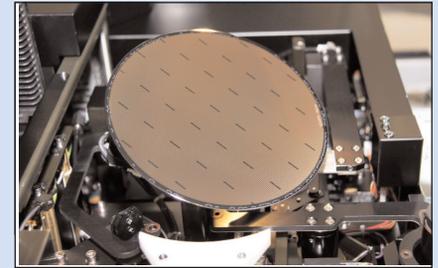
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Veeco's New TurboDisc EPIK700 GaN MOCVD System

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**p24** WIN Semiconductors has expanded its portfolio of highly integrated GaAs technologies with the release of the PIH0-03 pHEMT process.



**p40** Cardiff University in Wales, UK has opened the new refurbished £4m cleanroom at the Institute for Compound Semiconductors (ICS).



**p43** II-VI Epiworks has opened its new compound semiconductor material center of excellence in Champaign, IL.



Cover: Germany's 3-5 Power Electronics is entering the market with a new GaAs power semiconductor technology for high-voltage and high-current power electronics applications, after its first production plant entered operation in the Dresden Technology Center. **p16**

## Power electronics driving focus

June as usual saw the annual Power Conversion and Intelligent Motion (PCIM) Europe and IEEE International Microwave Symposium (IMS) events, which again offered the opportunity for both established industry giants and start-ups to present their latest technology developments and products.

At PCIM Europe (pages 18-29), silicon carbide launches included 1200V MOSFETs from Cree's Wolfspeed business (extending applications into electric vehicle drive-trains), Littelfuse (targeting electric vehicle chargers, data-center power supplies and renewable energy systems) and Microsemi (which is also sampling 700V SiC Schottky barrier diodes, as well as launching a new low-inductance package for SiC MOSFET power modules). Infineon has launched its first specifically automotive-targeted CoolSiC Schottky diodes (page 23), while ON Semiconductor has also expanded its SiC Schottky portfolio with automotive-specific AEC-qualified diodes (page 21).

According to IHS Markit (see page 7), the market for silicon carbide and gallium nitride power semiconductors will rise at a compound annual growth rate (CAGR) of over 35% from 2017 to nearly \$1bn in 2020 then \$10bn in 2027, driven partly by demand for hybrid/electric vehicle (HEV/EV) power-train inverters (as well as photovoltaic inverters and power supplies). Such demand has contributed to Rohm planning a new building at its Apollo plant in Chikugo, Japan in order to expand its production capacity for both SiC wafers and devices (page 20).

Infineon is also sampling its CoolGaN 400V and 600V enhancement-mode GaN HEMT transistors, for production by the end of 2018, citing applications such as telecom, adapter, wireless charging and server solutions (page 22).

Meanwhile, at IMS 2018, NXP launched new RF GaN wideband power transistors as well as third-generation silicon LDMOS products for macro and outdoor small-cell 5G cellular networks (page 26). Likewise, for telecom and radar markets Wolfspeed launched not only new GaN HEMTs but also silicon LDMOS products.

Such diversification from SiC and GaN to silicon follows Cree's acquisition in March of the RF Power business of Germany's Infineon Technologies. This is a turnaround from the thwarting in early 2017 of Cree's sale of its Wolfspeed Power & RF division to Infineon, when it intended to focus on its LED and Lighting Product businesses. Now, for its March quarter (excluding Infineon RF), Cree has reported Wolfspeed revenue up 46% year-on-year (rising from 16% to 23% of Cree's total revenue), compared with just 9% for LED Products and down 15% for Lighting Products (see page 68). Consequently, Cree's new long-term business strategy (announced in late February) involves a restructuring plan to right-size Lighting Products resources by the end of September, as well as focusing the LED Products business on higher-margin areas such as automotive lighting. Meanwhile, Cree's \$190m of annual capital expenditure is driven by a targeted doubling of power device manufacturing capacity by the end of 2018, and a quadrupling in Wolfspeed revenue by 2022 (growing from Cree's smallest business to its largest). To aid this (and drive greater efficiencies), Cree has combined the semiconductor manufacturing assets of Wolfspeed and LED Products under one leader (and likewise for the sales teams).

Such commitment from a formerly LED-focused firm exemplifies the maturing of wide-bandgap electronics into a major industry sector.

**Mark Telford, Editor**

[mark@semiconductor-today.com](mailto:mark@semiconductor-today.com)



**semiconductor**TODAY  
COMPOUNDS & ADVANCED SILICON



**Editor**

Mark Telford  
Tel: +44 (0)1869 811 577  
Cell: +44 (0)7944 455 602  
Fax: +44 (0)1242 291 482  
E-mail: [mark@semiconductor-today.com](mailto:mark@semiconductor-today.com)

**Commercial Director/Assistant Editor**

Darren Cummings  
Tel: +44 (0)121 288 0779  
Cell: +44 (0)7990 623 395  
Fax: +44 (0)1242 291 482  
E-mail: [darren@semiconductor-today.com](mailto:darren@semiconductor-today.com)

**Advertisement Sales**

Darren Cummings  
Tel: +44 (0)121 288 0779  
Cell: +44 (0)7990 623 395  
Fax: +44 (0)1242 291 482  
E-mail: [darren@semiconductor-today.com](mailto:darren@semiconductor-today.com)

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[www.higgs-boson.com](http://www.higgs-boson.com)

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

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

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- feature articles (technology, markets, regional profiles);
- conference reports;
- event calendar and event previews;
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## Micro- and mini-LED market to rise to \$1.38bn by 2022 Displays using mini-LED backlights on the market in second-half 2018

The market for micro-LED and mini-LED products will grow to \$1.38bn by 2022, forecasts a report by LEDinside (a division of market research company TrendForce).

Micro-LED displays and Mini-LED backlight technology have been in the spotlight at this year's exhibitions of consumer electronics and display technologies, and major manufacturers including Samsung, Sony and AUO have showcased related conceptual products. Also, Samsung may mass-produce ultra-large micro-LED TVs, driving more manufacturers to invest in mini-LED R&D.

### New technologies to accelerate micro-LED development

"Micro-LED still faces many technical bottlenecks, including epitaxial wafer/chip, transfer, full color, driver IC, backplane and inspection/repair technology," notes LEDinside research director Roger Chu. Transfer technology used to be the biggest bottleneck, but new transfer solutions have been emerging, such as pick & place transfer, fluid assembly, laser transfer and roller transfer. It is expected that there will be more

cost-competitive solutions in the future, which may accelerate the advancement of micro-LEDs.

LEDinside notes that micro-LED technology is most likely to be adopted for display products with special requirements, especially those beyond the capabilities of LCD and OLED displays. It expects that micro-LEDs will be gradually applied to augmented reality (AR) micro projections that require high brightness, automotive HUD (head-up display) projection applications, and ultra-large digital displays in the near future. LEDinside estimates the market for micro LED products in particular will reach \$694m by 2022.

### Mini-LEDs to see growth in high-end backlight market

Considering the existing technical barriers for micro-LED technology, manufacturers aim to launch mini-LED backlight solutions this year, hoping to boost demand. Displays using mini-LED backlights may appear on the market in second-half 2018, says LEDinside, and the market for mini-LED products is expected to reach \$689m by 2022.

Compared with conventional LED backlighting, mini-LED chips are smaller in size. Coupled with direct-type LED backlighting and local dimming, the number of LED chips used will grow in multiples, LEDinside notes. Mini-LED will therefore become a key application that drives the demand for LED chips, it adds.

However, the costs of mini-LED backlighting remain too high for mainstream displays, while problems of heat dissipation and power consumption have not yet been solved. So, mini-LEDs may enter the market through high-end consumer products such as gaming notebooks, gaming monitors, monitors with special applications, as well as niche products like high-end TVs with high resolution, high contrast and high color saturation. These products put more focus on specifications than on competitive prices, so they will become the main battlefield for vendors aiming to achieve technology differentiation through mini-LED backlight technology, LEDinside reckons.

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

## RF power semiconductor market reached almost \$1.5bn for 2017, driven by GaN

The market for RF power semiconductors (for <4GHz and >3W) reached almost \$1.5bn in 2017, says ABI Research. The wireless infrastructure segment was flat but other markets — notably military/defense — are moving forward. In particular, gallium nitride — long seen as the likely promising new 'material of choice' for RF power semiconductors — is continuing its march to capture share, the firm adds.

"Gallium nitride has the promise of gaining market share in 2018 and is forecast to be a significant force over the next few years,"

notes director Lance Wilson.

"It bridges the gap between two older technologies, exhibiting the high-frequency performance of gallium arsenide combined with the power handling capabilities of silicon LDMOS," he adds. "It is now a mainstream technology which has now achieved measurable market share and in future will capture a significant part of the market."

Wireless infrastructure, while representing about two-thirds of total sales, has been anemic recently. Growth for other segments outside of wireless infrastructure is showing

mid-single-digit compound annual growth rate (CAGR) over the forecast period of 2018–2023.

The vertical market showing the strongest uptick in the RF power semiconductor business, outside of defense, is commercial avionics and air-traffic control, which Wilson describes as now being "a significant market". While producers of these devices are in the major industrialized countries, this sub-segment market is now so global that end-equipment buyers can be anywhere, notes the report.

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

# GaN and SiC power semiconductor market growing at 35% CAGR to \$1bn in 2020 then \$10bn in 2027

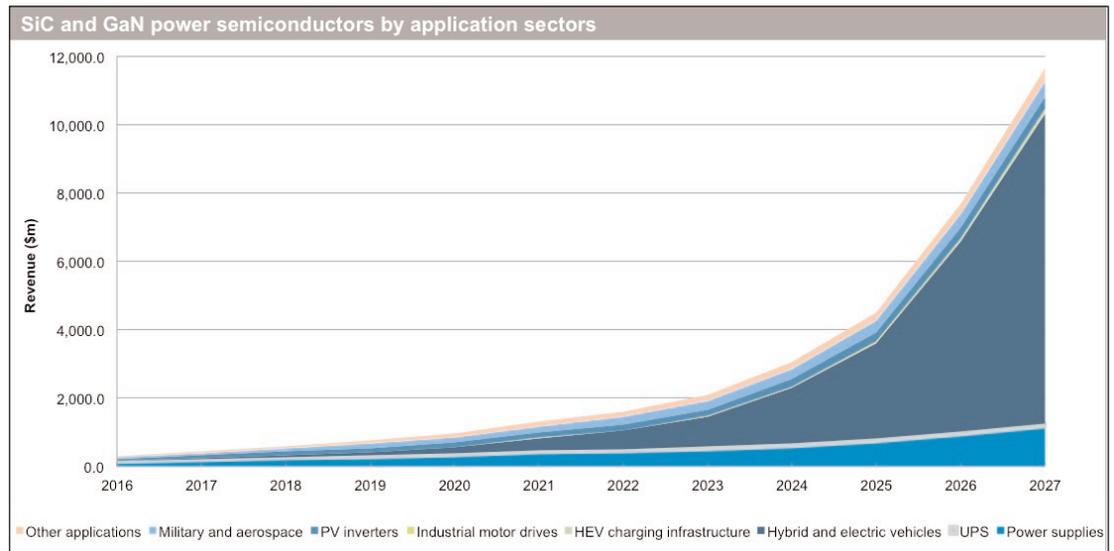
## Growth driven by power supplies, PV inverters and adoption in electric vehicle powertrain inverters

Energized by demand from power supplies, photovoltaic (PV) inverters and adoption in the main powertrain inverter in hybrid & electric vehicles (HEV/EV), the market for silicon carbide (SiC) and gallium nitride (GaN) power semiconductors will rise at a compound annual growth rate (CAGR) of over 35% from 2017 to nearly \$1bn in 2020 then \$10bn in 2027, forecasts the 'SiC & GaN Power Semiconductors Report — 2018' from IHS Markit.

In particular, by 2020 GaN-on-silicon transistors are expected to achieve price parity with silicon metal-oxide-semiconductor field-effect transistors (MOSFETs) and insulated-gate bipolar transistors (IGBTs), while also providing comparable performance. After this benchmark is reached, the GaN power market is expected to reach \$600m in 2024, and climb to over \$1.7bn in 2027.

Prospects for continuing strong growth in the SiC industry are high, fuelled predominantly by increasing sales of hybrid and electric vehicles. Market penetration is also growing, particularly in China, with Schottky barrier diodes, MOSFETs, junction gate field-effect transistors (JFETs) and other SiC discretes already appearing in mass-produced automotive DC-DC converters and on-board battery chargers.

It looks increasingly likely that powertrain main inverters — using SiC MOSFETs instead of silicon IGBTs — will start to appear on the market in 3-5 years, says Richard Eden, IHS Markit's principal analyst, power semiconductors. As there are many more devices used in main inverters than in DC-DC converters and on-board chargers, the required



quantity will also rise rapidly. Inverter manufacturers may eventually choose custom full-SiC power modules over SiC discretes, he adds. Integration, control and package optimization are the major strengths of module assemblers.

Not only will the number of per-vehicle SiC devices increase, but new global registration demand for both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) will also increase 10-fold between 2017 and 2027, as many global governments aim to reduce air pollution and lower dependence on vehicles burning fossil fuels, notes the report. China, India, France, Great Britain and Norway have already announced plans to ban cars with internal combustion engines in the coming decades, replacing them with cleaner vehicles. The prospects for electric vehicles generally, and for wide-bandgap semiconductors specifically, are therefore very good, the report reckons.

The biggest inhibitor to massive growth for SiC components could be GaN components, it is forecast. The first automotive AEC-Q101-qualified GaN transistor was launched in 2017 by Transphorm, and GaN devices manufactured on

GaN-on-Si epiwafers boast considerably lower costs. They are also easier to manufacture than anything produced on SiC wafers. For these reasons, GaN transistors could become the preferred choice in inverters in the late 2020s, ahead of more expensive SiC MOSFETs.

The most interesting story for GaN power devices in recent years has been the arrival of GaN system integrated circuits (ICs), which are GaN transistors co-packaged with silicon gate driver ICs, or monolithic all-GaN ICs, says the report. Once their performance is optimized for mobile phone and laptop chargers and other high-volume applications, usage may become prevalent in wider applications. In contrast, commercial GaN power diode development never really started, because they would not offer significant benefits over silicon devices, and developing them proved too costly to be viable, notes IHS Markit. Silicon carbide Schottky diodes already work well for that purpose and have a good pricing roadmap, it concludes.

<https://technology.ihs.com/601312/sic-gan-power-semiconductors-report-2018>

# Qorvo's quarterly revenue up 3.5% year-on-year, as 26% growth in Infrastructure & Defense Products counteracts drop in Mobile Products

## Faster-than-expected recovery in China handset demand to compensate for ZTE-related drop in IDP in June quarter

For full-year fiscal 2018 (to 31 March), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of \$2973.5m, down 1.9% on fiscal 2017's \$3032.6m.

Fiscal fourth-quarter 2018 revenue was \$664.4m, down 21.4% on \$844.8m last quarter but up 3.5% on \$642m a year ago and at the high end of the \$645–665m guidance range.

Mobile Product (MP) revenue was \$452m, down 29.6% on \$642m last quarter and 4.6% on \$474m a year ago but higher than expected due to improving handset demand in China.

"We are seeing increased demand in the performance tier for RF Flex and RF Fusion-based solutions as well as for antenna tuning, discrete components and BAW-based multiplexers," notes president & CEO Bob Bruggeworth. "Take for example our wins in Phase 6 architectures that include Qorvo's SAW [surface acoustic wave] and BAW [bulk acoustic wave] technologies. Our Phase 6 RF Fusion solutions include both the mid/high-band and low-band modules, which provide complete front-end coverage in two placements. In many cases, we're adding to our Phase 6 design wins with additional high-value content," he adds. This includes expanding support of a leading China-based smartphone maker with Phase 6 RF Fusion, as well as antenna tuning and envelope tracking (ET) for a marquee smartphone. Qorvo also expanded shipments of BAW-based band 1/3 quadplexers and commenced production shipments of Phase 6 RF Fusion to leading performance-tier smartphone makers.

Infrastructure & Defense Products (IDP) revenue was another record of \$212m, up 4.6% on \$202.7m last quarter and 26% on \$168m a year ago (the eighth consecutive quarter of double-digit year-on-year growth, contributing to full-year growth of over 20%). Growth was led by Internet of Things (IoT), defense and gallium nitride (GaN). "We successfully repositioned our product portfolio more than two years ago," says Bruggeworth. "IDP competes in diversified growth markets. We partner with the best in the business and we win with differentiated products and technologies," he adds.

"In defense, year-over-year growth was led by strength in ongoing production programs and the continued adoption of GaN for high-power applications," continues Bruggeworth. "In IoT, we continue to advance our 'Pod in Every Room' vision [yielding record smart-home revenue] with multiple 2.4GHz, 5GHz and BAW filter design wins with leading meshed Wi-Fi home networking system providers. We also achieved record revenue in low-power wireless, led by our production ramp of our multi-protocol SoC [system-on-a-chip] for Samsung's remote controls."

On a non-GAAP basis, gross margin was 48%, level with last quarter and up from 46.2% a year ago but at the lower end of the 48–48.5% guidance range due to the effects of product mix within both business units.

Operating expenses were \$155.6m, up from \$150.8m last quarter (and above the targeted \$153m) due to higher development program spending and seasonal payroll effects, but down from \$163.1m a year ago due to ongoing productivity efforts

(including September-quarter restructuring activities).

Operating income was \$163.1m (operating margin of 24.5% of sales), down from \$254.4m (30.1% margin) last quarter but up from \$133.4m (20.8% margin) a year ago.

Likewise, net income was \$138.6m (\$1.07 per diluted share, above the expected \$1.05), down from \$220.2m (\$1.69 per diluted share) last quarter but up from \$111.7m (\$0.85 per diluted share) a year ago.

Operating cash flow has fallen from \$270.1m last quarter to \$259m. Capital expenditure (CapEx) shrank again sequentially from \$45.5m to \$32.2m (compared with \$165.8m a year ago, when Qorvo was adding filter manufacturing capacity — full-year CapEx was under 10% of sales for fiscal 2018 compared with nearly 20% a few years ago). Qorvo hence achieved its second consecutive quarter of record free cash flow, at \$226.8m (above the forecasted \$200m), boosting full-year free cash flow to \$583m (in the last two quarters, individually, the firm has generated more free cash flow than it did in all of fiscal 2017).

During the quarter, Qorvo repurchased \$51m of stock. Cash and cash equivalents overall rose from \$841.3m to \$926m.

"In fiscal 2018, IDP expanded margins and achieved outstanding revenue growth, up over 20%, while Mobile Products expanded margins and built a solid foundation for profitable growth," says Bruggeworth. "I'm particularly pleased with our BAW-based design-win momentum across multiple products and customers, which we expect will lift factory utilization in the September quarter and beyond."

During fiscal Q4/2018, Qorvo received production orders from a

leading Korea-based smartphone maker for high-band BAW-based RF Fusion modules for 2018-model high-volume mass-tier smartphones. Qorvo also launched the industry's first BAW filter to deliver a quadrupling in power handling capabilities for 5G massive-MIMO front-end modules. "In infrastructure, the timeline for 5G deployment has accelerated and Qorvo is in close collaboration with customers by participating in dozens of 5G field trials and demos," says Bruggeworth. "We extended our 5G market leadership by adding the industry's first 28GHz GaN-on-SiC front-end module for base stations. This follows on the footsteps of the industry's first 39GHz front-end module which we released last year," he adds. "5G is coming across networks and mobile devices and it is accelerating the requirements for gigabit LTE, which will serve as the backbone for 5G. Gigabit LTE requires best-in-class, highly integrated placements and Qorvo is targeting the most complex and most valuable solutions, especially those that require BAW-based content."

In addition, Qorvo announced what is claimed to be the most powerful GaN-on-SiC transistor, boosting signal integrity and range with 1.8kW of output power at 65V.

"In both Mobile Products and IDP, Qorvo is addressing our customers' most critical challenge as the complexity of their products continues to increase. This favors superior performance as a differentiator and increases the value of enabling technologies like BAW and GaN," says Bruggeworth.

"We are forecasting significant growth in BAW-based products across customers, and our BAW factory utilization looks strong as we move into fiscal 2019," he adds.

For fiscal first-quarter 2019 (to end-June 2018), Qorvo forecasts revenue of \$645-665m. "We expect IDP to post another quarter of solid year-over-year growth, but to decline sequentially [following a very good fiscal Q4/2018] due partly to recent US Department of Commerce

actions on [China-based] ZTE [which comprises about \$10m of quarterly revenue, mostly in IDP]," says chief financial officer Mark Murphy. "For Mobile, we see sequential and year-over-year revenues up slightly and an improving demand environment in China."

Gross margin should fall to about 44%, reflecting:

- Near-term impacts of a weaker overall product mix — about half of the sequential decline is due to an increase in legacy lower-tier and less profitable products in the mix (although this is expected to reverse through the year after new product launches and as the mix shifts to higher-margin products in both mobile and IDP);
- Costs associated with low SAW fab capacity utilization. "While these costs weigh on margins through the year, with low seasonal revenues they are particularly impactful in the June quarter... We expect this impact to moderate through the year as revenues increase and our product mix shifts," says Murphy. "We will continue to work to minimize the burden of our SAW under-utilization. Outside our SAW capacity, our utilization outlook is positive," he adds.

"We view the June quarter as a transition period [from legacy, less advanced products and more SAW-related content to a portfolio that's more BAW related and other advanced technologies as well as GaN] and forecast gross margins to return to more normal levels in the September quarter [47-48%]," says Murphy. Despite these near-term impacts, Qorvo expects gross margin of at least 50% in fiscal second-half 2019 and about 49% for the full year. "Margin outlook for the full year of fiscal 2019 remains positive as we optimize our product portfolio, grow our top line, improve factory utilization and drive additional operational improvements," he adds.

Operating expenses should rise to \$165m in fiscal Q1/2019 due to higher personnel costs (including increased design activity) then remain slightly elevated over fiscal

first-half 2019 and trend down in the second half, totaling less than 20% of sales for the full year. "We expect to continue driving OpEx down as a percent of our revenue," says Murphy.

Diluted earnings per share should fall further to \$0.75 in fiscal Q1/2019.

"We are targeting our markets' fastest-growing and most profitable opportunities and we're gaining design wins across our customer base," says Bruggeworth. "We are poised to benefit from the strong secular trends in gigabit LTE, 5G, IoT and GaN," he adds.

"For the full year of fiscal 2019, we currently expect our premium Mobile Products and continued strength in defense, IoT and GaN will generate revenue growth of 9-10%," says Murphy. "With more profitable growth in mobile and robust growth in IDP, expanding operating margins and sustained low levels of CapEx, we expect to generate free cash flow of \$700-800m in fiscal year 2019," he adds.

"As we continue on our lean journey and become more efficient through operational excellence, we expect to grow the business with greater capital efficiency, by shrinking die sizes, expanding wafer diameters and leveraging our foundry relationships," says Bruggeworth. "We will roll out die shrinks and wafer conversions to help manage the need for additional capital expenditures to meet increases in BAW demand," he adds. BAW-based products are expected to rise from 22-23% of Mobile Products' revenue in fiscal 2018 to about 30% in fiscal 2019 then about half by fiscal 2021.

"Qorvo is better positioned today to target and win our markets' highest-growth and most complex opportunities, which will drive us toward our target operating model," says Bruggeworth. "We remain on track to achieve the operating margin target we laid out at our Investor Day last May of 33% by fiscal year 2020," adds Murphy.

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

# Skyworks' March-quarter revenue grows a more-than-expected 7% year-on-year

## Growth in Broad Markets mitigating softness at leading smartphone customers and US ban on ZTE

For its fiscal second-quarter 2018 (to end-March), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reported revenue of \$913.4m (a record for fiscal Q2), down 13% on \$1052m last quarter but up 7% on \$851.7m a year ago (and exceeding the \$910m guidance).

Mobile (Integrated Mobile Systems and Power Amplifiers) comprised 73% of revenue (down from 75% last quarter) and Broad Markets 27% (up from 25%). Broad Markets revenue grew about 10% sequentially.

"Skyworks delivered record top- and bottom-line results for the March quarter, driven by global demand for our high-performance connectivity engines," says president & CEO Liam K. Griffin.

During the quarter, Skyworks partnered with the world's largest automotive manufacturer to leverage connectivity across their global fleet; deployed integrated solutions for Honeywell's LTE handheld enterprise hubs; ramped Wi-Fi and ZigBee modules for Nest's connected video systems; secured new design wins at Belkin for high-speed mesh networks; supported Garmin's latest Forerunner advanced fitness smartwatches; delivered SkyOne and SkyBlue platforms for upcoming Lenovo and Asus high-performance notebooks; and launched 802.11ac solutions for the newest DIRECTV streaming gateway.

On a non-GAAP basis, gross margin was 50.7%, down on the record 51.4% last quarter but up from 50.4% a year ago.

Operating expenses have risen further, from \$116m a year ago and \$127m last quarter to \$132m (14.5% of revenue).

Operating income was \$331.1m (operating margin of 36.3% of revenue), down from \$414m

last quarter but up from \$312.5m a year ago.

Likewise, net income was \$302.3m (\$1.64 per diluted share, exceeding guidance by \$0.04), down from the record \$371.5m (\$2.00 per diluted share) last quarter but up from \$272m (\$1.45 per diluted share) a year ago.

"We demonstrated continued strength in our financial fundamentals as improvements in profitability directly translated into cash flow growth," says Griffin. Operating cash flow was \$434.2m (up from \$360.8m last quarter). Capital expenditure (CapEx) was \$90.3m. Free cash flow was hence \$344m (38% of revenue).

During the quarter, Skyworks paid dividends of \$58.4m and spent \$111.7m to repurchase more than 1 million shares of common stock. Overall, cash balance rose from \$1.682bn to \$1.881bn.

Skyworks' board of directors has subsequently declared a cash dividend of \$0.32 per share of common stock, payable on 12 June, to stockholders of record at the close of business on 22 May.

"Our solutions are enabling an expanding and diversified set of end markets spanning the Internet of Things, automotive, home security and factory automation," says Griffin.

During the quarter, Skyworks captured strategic design wins with leading mobile customers across a number of flagship platforms, including SkyOne, DRx, GPS, Wi-Fi, power management, and precision antenna tuning solutions. In parallel, in infrastructure markets, the firm deployed Massive MIMO solutions for India's largest network carrier, and collaborated with a premier European base-station supplier for small-cell deployments supporting AT&T, Verizon, T-Mobile, and Vodafone.

Skyworks also launched the Sky5 platform enabling 5G communications. "Skyworks is leveraging our deep systems knowledge, strategic partnerships, and formidable investments to accelerate the deployment of 5G, uniquely meeting the requirements for low-, mid-, high- and ultra-high-frequency bands with our differentiated Sky5 platform," says Griffin. "With the launch of Sky5, Skyworks is well positioned to capitalize on the transformational applications ahead — powering 5G networks and facilitating instantaneous, reliable and secure wireless connectivity," he adds.

"Strong growth in our broad market portfolio is mitigating the near-term softness at leading smartphone customers and the trade restrictions imposed by the US government on a Chinese OEM [ZTE, involving a \$25-30m hit on revenue, mostly in mobile, but including some infrastructure]," says senior VP & chief financial officer Kris Sennesael.

For fiscal third-quarter 2018 (to end-June), Skyworks hence expects revenue to fall to \$875-900m (rather than being roughly flat, without losing the ZTE revenue). Nevertheless, with operating expenses remaining flat sequentially, gross margin should be flat to up, at 50.7-51%. Diluted earnings per share are expected to fall to \$1.59.

"Based on new program ramps heading into the second half of the calendar year, we anticipate a resumption of sequential revenue growth in the September quarter with sustained momentum into the December period [following a traditional seasonal pattern for mobile and smartphones]," says Sennesael. In second-half 2018, further gross margin improvements towards the target model of 53% are expected.

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

## Qorvo appoints corporate VP global operations

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has appointed Paul J. Fego as corporate vice president, global operations (effective 30 July). Reporting to president & CEO Bob Bruggeworth, he will assume responsibility for global operations including internal and external wafer fabrication, assembly & test technology and manufacturing.

"Paul brings us more than 38 years of semiconductor technology and manufacturing experience with several large and complex global companies," says Bruggeworth. "He will play a critical role in helping us execute our strategic vision of consolidating our global operations organization into a highly efficient, collaborative team that helps drive our future growth and operational excellence," he adds.

Fego was most recently VP & man-

ager of the Worldwide Manufacturing group at Texas Instruments, where he managed all of its wafer fabrication, assembly and test operations in nine countries. He began his career at Texas Instruments as a manufacturing supervisor in 1980, rose through the ranks to become manufacturing manager and then left in 1989 to become operations director at ST Microelectronics.

In 2002, he became president & chief operating officer at photomask maker Photronics Inc, until he returned to Texas Instruments in 2005 to head up its worldwide manufacturing. Fego has a bachelor's degree from Rutgers University.

"I look forward to working with Bob and the Qorvo team to build a global operations team that helps drive future growth and operational excellence," comments Fego.

In connection with Fego's appointment, Steven R. Grant, VP of wafer fab technology and manufacturing,

and James D. Stilson, VP of assembly & test technology and manufacturing, separately announced their intention to retire from the firm in the future. Both Grant and Stilson will continue in an advisory capacity and have committed to work closely with Fego to ensure a seamless transition of their respective responsibilities for wafer fabrication, assembly and test operations.

"Steve Grant and Jim Stilson have both made tremendous contributions to Qorvo... I want to thank them both for those contributions, especially for their leadership in building the operational infrastructure for the company following its creation from the combination of RFMD and TriQuint in 2015," says Bruggeworth. "Steve started with TriQuint Semiconductor in 2008 as vice president of worldwide operations, while Jim started with RFMD in 2004 as its vice president of operations."

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

## Guerrilla RF launches low-current LNAs/linear drivers with integrated bypass as its first InGaP HBT products

Guerrilla RF Inc of Greensboro, NC, USA — a provider of radio-frequency integrated circuits (RFICs) and monolithic microwave integrated circuits (MMICs) for wireless applications — has added to its family of low-current, low-noise amplifiers and linear drivers with two devices that are tunable over 100–3800MHz, each exhibiting what are claimed to be outstanding gain and noise figure with a typical bias condition of 3.3V and 15mA.

The new broadband, low-noise linear amplifiers, with and without integrated bypass, cover a wide bandwidth with minimal external parts — yielding a compact, low-cost solution. They integrate a low noise figure, good linearity and low-loss bypass functionality into the firm's small DFN-6 (1.5mm x 1.5mm) application footprint, making it suitable for demanding small-cell,

cellular booster and repeater transmit–receive applications in the 700–3800MHz frequency bands.

The new LNAs/linear drivers address a growing industry need for cost-effective, broadband, discrete amplifiers delivering strong, consistent performance over a wide range of operating conditions. "With flexible biasing ( $V_{dd} = 2.7\text{--}5.0\text{V}$ ;  $I_{ddq} = 10\text{--}25\text{mA}$ ), these amplifiers provide consistent performance at low currents and very competitive prices," says Alan Ake, VP of applications and technical marketing.

**Following this introduction of the firm's InGaP HBT portfolio, additional announcements will be made in the coming months about new power amplifiers**

The GRF2373 and GRF2374 comprise Guerrilla RF's initial product offerings utilizing indium gallium phosphide heterojunction bipolar transistors (InGaP HBTs).

Samples and evaluation boards are available now, prior to production in fourth-quarter 2019. Pricing is \$0.40 and \$0.42 each (in 10,000-unit quantities) for the GRF2373 and GR2374, respectively.

Following this introduction of the firm's InGaP HBT portfolio, additional announcements will be made in the coming months about new power amplifier products, notes Ake.

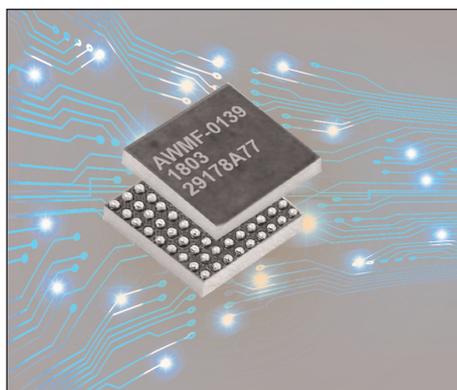
According to Research and Markets, the overall wireless network infrastructure market will rise at a compound annual growth rate (CAGR) of over 5% to more than \$104bn annually by the end of 2020.

<http://guerrilla-rf.com>

# Anokiwave adds 24/26GHz IC to new family supporting 3GPP-compliant mmW 5G equipment

Anokiwave Inc of San Diego, CA, USA — which provides highly integrated silicon core chips and III-V front-end integrated circuits for communications and radar applications needing millimeter-wave (mmW) active antenna-based solutions — has launched the next product in its new family of 5G-Gen 2 silicon quad core ICs that enable 3GPP-compliant base stations. With the worldwide release of the new 24/26GHz AWMF-0139 IC, the 5G-Gen 2 IC family now supports all major 5G mmW bands — 24/26GHz, 28GHz and 37/39GHz — and is part of Anokiwave's on-going strategy to enable the commercialization of 5G mmW systems with silicon ICs.

The AWMF-0139 is a highly integrated silicon IC packaged in a wafer-level chip-scale package (WLCSP), easily fitting within the typical 5.77mm lattice spacing at 26GHz. It operates at 24.25–27.5GHz, supports four radiating elements,



**The new 24/26GHz AWMF-0139 IC.**

and includes gain and phase controls for analog RF beam steering. Anokiwave's patent-pending IP blocks implemented in silicon technology are said to enable low-cost hybrid beam forming with high energy efficiency and 5G fast beam steering.

**5G operating frequencies around the world are converging on three mmW bands**

"5G operating frequencies around the world are converging on three mmW bands — 24/26GHz, 28GHz and 37/39GHz," says chief systems architect David Corman. "As the push to roll out 5G networks is proceeding at full speed, Anokiwave is executing on an aggressive strategy to deliver 5G solutions with industry-first ICs at these important bands," he adds.

"Today's announcement of the complete family of ICs that both enable 3GPP compliance and cover the important 5G bands is an essential step that allows network operators to roll out 5G coverage in earnest."

Anokiwave offers evaluation kits for ease of adoption of the technology and capabilities. The kits include boards with the IC, USB-SPI interface module with drivers, and all required cables. Pilot production deliveries of the AWMF-0139 are available now.

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

## Anokiwave introduces second set of intelligent gain block ICs in family of mmWave multi-market solutions

Continuing to redefine traditional single-function gain blocks, Anokiwave is releasing a set of two new ICs in a family of multi-function microwave and millimeter-wave silicon ICs, offering complete transmit/receive functionality with active gain and phase control. The new 'Intelligent Gain Block' (IGB) IC family offers versatile RF blocks that can be used in a wide range of applications including SatCom, radar, 5G communications and sensing.

Similarly to the previously released ICs in the IGB family (AWMF-0116 and AWMF-0117), The AWMF-0141 and AWMF-0143 provide a power amplifier (PA), low-noise amplifier (LNA), 6-bit gain and phase control and a transmit/receive (T/R) switch, all

integrated into a single IC operating in the Ku- and Ka-bands. Removing the T/R switch allows more flexibility and improved output power and noise figure.

The AWMF-0141 operates at 10.5–16GHz, providing +13.5dBm power output during transmit and 1.5dB noise figure during receive. The AWMF-0143 operates at 26–30GHz with +13dBm of power output during transmit and 3.0dB noise figure during receive. Both ICs provide 31.5dB of dynamic range and are packaged in a 2.5mm x 2.5mm wafer-level chip-scale package (WLCSP).

"The unique design of these ICs allows them to be used for highly integrated millimeter-wave arrays (such as 5G, SatCom or phased-array radars) or as a replacement

of single-function discrete blocks," says VP of sales Abhishek Kapoor. "With this new product family, designers can now use the same IC for multiple functions across the RF signal chain, have increased control using a software interface, and provide equivalent or better performance than traditional discrete gallium arsenide (GaAs) ICs," he adds. "We see these as the versatile new intelligent gain blocks of the microwave and millimeter-wave world."

For ease of adoption of the technology and capabilities, Anokiwave offers evaluation kits that include boards with the IC, USB-SPI interface module with drivers, and all required cables. Pilot-production deliveries are available now.

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

## Anokiwave expands design center in Billerica

Anokiwave Inc of San Diego, CA, USA — which provides highly integrated silicon core chips and III-V front-end integrated circuits for millimeter-wave (mmW) markets and active antenna-based solutions — has expanded its design center in Billerica, MA into a newly remodeled office to accommodate its rapid growth in highly integrated IC solutions for 5G communications, mobile satellite communications, and aerospace & defense markets that require millimetre-wave active antenna-based solutions.

With the expansion, Anokiwave has more than doubled its lab area for design validation and pilot-

production activities and now features the capability for pilot production of mmW wafer-level chip-scale packaged (WLCSP) ICs within the facility.

The updated modern open-concept floor plan includes a low-noise environment suitable for engineering teams, energy-efficient LED lights, with areas to accommodate larger groups including 'huddle rooms' for employees to utilize for meetings and brainstorming sessions. Anokiwave says that its initiative to go green with motion sensor lights and updated electronics has continued to be a priority.

"Anokiwave's continued product leadership in the rapidly evolving mmW active antenna market required a larger space to accommodate our growing staff," says chief operating officer Carl Frank. "The highly integrated silicon IC design expertise and innovative culture is at the core of Anokiwave's mission of enabling a new world," says founder & chief technology officer Nitin Jain. "Our team continues to demonstrate leadership in the market with exciting new product launches planned over the next few months in our key 5G, SatCom, and radar markets."

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

## Specialty foundry TowerJazz achieves IATF 16949 Automotive Quality Certification

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its US subsidiaries Jazz Semiconductor Inc in Newport Beach, CA and TowerJazz Texas Inc in San Antonio, TX, and at TowerJazz Japan Ltd) has attained the latest Automotive Quality Certification, IATF 16949 (the industry's highest standard of quality system for automotive suppliers).

The standard provides guidance and tools for manufacturers to ensure consistency with tight quality requirements, customer satisfaction and continuous improvement. This is achieved by proactive risk mitigation, advanced process and equipment control, and organizational mindset for quality and efficiency.

TowerJazz says that the new quality certification, together with decades-long automotive experience and a wide range of analog specialty manufacturing processes at all of its worldwide manufacturing facilities, enables it to meet the increasing demand for semiconductor content in the automotive market.

The firm says it is providing full support to its automotive customers, meeting their specific requirements, and working mutually to achieve zero defects and high reliability.

TowerJazz is addressing the analog automotive semiconductor market with technology developed through close partnerships and roadmap alignment with market leaders and global customer service. At the AutoSens 2018 conference in Detroit, MI, USA (14-17 May), TowerJazz showcased its offerings including CMOS image sensors (CIS), analog RF and power management manufacturing technologies addressing ADAS (advanced driver assistance systems) and autonomous driving requirements. TowerJazz has qualified each major process flow in at least two geographically distinct production sites to ensure customers with supply and capacity flexibility at all times.

"The new IATF certificate demonstrates our continued commitment to providing a best-in-class environment, ensuring the highest quality and reliability in manufacturing

next-generation automotive components," says Ilan Rabinovich, worldwide senior VP of quality & reliability.

"With the rapid expansion of automotive semiconductor content needed to meet the requirements of ADAS and autonomous cars, TowerJazz is well prepared to meet automotive customer demands with a broad offering of the highest-quality manufacturing technologies," reckons Dr Amol Kalburge, head of the automotive program at TowerJazz. "Our extensive collaboration with the leaders in this market is key to creating value for our customers, offering them innovative technologies that best suit their needs."

TowerJazz exhibited its automotive manufacturing solutions at AutoSens. In addition, Dr Amol Kalburge, head of the automotive program at TowerJazz, presented the 'Role of Specialty Analog Foundry in Enabling Advanced Driver Assistance Systems (ADAS) and Autonomous Driving'.

[www.towerjazz.com/automotive.html](http://www.towerjazz.com/automotive.html)  
<https://auto-sens.com/agenda-in-detroit>

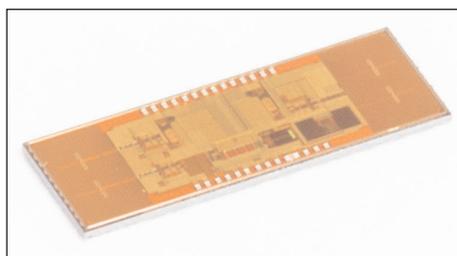
# Imec demonstrates compact low-power 140GHz CMOS radar with on-chip antennas

At the IEEE MTT-S International Microwave Symposium (IMS 2018) in Philadelphia, PA, USA, nanoelectronics research centre imec of Leuven, Belgium has unveiled what is said to be the first CMOS 140GHz radar-on-chip system with integrated antennas in standard 28nm technology.

The achievement is reckoned to be an important step in the development of radar-based sensors for smart intuitive applications such as building security, remote health monitoring of car drivers, breathing and heart rate of patients, and gesture recognition for man-machine interaction.

Radars are promising as sensors for contactless, non-intrusive interaction in Internet of Things (IoT) applications such as people detection & classification, vital signs monitoring and gesture interfacing. Broad adoption will only be possible if radars achieve a higher resolution, become much smaller, more power efficient to run, and cheaper to produce and to buy, so this is what imec's research on 140GHz radar technology targets.

The low-power 140GHz radar solution comprises an imec proprietary two-antenna SISO (single-input single-output) radar transceiver chip and a frequency-modulated continuous-wave phase-locked loop (FMCW PLL), off-the-shelf analog-to-digital converters



(ADCs) and a field-programmable gate array (FPGA) and a Matlab chain. The transceiver features on-chip antennas achieving a gain close to 3dBi. The radar link budgets are supported due to a transmitter effective isotropic radiated power (EIRP) that exceeds 9dBm and a receiver noise figure below 6.4dB. The total power consumption for transmitter and receiver remains below 500mW, which can be further reduced by duty cycling. The FMCW PLL enables fast slopes up to 500MHz/ $\mu$ s over a 10GHz bandwidth around 140GHz with a slope linearity error below 0.5% and has a power consumption below 50mW. The FPGA contains real-time implementation of basic radar processing functions such as FFTs (fast Fourier transforms)

**First applications are expected to be person detection and classification for smart buildings, remote car driver vital signs monitoring and gesture recognition**

and filters, and is complemented by a Matlab chain for detections, CFAR (constant false alarm rate), direction-of-arrival estimation and other advanced radar processing.

"With our prototype radar, we have demonstrated all critical specs for radar technology in 28nm standard CMOS technology," says imec's IoT program director Wim Van Thillo. "We are well advanced in incorporating multiple antenna paths in our most recent generation solution, which will enable a fine angular resolution of 1.5cm in a complete MIMO radar form factor of only a few square centimeters. We expect this prototype in the lab by the end of 2018, at which point our partners can start building their application demonstrators," he adds. "First applications are expected to be person detection and classification for smart buildings, remote car driver vital signs monitoring (as cars evolve towards self-driving vehicles), and gesture recognition for intuitive man-machine interactions. Plenty more innovations will be enabled by this technology, once app developers start working with it."

The imec 140GHz radar open innovation R&D collaborative program has been endorsed by Panasonic, and imec invites potential interested parties to join.

[www.ims2018.org](http://www.ims2018.org)  
[www.imec.be](http://www.imec.be)

## Custom MMIC receives 5-Star Supplier Excellence award from Raytheon

Monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA has been recognized by Raytheon Company of Waltham, MA, USA with a 5-star award during the Raytheon Integrated Defense Systems (IDS) 2018 Supplier Excellence Conference.

Raytheon's Integrated Defense

Systems business instituted the annual Supplier Excellence Awards program to recognize suppliers that have provided outstanding service and partnership in exceeding customer requirements. Award candidates are judged on criteria including overall quality, on-time delivery and demonstrated com-

mitment to continuous improvement. A 5-Star award is the highest level of recognition that a Raytheon Integrated Defense Systems business supplier can achieve for excellence in quality and performance, and Custom MMIC was one of nine companies selected.

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

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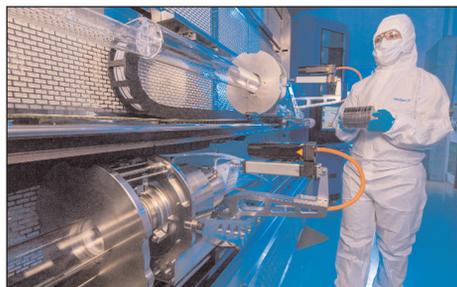
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## 35PE begins production of GaAs power semiconductors Fab-lite Dresden start-up targets 600V and 1700V power electronics

3-5 Power Electronics GmbH (35PE) of Dresden, Germany — which was founded in 2015 and specializes in developing and producing gallium arsenide (GaAs) power semiconductors — is entering the market with a new technology for high-voltage and high-current power electronics applications. This follows the firm's first production plant going into operation in the Dresden Technology Center on 11 April.

"Silicon-based elements are used for many applications today. However, these elements do not achieve the level of performance that will be required in the future for goals such as the implementation of Industry 4.0-capable technologies or the breakthrough of electric mobility," say joint managing directors Dr Gerhard Bolenz and Dr Volker Dudek, who co-founded 35PE with Richard J. Kulle. "The gallium arsenide structures that we produce offer the required power density, efficiency and reliability within an incredibly compact system," they add.

In its production plant, 35PE processes GaAs wafers under high vacuum to produce GaAs power semiconductors. So far, 12 patents have been applied for and regis-



**High-vacuum processing of GaAs wafers in 35PE's new GaAs power semiconductor production plant. Photo: 35PE/Kristin Schmidt.**

tered in Europe, China, Japan and the USA for process technology, material designs and component designs. Further applications are currently being processed.

The firm employs a fab-lite business model, in which 35PE performs core processes in-house and outsources standard services to contract manufacturers. The resulting GaAs diodes are said to meet the requirements placed on power electronics in areas such as modern industrial applications, renewable energy generation and fully electric or hybrid electric vehicles (EVs/HEVs). In the medium- and high-voltage range (600V and 1700V), they supplement silicon-based and silicon carbide (SiC)-based power electronics and are said to offer improved

energy efficiency while also reducing the weight, size and overall cost of the respective complete system.

Through its products and expertise, 35PE reckons that it can participate in the high growth forecasted for the power electronics market, particularly in the Far East. In addition to the firm's own sales activities in Europe and the Americas, an international network including strategic partners in China and Japan is targeted at enabling rapid entry to the Asian market.

Additional partnerships are currently being developed regarding location. "When we were looking for a location, our first choice was Silicon Saxony, with Dresden as the hub," say Bolenz and Dudek. "This location offers a great opportunity to establish a competence center for gallium arsenide power semiconductors together with other specialists in the semiconductor industry and in the field of semiconductor research, and in doing so, to achieve a global presence," they believe, citing a major objective behind their decision to choose Saxony as a location.

35PE currently has six employees and hopes to grow this to more than 20 within about three years.

[www.3-5pe.com](http://www.3-5pe.com)

## Pasternack signs RF Design as distributor for South Africa and Namibia

Pasternack Inc of Irvine, CA, USA (which makes both passive and active RF, microwave and millimeter-wave products) has signed RF Design of Cape Town, South Africa as an authorized distributor of Pasternack products in South Africa and Namibia.

RF Design joins a roster of international distributors that have partnered with Pasternack to increase its sales channels and provide value-added services to the RF market worldwide. As an official

distributor of Pasternack products, RF Design can now offer its customers access to what is claimed to be the industry's largest selection of RF, microwave and millimeter wave products available with same-day shipping from the USA.

"Expanding Pasternack's presence into the South African market has long been viewed as a great opportunity for our business," says Norm Brodeur, director of global distribution at Pasternack's parent company Infinite Electronics.

"Partnering with RF Design, the premier RF distribution company in South Africa, is an exciting development and will be mutually beneficial for our businesses," he adds. "By enlisting this top-notch supplier of RF and microwave components, we will effectively be able to extend our product reach, technical support and customer service channels, and have a visible presence in South Africa and Namibia."

[www.rfdesign.co.za](http://www.rfdesign.co.za)

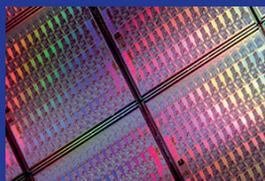
[www.pasternack.com](http://www.pasternack.com)

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# Microsemi announces low-inductance SP6LI package for SiC MOSFETs, enabling high current, high switching frequency and high efficiency

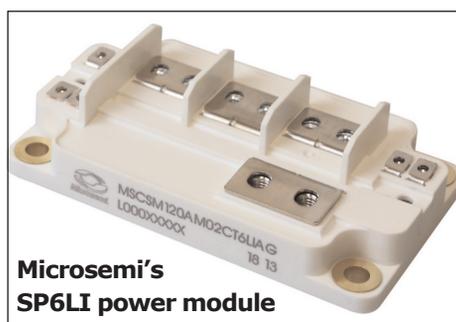
Microsemi Corp of Aliso Viejo, CA, USA (which makes chips for aerospace & defense, communications, data-center and industrial markets) has announced its extremely low-inductance package dedicated to high-current, low specific on-resistance ( $R_{DSon}$ ) silicon carbide (SiC) MOSFET power modules.

Developed specifically for the SP6LI product family, the new package is designed to offer 2.9nH stray inductance suitable for SiC MOSFET technology and enable high current, high switching frequency and high efficiency.

The SP6LI power modules in the new packaging, along with other SiC power modules from Microsemi's existing product family, were showcased at PCIM Europe 2018 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (5–7 June).

Microsemi says that, as it continues to expand its SiC solutions, it has become one of the few suppliers providing a range of Si/SiC power discrete and module solutions to the market. With what is claimed to be one of the lowest stray inductance packages in the industry dedicated to high-current SiC MOSFET power modules, the SP6LI product family features five standard modules, offering phase leg topology ranking from 1200V, 210A to 586A at a case temperature ( $T_c$ ) of 80°C to 1700V, 207A at a  $T_c$  of 80°C.

The SP6LI power modules feature a phase leg topology made of SiC power MOSFETs and SiC Schottky diodes, and offer an extremely low  $R_{DSon}$  down to 2.1m $\Omega$  per switch and an internal thermistor for temperature monitoring. They also offer screw-on terminals for both signal and power connections, as well as isolated and high-thermal-conductivity substrates (aluminium nitride as a standard and silicon nitride as an option) for improved thermal performance.



In addition, the standard copper base-plate can be replaced as an option with aluminium silicon carbide (AlSiC) material, enabling higher power-cycling capabilities.

Other key features include:

- an optimized layout for multi-SiC MOSFET and diode chips assembly in phase leg topology;
- a symmetrical design to accept up to 12 SiC MOSFET chips in parallel per switch;
- each die in parallel with its own gate series resistor for homogenous current balancing;
- high current capability up to 600A at very fast switching frequency; and
- optional mix of assembly materials to better address different markets and applications.

Offering higher power density and a compact form factor, the new package enables fewer modules in parallel to achieve complete systems, helping to further downsize equipment.

The SP6LI power modules can be used in switch mode power supplies (SMPS) and motor control in industrial, automotive, medical, aerospace and defense applications. Examples include electric vehicle/hybrid electric vehicle (EV/HEV) powertrain and kinetic energy recovery systems (KERS); aircraft actuation systems; power generation systems; switched mode power supplies for applications including induction heating, medical power supplies and electrification of trains; photovoltaic

(PV)/solar/wind converters and uninterrupted power supply (UPS).

"Our extremely low stray inductance standard SP6LI package is ideal for improving the performance of SiC MOSFETs for high-switching, high-current and high-efficiency applications, offering a smaller-sized power systems solution which can help customers significantly reduce their equipment needs," says Leon Gross, VP & business unit manager for Microsemi's Discrete and Power Management business unit. "These superior switching characteristics of our low-inductance package enable customers to develop higher-performance and highly reliable systems to help differentiate them from the competition."

According to market research firm Technavio, the SiC market for semiconductor applications is expected to grow at a compound annual growth rate (CAGR) of more than 18% to nearly \$540.5m by 2021. In particular, IHS Markit's research forecasts that by 2025 SiC MOSFETs will generate revenue exceeding \$300m — almost reaching the levels of SiC Schottky diodes — to become the second best-selling SiC discrete power device type.

During the PCIM Europe exhibition, Microsemi's product experts showcased its next-generation SiC solutions, including its new low-inductance SiC-based SP6LI power module. In addition, the firm's recently announced next-generation 1200V, 40m $\Omega$  SiC MOSFET device and 1200V, 10/30/50A SiC diode product will be showcased, along with a power factor correction (PFC) reference design.

The SP6LI product family is sampling now with the low-inductance package. [www.mesago.de/en/PCIM/main.htm](http://www.mesago.de/en/PCIM/main.htm) [www.microsemi.com/packaging-information/partpackage/details?pid=125782](http://www.microsemi.com/packaging-information/partpackage/details?pid=125782)

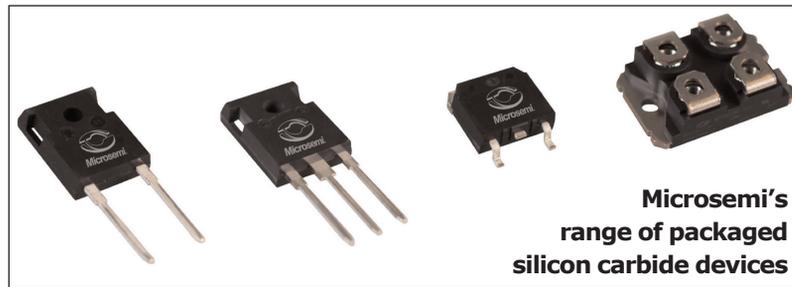
# Microsemi samples next-generation 1200V MOSFET and 700V Schottky barrier diode devices

Microsemi Corp of Aliso Viejo, CA, USA (which makes chips for aerospace & defense, communications, data-center and industrial markets) is expanding its silicon carbide (SiC) MOSFET and diode product portfolios early next quarter, including samples of its next-generation 1200V, 25mΩ and 80mΩ SiC MOSFET devices; next-generation 700V, 50A Schottky barrier diode (SBD) and corresponding die.

These SiC products, along with other recently announced devices in the SiC SBD/MOSFET product families, were demonstrated at PCIM Europe 2018 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (5–7 June).

Microsemi says that, as it continues to expand development efforts for its SiC product family, it has become one of the few suppliers providing a range of Si/SiC power discrete and module solutions to the market. The next-generation SiC MOSFETs are suitable for industrial and automotive markets applications, including hybrid electric vehicle (HEV)/EV charging, conductive/inductive onboard chargers (OBCs), DC-DC converters and EV powertrain/traction control. They can also be used for switch mode power supplies (SMPS), photovoltaic (PV) inverters, and motor control in medical, aerospace, defense and data-center applications.

"Fast adoption of SiC solutions for applications such as EV charging, DC-DC converters, powertrain, medical and industrial equipment, and aviation actuation demand a high degree of efficiency, safety and reliability on components used in such systems," says Leon Gross, VP & business unit manager for Microsemi's Power Discretes and Modules business unit. "Microsemi's next-generation SiC MOSFET and SiC diode families will include AEC-Q101 qualifications, which will ensure high reliability while ruggedness is demonstrated by



high repetitive unclamped inductive switching (UIS) capability at rated current without degradation or failures."

According to market research firm Technavio, the SiC market for semiconductor applications is expected to grow at a compound annual growth rate (CAGR) of more than 18% to nearly \$540.5m by 2021. In particular, it forecasts that the SiC market for automotive semiconductor applications will grow at a CAGR of nearly 20%. Microsemi reckons that it is well-positioned with these trends, with its SiC MOSFET and Schottky barrier diode devices avalanche-rated with a high short-circuit withstand rating for robust operation, and the capabilities necessary to enable these growing application trends.

Microsemi claims that its next-generation 1200V, 25/40/80mΩ SiC MOSFET devices and die as well as its next-generation 1200V and 700V SiC SBD devices offer benefits compared with competing silicon/SiC diode/MOSFET and IGBT solutions, including more efficient switching at higher switching frequencies as well as higher avalanche/UIS rating and higher short-circuit withstand rating for rugged and reliable operation. For example, SiC MOSFETs are developed with a balance of specific on-resistance, low gate and thermal resistances, and low gate threshold voltage and capacitance for reliable operation. Designed for high-yield processes and low parameter variation across temperature, they operate at higher efficiency (compared with Si and IGBT solutions) across

high junction temperature (175°C) to extend battery systems like those in HEV/EV

applications.

The new devices being sampled also offer what is claimed to be excellent gate integrity and high gate yield, as verified through high-temperature reverse bias (HTRB) and time-dependent dielectric breakdown (TDBD) tests, which are part of its AEC-Q101 qualification in progress. Other key features include:

- high UIS capability, 1.5–2x higher than competing SiC MOSFETs and gallium nitride (GaN) devices for avalanche ruggedness;
- high short-circuit rating 1.5–5x higher than competing SiC MOSFET devices for more rugged operation;
- up to 10x lower failure-in-time (FIT) rate than comparable Si IGBTs at rated voltage for neutron susceptibility and with comparable performance against SiC competition pertaining to neutron irradiation; and
- higher SiC power density versus silicon, enabling smaller magnetics/transformers/DC bus capacitors and less cooling elements for more compact form factor to lower overall system costs.

At PCIM Europe 2018, Microsemi demonstrated its next-generation SiC solutions, and in particular its recently announced next-generation 1200V, 40mΩ SiC MOSFET device and 1200V, 10/30/50A SiC diode products. The 1200V SiC MOSFET devices and die as well as the firm's 1200V and 700V SiC SBDs are sampling now.

[www.mesago.de/en/PCIM/main.htm](http://www.mesago.de/en/PCIM/main.htm)  
[www.microsemi.com/product-directory/discretes/3613-silicon-carbide-sic](http://www.microsemi.com/product-directory/discretes/3613-silicon-carbide-sic)

## Wolfspeed's new third-generation 1200V MOSFET extends SiC-based power conversion into EV drivetrains

Wolfspeed of Durham, NC, USA — a Cree Company that makes silicon carbide (SiC) power products and GaN-on-SiC high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs) — says that its new C3M third-generation 1200V SiC MOSFET family can be used in the drivetrain of electric vehicles (EVs).

Development of the switching device, which enables high-voltage power conversion, brings increased efficiency to the drivetrain while lowering system costs, paving the way for longer driving range and better overall EV performance.

"There is a growing global demand for more electric vehicles on the road, with nearly all vehicle manufacturers announcing new electric platforms across their fleets," says Cree Inc CEO Gregg Lowe. Wolfspeed's new silicon carbide MOSFET portfolio helps to foster the adoption of electric vehicles, he adds.

In 2015, Wolfspeed introduced what was claimed to be the industry's first 900V SiC MOSFET family, enabling

SiC adoption in off-board and on-board chargers by delivering smaller and higher-efficiency next-generation power conversion systems at cost parity with silicon-based solutions. The new 1200V MOSFET extends the firm's technology into the drivetrain, enabling the most efficient EV power converter systems.

Wolfspeed says that its new C3M 1200V SiC MOSFET can handle high current with what is claimed to be the industry's lowest drain-source on resistance ( $R_{DS(on)}$ ) performance at 1200V and the lowest switching losses, giving it the highest figure of merit on the market, which increases the distance that consumers can drive on a single charge.

"Wolfspeed's expanded SiC portfolio will make it possible for auto suppliers and manufacturers to develop the EV ecosystem of the future," says Wolfspeed's general manager Cengiz Balkas. "Our components enable smaller, lighter systems that deliver more miles per charge. This allows us to bridge the gap between EVs and gas vehicles

on cost and performance."

Engineering samples of Wolfspeed's newest-generation 1200V SiC MOSFETs are available to select customers and will be in full distribution later this year.

As well as the 1200V SiC MOSFET, Wolfspeed says that it continues to deliver better charging efficiency for EVs with enhanced SiC products for on-board and off-board chargers, including:

- E-Series diodes: the first 1200V SiC diodes to be both automotive qualified and high-humidity/high-voltage/high-temperature qualified;
- 20kW two-level AFE (active front-end) and 20kW DC/DC converters: demonstrating how Wolfspeed C3M SiC MOSFETs can cut power losses and simplify system designs; and
- 6.6kW bi-directional on-board charger: delivers optimal efficiency for high-power-density, on-board charger applications.

[www.mesago.de/en/PCIM/main.htm](http://www.mesago.de/en/PCIM/main.htm)  
[www.wolfspeed.com/RF](http://www.wolfspeed.com/RF)

## ROHM plans new building to expand SiC production

To meet the growing demand for its silicon carbide power devices, Kyoto-based ROHM plans a new building at its Apollo plant in Chikugo, Japan to expand production capacity.

The properties of SiC offer comprehensive applications in power electronics. SiC-based voltage converters have significantly less losses than conventional silicon-based converters. SiC also enables significantly smaller modules, components and systems than silicon. The increasing demand for the most energy-efficient devices possible will therefore increase demand for SiC components in the coming years, says ROHM.

The SiC market is forecasted to exceed \$1bn by 2021. The largest share comprises power supply

applications, such as power conditioners, battery chargers for electric vehicles and the power grid. However, the main inverter of electric vehicles also represents a significant part of the market potential for SiC components.

In 2010 ROHM started mass production of SiC power components such as SiC Schottky diodes and MOSFETs. It claims to have been the first supplier to produce complete SiC power modules and SiC trench MOSFETs. The firm has also introduced a vertically integrated production system throughout the group, spanning the entire manufacturing process from SiC wafers through devices to packaging.

ROHM says that it is targeting the top market share in SiC wafers and

components, and hence its production capacity must be greatly increased. Production efficiency is to be improved by further increasing wafer size and using the latest equipment. Secondly, constructing a new factory or building is also necessary. The new three-storey building at Apollo will increase production area by about 11,000m<sup>2</sup>. With detailed planning having just begun, construction is scheduled to begin next February and be completed by the end of 2020.

Going forward, ROHM Group aims to continue to ensure stable product supply by strengthening production capacity while implementing multi-site production, inventory control, and disaster prevention activities.

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

# ON Semiconductor adds AEC-qualified SiC Schottky diodes for demanding automotive applications

At PCIM Europe 2018 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (5-7 June), ON Semiconductor of Phoenix, AZ, USA — which supplies power management, analog, sensors, logic, timing, connectivity, discrete, system-on-chip (SoC) and custom devices — announced an expansion of its silicon carbide (SiC) Schottky diode portfolio to include devices specifically intended for demanding automotive applications. The new AEC-Q101 automotive-grade SiC diodes are said to deliver the reliability and ruggedness needed by modern automotive applications, along with the performance benefits synonymous with wide-bandgap (WBG) technologies.

As well as providing superior switching performance and higher reliability compared with silicon devices, the diodes have no reverse recovery current, and switching performance is independent of temperature. The thermal performance, increased power density and reduced EMI, as well as decreased system size and cost, make SiC attractive for the growing number of high-performance automotive applications, the firm adds.

The new SiC diodes are available in popular surface-mount and through-hole packages, including

TO-247, D2PAK and DPAK. The FFSHx0120 1200V Gen1 devices and FFSHx065 650V Gen2 devices offer zero reverse recovery, low forward voltage, temperature-independent current stability, extremely low leakage current, high surge capacity and a positive temperature coefficient. They deliver improved efficiency, while the faster recovery increases switching speeds, reducing the size of magnetic components required.

To meet the robustness requirements and perform reliably in the harsh electrical environments of automotive applications, the diodes have been designed to withstand high surge currents. They also include a unique, patented termination structure that improves reliability and enhances stability. Operating temperature range is  $-55^{\circ}\text{C}$  to  $+175^{\circ}\text{C}$ .

“By expanding our Schottky diode range with AEC-qualified devices, ON Semiconductor is bringing the significant benefits of SiC technology to automotive applications, allowing our customers to achieve the demanding performance requirements of this sector,” says senior director Fabio Necco. “SiC technology is a perfect fit for the automotive environment, where it delivers greater efficiency, faster

switching, improved thermal performance and high levels of robustness,” he adds. “In a sector where saving space and weight are critical, the greater power density of SiC - which helps reduce overall solution size - along with the associated benefit of smaller magnetics, is most welcome.”

The new devices are being demonstrated during PCIM, along with the firm’s solutions in areas such as wide-bandgap, automotive, motor control, USB type-C power delivery, LED lighting and smart passive sensors (SPS) for industrial predictive maintenance applications.

ON Semiconductor is also demonstrating its advanced SPICE model that is sensitive to process parameter and layout perturbations, and is therefore said to represent a step-change versus existing industry modelling capabilities. Using the tool, circuit designers can evaluate technologies early in the simulation process, rather than through costly and time-consuming fabrication iterations. A further benefit of the robust SPICE agnostic model is that it can port across multiple industry standard simulation platforms.

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## Infineon to start volume production of CoolGaN 400V and 600V e-mode HEMTs by end 2018

At PCIM Europe 2018 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (5–7 June), Munich-based Infineon Technologies AG showcased CoolGaN products in telecom, adapter, wireless charging and server solutions. With engineering samples available now, the firm announced that it is starting volume production of CoolGaN products by the end of 2018.

“The next big thing in power management is gallium nitride,” believes Steffen Metzger, Infineon’s senior director High Voltage Conversion. “The market for GaN has been gaining a strong momentum; the advantages of using this technology in certain applications are

evident,” he adds. “From operating expense and capital expenditure reduction, through higher power density enabling smaller and lighter designs, to overall system cost reduction, the benefits are compelling.”

During the quality management process not only the CoolGaN device is tested but also its behavior in the application. At 100ppm (parts per million), predicted lifetime is about 55 years (exceeding the expected lifespan by 40 years). CoolGaN enables, for example, doubled output power in a given energy storage slot size, freeing up space and realizing higher efficiency at the same time, says Infineon.

Full production of CoolGaN 400V and 600V enhancement-mode high-electron-mobility transistors (e-mode HEMTs) will start by end of 2018.

CoolGaN 400V will be available in 70mΩ in SMD bottom-side-cooled TO-leadless and top-side-cooled DSO-20-87 packages. CoolGaN 600V will be available in top-side-cooled DSO-20-87 and bottom-side-cooled DSO-20-85 packages.

With 70mΩ and 190mΩ 600V CoolGaN devices in bottom-side-cooled TO-leadless and DFN 8x8 packages, the 600V CoolGaN portfolio will be complemented.

[www.mesago.de/en/PCIM/main.htm](http://www.mesago.de/en/PCIM/main.htm)  
[www.infineon.com/gan](http://www.infineon.com/gan)

## Wolfspeed’s adds LDMOS and GaN HEMT products for telecom and radar markets

Wolfspeed of Durham, NC, USA — a Cree Company that makes silicon carbide (SiC) power products and GaN-on-SiC high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs) — has launched new LDMOS and GaN HEMT products that are said to enable smaller systems with greater reliability and efficiency. Wolfspeed’s recent acquisition of the Infineon RF power business expanded its product portfolio, accelerating its progress in developing innovations for telecom and aerospace/defense applications.

“The acquisition of Infineon’s RF power business has enabled Cree’s Wolfspeed business to transition to the next level of the RF power semiconductor business,” comments Lance Wilson, research director at ABI Research. “Historically, Wolfspeed has been a principal player in GaN technology, but the addition of Infineon’s LDMOS portfolio has put them into the top echelon of high-power RF.”

The acquisition brings LDMOS technology and expertise to Wolfspeed, enabling it to provide the optimal RF power solution to meet customers’ needs, regardless of the type of technology used, the firm says.

The expansion includes Wolfspeed’s new 28V 2620–2690MHz Asymmetric Doherty Transistor, which is an LDMOS Doherty transistor that utilizes LD12 technology. This and other LD12 components use a plastic overmold package that delivers the same performance as open cavity packages, offering significant increases in efficiency at a lower cost. Such plastic packages can bring significant cost savings to telecom applications, says Wolfspeed.

“Wolfspeed is committed to supporting the growth of our LDMOS portfolio, as shown by the release of our new 28V Asymmetric Doherty Transistor,” says Gerhard Wolf, Wolfspeed’s VP & general manager of RF. “The expansion of our LDMOS portfolio delivers on the

promise of continued innovation for cellular applications, like improved 4G networks and the shift to 5G networks.”

In the radar market, Wolfspeed is providing aerospace & defense operators better target discrimination and a longer detection range with the launch of the highest-output-power GaN products on the market, including a 1200W packaged GaN HEMT.

The 1200W GaN HEMT delivers what is claimed to be the highest output power for a GaN L-band radar product on the market. The device’s high output power enables fewer devices to be used, resulting in simplified system architectures, lower materials costs, reduced energy consumption and increased system reaction time that is critical in defense and aerospace settings.

The new LDMOS and GaN HEMT technologies were on display at the IEEE MTT International Microwave Symposium (IMS 2018) in Philadelphia, MA, USA (10–15 June).

[www.ims2018.org](http://www.ims2018.org)

## Infineon launches first automotive CoolSiC Schottkys

At PCIM Europe 2018 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (5–7 June), Infineon Technologies AG of Munich, Germany presented the first products in its automotive silicon carbide portfolio: the CoolSiC Schottky diode family is now ready for existing and future on-board charger (OBC) applications in hybrid and electric vehicles. Infineon has designed the diodes specifically to meet the high requirements of the automotive industry regarding reliability, quality and performance.

"The SiC technology is now mature to be deployed at broad scale in automotive systems," says Stephan Zizala, VP & general manager for Automotive High Power at Infineon. "The launch of the automotive CoolSiC Schottky diode

family is a milestone in the deployment of Infineon's SiC product portfolio for on-board charger, DC/DC converters and inverter systems," he adds.

The new product family is based on Infineon's fifth-generation Schottky diode, which has been further improved to meet the reliability requirements demanded by the automotive industry. Due to a new passivation layer concept, this is claimed to be the most robust automotive device available on the market regarding humidity and corrosion. Moreover, because it is based on 110µm-thick wafer technology, it exhibits what is reckoned to be one of the best figures of merit ( $Q_c \times V_f$ ) in its category (a lower figure of merit implies lower power losses and hence better electrical performance).

Compared to the traditional Silicon Rapid diode, the CoolSiC automotive Schottky diode can improve the efficiency of an on-board charger by one percentage point over all load conditions, says Infineon. This leads to a potential reduction of 200kg in CO<sub>2</sub> emissions over the typical lifetime of an electric car (based on the German energy mix), it is reckoned.

The first derivate (in the 650V class) will be available on the open market in September. Using a standard 3-pin TO247 package, the new products can easily be implemented into an on-board charger system, says Infineon. They can be used optimally in combination with Infineon's TRENCHSTOP insulated-gate bipolar transistor (IGBT) and CoolMOS products.

[www.mesago.de/en/PCIM/main.htm](http://www.mesago.de/en/PCIM/main.htm)

## Littelfuse adds GEN2 1200V SiC Schottky diodes

At PCIM Europe 2018 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (5–7 June), Littelfuse Inc of Chicago, IL, USA, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), introduced an expanded portfolio of silicon carbide (SiC) power semiconductor devices with the addition of five GEN2 Series 1200V, 3L TO-247 Schottky diodes and three GEN2 Series 1200V, 2L TO-263 Schottky diodes. Compared with silicon devices, GEN2 SiC Schottky diodes dramatically reduce switching losses and allow for substantial increases in the efficiency and robustness of power electronics systems, says the firm.

High-efficiency benefits that SiC technologies enable offer multiple advantages to the designers of electric vehicle (EV) chargers, data-center power supplies and renewable energy systems, notes Littelfuse. Because the GEN2 SiC Schottky diodes dissipate less

energy and can operate at higher junction temperatures than many alternative solutions, they require smaller heat sinks and enable a smaller system footprint. End-users can benefit from more compact, energy-efficient systems and a potential lower total cost of ownership, adds the firm.

The 3L TO-247 GEN2 SiC Schottky diodes are available with current ratings of 10A, 15A, 20A, 30A and 40A. The 2L TO-263 GEN2 SiC Schottky diodes are available with current ratings of 10A, 15A and 20A. All have negligible reverse recovery current, accommodate high surge currents without thermal runaway, and operate at junction temperatures as high as 175°C. They are suitable for applications that require improved efficiency and reliability and simpler thermal management than standard silicon bipolar power diodes can provide, such as:

- power factor correction (PFC);
- buck/boost stages in DC-DC converters;
- free-wheeling diodes in inverter

stages (switch-mode power supplies, solar, UPS, industrial drives);

- high-frequency output rectification; and

- electric vehicle (EV) charging stations.

"These GEN2 SiC Schottky diodes in 3L TO-247 and 2L TO-263 packages complement the 1200V SiC MOSFETs and other GEN2 1200V SiC Schottky diodes already available from Littelfuse," says Michael Ketterer, global product marketing manager, Power Semiconductors, Semiconductor business unit at Littelfuse. "We continue to strengthen our broad product portfolio which, after the acquisition of IXYS, positions Littelfuse as a tier-1 supplier for power semiconductor devices."

GEN2 Series SiC Schottky diodes are available in TO-247-3L and TO-263-2L packaging in tubes in quantities of 450. Sample requests may be placed through authorized Littelfuse distributors worldwide.

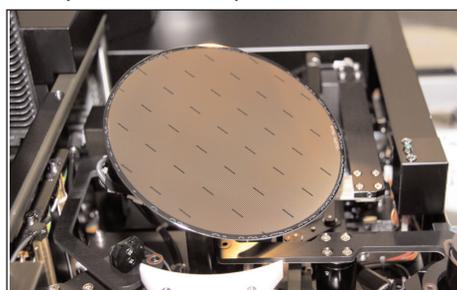
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[www.littelfuse.com](http://www.littelfuse.com)

## WIN releases platform integrating 0.1 $\mu$ m GaAs pHEMTs with monolithic PIN and vertical Schottky diodes

### Combination provides power and low-noise applications with on-chip limiters, detectors, mixers, PIN switch and ESD protection

WIN Semiconductors Corp of Taoyuan City, Taiwan — the largest pure-play compound semiconductor wafer foundry — has expanded its portfolio of highly integrated gallium arsenide (GaAs) technologies with the release of a new pseudo-morphic high-electron-mobility transistor (pHEMT) technology.

The PIH0-03 platform adds a highly linear vertical Schottky diode (with a cut-off frequency of more than 600GHz) as well as multi-function PIN diodes, monolithically integrated with WIN's mature PP10 high-performance 0.1 $\mu$ m pHEMT process while preserving its state-of-the-art millimetre-wave performance. WIN says that the availability of monolithic PIN and Schottky diodes with a high-performance millimeter-wave transistor enables on-chip integration of a wide range of functions, including mixers, temperature/power detecting, limiters and high-frequency switching, and supports power, low noise and optical applications



through 100GHz.

The integrated technology provides multiple pathways to add on-chip functionality and reduce the overall die count of complex multi-chip modules used in a variety of end-markets, says the firm. In addition to high-frequency switching, the monolithic PIN diodes can be used for low-parasitic-capacitance ESD protection circuits, and as an on-chip power limiter to protect sensitive low-noise amplifiers (LNAs) in phased-array radars. The vertical Schottky diodes enable numerous detecting and mixing functions and can be combined with the PIN diodes in unique

limiter applications.

"Today's complex systems and highly competitive markets require increased mmWave performance and more functionality per chip," says senior VP David Danzilio.

"The PIH0-03 platform is the latest example of how WIN Semiconductors is addressing these critical market needs by offering high-performance GaAs technologies with new levels of multi-function integration," he adds. "To meet the ever-increasing demands of next-generation mobile user equipment, wireless infrastructure, fiber-optic and military applications, WIN Semiconductors continues to commercialize advanced, highly integrated GaAs solutions."

WIN showcased its compound semiconductor RF and mm-Wave solutions at the IEEE MTT-S International Microwave Symposium (IMS 2018) in Philadelphia, PA, USA (10–15 June).

[www.ims2018.org](http://www.ims2018.org)

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

## Custom MMIC launches GaAs and GaN MMICs at IMS

At the IEEE MTT International Microwave Symposium (IMS 2018) in Philadelphia, MA, USA (10–15 June), monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA launched the CMD283C3 ultra-low-noise amplifier (ULNA) MMIC, which provides a 0.6dB noise figure, outperforming all other LNA MMICs, it is claimed, and rivaling discrete component implementations. It operates over a frequency range of 2–6GHz (S- and C-band) and has output third-order intercept point (IP3) of +26dBm.

Also being introduced are four members of the firm's new gallium arsenide (GaAs) MMIC digital attenuator family. The

CMD279 and CMD280 operate up to 30GHz with 5-bit control. Attenuation range is up to 15.5dB. Two 2-bit attenuators, the DC–35GHz CMD281 and DC–40GHz CMD282, offer coarser control in 2dB and 4dB steps, respectively. All four devices offer input IP3 of +42dBm.

The latest distributed amplifier, the DC–20GHz CMD249P5, offers a positive gain slope with nominal 12dB gain. The GaAs device features saturated power output ( $P_{sat}$ ) of +30dBm and output IP3 of +38dBm.

Custom MMIC also continues to enhance its line of low-phase-noise amplifiers (LPNAs). Responding to customer requests to assist in reducing unwanted phase noise and improve signal integrity and

target acquisition in military radar systems, these LPNAs operate at up to 40GHz and offer low phase noise performance down to  $-165\text{dBc/Hz}$  at 10kHz offset. They can serve as local oscillator (LO) drivers or receiver amplifiers in a variety of phased-array radar, electronic warfare (EW), military radio, instrumentation, and aerospace and space communication designs.

Further MMIC releases on the firm's horizon include more ultra-low-noise amplifiers and digital attenuators, as well as broadband distributed power amplifiers and gallium nitride (GaN) mixers.

[www.ims2018.org](http://www.ims2018.org)

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

## Qorvo launches ultra-compact GaN X-band front-end modules for radar applications

At the IEEE MTT-S International Microwave Symposium (IMS 2018) in Philadelphia, MA, USA (12–15 June), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) launched high-performance X-band front-end modules (FEMs) for use in next-generation active electronically scanned array (AESA) radar. The export-compliant gallium nitride (GaN) products also meet the need for high RF power survivability essential for mission-critical operations.

Demand for RF front-end components for radar applications is expected to rise at a compound annual growth rate (CAGR) of 9% to more than \$1bn in 2022. In particular, according to Strategy

Analytics the market for RF GaN devices for defense applications such as radar, electronic warfare and communications is projected to grow at 24% CAGR over the next five years, as the adoption rate of GaN significantly outpaces other technology choices.

The new QPM2637 and QPM1002 FEMs are based on Qorvo's GaN technology, enabling higher efficiency, reliability, power and survivability, as well as savings in size, weight and cost.

The GaN FEMs provide four functions in a single compact package, including an RF switch, power amplifier (PA), low-noise amplifier (LNA) and limiter. They can withstand up to 4W of input power on the receive side without permanent damage, compared with a typical gallium arsenide (GaAs) low-noise

amplifier, which can be damaged by less than 100mW of input power.

"Qorvo's field-proven GaN technology has enabled our customers to solve many challenges associated with the design of AESA radar systems, including greater power output and reliability," says Roger Hall, general manager of High Performance Solutions at Qorvo. "The introduction of our new export-compliant GaN modules enhances our ability to deliver the highest levels of integration with four parts in one, so that customers can choose the smallest, highest-performance FEMs for mission-critical radar systems."

The new products — which are EAR99 export compliant — are now sampling to qualified customers.

[www.ims2018.org](http://www.ims2018.org)

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

## Qorvo adds power amplifiers and front-end modules for massive MIMO and 5G base stations

At IMS 2018, Qorvo introduced five new power amplifiers (PAs) and front-end modules (FEMs) that further expand its portfolio of RF products for massive MIMO and 5G base stations. The highly integrated, efficient, small-size modules support all frequency bands used for pre-5G and 5G architectures, from 3GHz to 39GHz.

The market for massive MIMO base station configurations is expected to support \$1bn in RF solutions by 2022, forecasts EJL Wireless Research.

Due to its performance, efficiency and power, Qorvo says that its gallium nitride (GaN) technology

enables the transmission of multiple data streams with greater capacity, supporting rapid, cost-effective implementation of 5G networks.

The new products (for sub-6GHz 5G) include:

- two 2-stage Doherty power amplifiers (3.4–3.6GHz QPA3506 and 4.4–5GHz QPA4501);
- two integrated front-end modules (QPB9319 and QPB9329); and
- a wideband driver amplifier (the 1.8–5GHz QPA9120).

Qorvo recently unveiled two additional amplifiers — the QPF4005 and the QPF4006 —

said to be the industry's first GaN FEMs for 39GHz.

"With our products at work in dozens of 5G field trials, Qorvo continues to be a leading enabler of 5G, supporting exponential growth in mobile data," says Roger Hall, general manager of High Performance Solutions at Qorvo. "Today's RF portfolio expansion provides customers with the broadest range of 5G connectivity solutions in sub-6GHz and mmW 5G," he adds.

Engineering samples of the new products are now available to wireless infrastructure customers.

[www.qorvo.com/5G](http://www.qorvo.com/5G)

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## NXP adds high-power GaN RF and Si-LDMOS products for 5G cellular networks

At the IEEE International Microwave Symposium (IMS 2018) in Philadelphia, PA, USA (12–15 June), NXP Semiconductors N.V. of Eindhoven, The Netherlands expanded its cellular infrastructure portfolio by introducing new RF gallium nitride (GaN) wideband power transistors as well as Airfast third-generation silicon laterally diffused metal-oxide-semiconductor (Si-LDMOS) products for macro and outdoor small-cell 5G cellular networks.

“NXP released the world’s first LDMOS product in 1992 — today, we are extending our RF leadership with industry leading GaN technology, developed with the highest linear efficiency for cellular applications,” says Paul Hart, senior VP & general manager of NXP’s RF Power business.

Spectrum expansion, higher-order modulation, carrier aggregation, full-dimension beam forming and other enablers of 5G connectivity will require an expanded base of technologies to support enhanced mobile broadband connectivity, says NXP. With spectrum usage and network footprints, multiple-input multiple output (MIMO) technologies from four transmit (4TX) antennas to 64 TX and higher will be employed. The future of 5G networks will



depend on GaN and Si-LDMOS technologies, NXP notes.

The new products (packaged in a compact footprint) include:

- A3G22H400-04S: Suitable for 40W base stations, this GaN product yields up to 56.5% efficiency and 15.4dB of gain and covers cellular bands from 1800MHz to 2200MHz.
- A3G35H100-04S: Providing 43.8% efficiency and 14dB of gain, this GaN product enables 16 TX MIMO solutions at 3.5GHz.
- A3T18H400W23S: This Si-LDMOS product is paving the way to 5G at 1.8GHz with Doherty efficiency up to 53.4% and gain of 17.1dB.
- A3T21H456W23S: Covering the full 90MHz band of 2.11-2.2GHz, this solution exemplifies NXP’s Si-LDMOS performance for efficiency,

RF power and signal bandwidth.

- A3I20D040WN: Within NXP’s family of integrated ultra-wide-band LDMOS products, this solution offers peak power of 46.5dBm with 365MHz wideband class AB performance of 32dB of gain, and 18% efficiency at 10dB OBO.

- A2I09VD030N: This product offers peak power of 46dBm with class AB performance of 34.5dB gain, and 20% efficiency at 10dB OBO. The RF bandwidth is 575–960MHz.

NXP notes that the breadth of its RF Power technologies — which include GaN, silicon-LDMOS, SiGe, and GaAs — allows product options for 5G that span frequency and power spectrums with varying levels of integration. This wide array of options — combined with the products that NXP builds for digital computing, and baseband processing — makes NXP a supplier of end-to-end 5G solutions.

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

## Integra showcases new RF power devices at IMS 2018

At the IEEE MTT-S International Microwave Symposium (IMS 2018) in Philadelphia, MA, USA (10–15 June), Integra Technologies Inc (ITI) of El Segundo, CA, USA, which makes high-power RF and microwave transistors and power amplifier modules, showcased several new devices, including an array of 50Ω (fully matched) RF power transistors and integrated RF power modules (pallets) for pulsed radar applications.

The IGNP0912L1KW is a GaN/SiC (gallium nitride on silicon carbide) RF power module for L-band avionics systems operating over the instantane-

ous bandwidth 0.960–1.215GHz. The integrated amplifier module supplies a minimum of 1000W of peak pulse power, under conditions of 2.5ms pulse width and 20% duty cycle, while offering what is claimed to be excellent thermal stability.

The IGT5259L50 is a GaN/SiC transistor, offering 50W at 5–6GHz for pulsed C-band radar applications.

The IGN1214L500B is a high-power GaN/SiC high-electron-mobility transistor (HEMT) designed for long-pulse L-band radar applications that supplies 500W at 1.2–1.4GHz and offers 50V drain bias, 15.5dB

gain, and 65% efficiency.

Earlier, in May, ITI launched a GaN/SiC RF power transistor for C-band continuous-wave applications. The IGT5259CW25 is fully matched to 50Ω, operates over the instantaneous bandwidth 5.2–5.9GHz, and offers a minimum of 25W of output power at 36V drain bias. It features 12dB of gain and 48% efficiency under CW conditions. Negative gate voltage and bias sequencing are required when using the transistor.

[www.integrattech.com/](http://www.integrattech.com/)  
**50-ohm-rf-power-transistors**

# Navitas CTO Kinzer inducted into inaugural Power Electronics Hall of Fame

At the 30th IEEE International Symposium on Power Semiconductor Devices and ICs (ISPSD 2018) in Chicago (13-17 May), Dan Kinzer — co-founder & chief technology officer/chief operating officer of Navitas Semiconductor Inc of El Segundo, CA, USA — was inducted into the ISPSD inaugural Hall of Fame.

“It has been an opportunity to look back at the first revolution in power electronics 30 years ago with the mass adoption of power MOSFETs & switching regulators...and appreciate that we are at the start of the next revolution with the world’s first GaNFast power ICs and resonant topologies which will enable a new class of ultra-high-frequency, high-efficiency and high-density converters,” says Kinzer.

Navitas introduced what it claimed to be the first commercial GaN



**Dan Kinzer.**

power ICs. The firm says that its proprietary ‘AllGaN’ process design kit (PDK) monolithically integrates GaN power field-effect transistors (FETs)

with logic and analog circuits, enabling smaller, higher-energy-efficiency and lower-cost power for mobile, consumer, enterprise and new energy markets.

Kinzer has been inducted into the founding class of 2018 for his “contributions to power MOSFET technology and his leadership role in organizing ISPSD conferences,” says Dr John Shen, ISPSD conference chair and Grainger Professor of Electrical and Computer Engineering at Illinois Institute of Technology. “He has been one of the founders of the conference and has made

tremendous contributions to the field.”

Since graduating from Princeton University in 1978, Kinzer’s career has been highlighted by industry-first milestones and over 100 patents. For 25 years, he has led R&D at the VP level or higher at International Rectifier (Infineon), Fairchild (On Semiconductor) and then co-founded Navitas in 2014. Starting with silicon technology spanning 20V to 2000V and covering MOSFET transistors, high-voltage power ICs and insulated-gate bipolar transistors (IGBTs), Kinzer advanced new wide-bandgap silicon carbide (SiC) and gallium nitride (GaN) device design and fabrication processes to achieve proven, mass-production status and drive a next generation of energy-saving power converters.

[www.ispsd2018.com](http://www.ispsd2018.com)

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

## Navitas co-founder Kinzer presents keynote at inaugural IEEE WiPDA Asia conference

At the inaugural IEEE Workshop on Wide Bandgap Power Devices and Applications in Asia (WiPDA Asia 2018) in Xi’an Shanxi, China (17–19 May), Navitas Semiconductor’s co-founder & chief technology officer/chief operating officer Dan Kinzer delivered a keynote address to share the latest GaNFast power IC technology developments.

Founded in 2013, Navitas introduced what it claimed to be the first commercial GaN power ICs. The firm says that its proprietary ‘AllGaN’ process design kit (PDK) monolithically integrates GaN power field-effect transistors (FETs) with logic and analog circuits, enabling smaller, higher-energy-efficiency and lower-cost power for mobile, consumer, enterprise and new energy markets.

“This inaugural WiPDA Asia conference brings a forum to

China and the rest of Asia for the best minds in next-generation, wide-bandgap power semiconductor devices to share their advances,” says Kinzer. “It is an excellent opportunity to show the device-level and system-level performance and robustness benefits of GaNFast power ICs,” he adds. The advances are enabling a “new class of high-frequency, high-efficiency and high-density power systems.”

In his keynote ‘GaN Power IC Performance, Reliability and System Benefits’ on 19 May, Kinzer discussed GaN-integrated features such as drivers, voltage regulators, level shifters, bootstrap-charging, dV/dt control, with shoot-through and ESD protection. These features are said to not only protect the system but also cut frequency-related losses so

dramatically that they enable a 10–20x increase in switching frequency with lower total losses. The resulting efficiency allows a new generation of high-density power converters to operate with minimum heatsinking and well-controlled case and external touch temperatures.

“China is a very strategic region for Navitas and for the power electronics industry,” comments Charles Zha, Navitas’ senior director of China sales. “We are investing aggressively in China — last month we announced our first China sales office and applications lab in Shenzhen,” he adds. “This invited keynote at the first ever WiPDA event in China further reinforces the Navitas commitment to bring the world’s most advanced power semiconductors to the region.”

[www.wipda-asia.org](http://www.wipda-asia.org)

## EPC gives technical presentations on GaN technology and applications at PCIM Europe

At PCIM Europe 2018 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (5–7 June), 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 — exhibited its latest eGaN FETs and ICs in customers' end-products enabled by eGaN technology.

EPC gave live demonstrations of eGaN devices in several applications including: an eGaN-based

48V–12V DC–DC power converter for advanced computing and automotive applications; a high-power nanosecond pulsed eGaN laser driver for LiDAR used in autonomous vehicles; a table that can transfer up to 60W wirelessly; and a precision motor drive using a high-speed, highly efficient GaN-based module.

In addition, EPC gave five technical presentations on GaN technology and applications:

- 'GaN-Based Multilevel Intermediate Bus Converter for 48 V Server Applications' by

David Reusch;

- 'High Performance Thermal Solution for High Power GaN FET Based Power Converters' by Michael de Rooij and David Reusch;

- 'GaN – Devices for the Future Design' by Alex Lidow;

- 'High Power Nanosecond Pulse Laser Driver using an eGaN FETs' by John Glaser;

- '6.78 MHz Multi Amplifier and Transmit Coil eGaN FET based Class-E Wireless Power System Evaluation' by Michael de Rooij.

[www.mesago.de/en/PCIM/main.htm](http://www.mesago.de/en/PCIM/main.htm)

## EPC launches 350V, 65mΩ, 26A eGaN power transistor almost 20 times smaller than silicon equivalent

EPC has launched the EPC2050, a 350V GaN transistor with a maximum  $R_{DS(on)}$  of 65mΩ and a 26A pulsed output current. Applications include electric vehicle (EV) charging, solar power inverters, motor drives, and multi-level converter configurations, such as a 3-level, 400V input to 48V output LLC converter for telecom or server power supplies.

The EPC2050 is just 1.95mm x 1.95mm (3.72mm<sup>2</sup>), so designers no longer have to choose between size and performance, says the firm. A highly efficient half-bridge with gate driver hence occupies five times less area than a comparable silicon solution. Despite the small size of the chip-scale packaging, the EPC2050 is said to handle thermal conditions more efficiently than plastic-packaged MOSFETs.

"The performance and cost gap of silicon with eGaN technology widens with the 350V EPC2050, that is almost 20 times smaller than the closest silicon MOSFET," says CEO Alex Lidow.

In addition, the 2" x 1.5" (51mm x 38mm) EPC9084 development board is a 350V

**350 V eGaN® FET...**  
**Small Footprint, Big Power**

**Gate Drive IC**  
 25 mm<sup>2</sup>

**EPC2050**  
 350 V, 26 A  
 4 mm<sup>2</sup>

**Total Half-Bridge Footprint = 33 mm<sup>2</sup>**

(maximum device voltage) half-bridge featuring the EPC2050 and the Silicon Labs Si8274GB1-IM gate driver, designed for optimal switching performance and containing all critical components for easy evaluation of the 350V EPC2050 eGaN FET.

The EPC2050 eGaN FET is priced at \$3.19 each (in 1000-unit quantities) and the EPC9084 develop-

ment board is priced at \$118.75 each. Both are available for immediate delivery from distributor Digi-Key Corp.

<http://www.digikey.com/Suppliers/us/Efficient-Power-Conversion.page?lang=en>  
[www.epc-co.com/epc/Products/eGaNfetsandICs/EPC2050.aspx](http://www.epc-co.com/epc/Products/eGaNfetsandICs/EPC2050.aspx)  
[www.epc-co.com/epc/Products/DemoBoards/EPC9084.aspx](http://www.epc-co.com/epc/Products/DemoBoards/EPC9084.aspx)

# EPC completes automotive AEC Q101 qualification for two eGaN devices

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 achieved AEC Q101 qualification of two eGaN devices, opening up a range of applications in automotive and other harsh environments.

The EPC2202 and EPC2203 are both discrete transistors in wafer-level chip-scale packaging (WLCS) with 80VDS ratings and will soon be followed by several more discrete transistors and integrated circuits designed for the harsh automotive environment.

eGaN technology has been in mass production for over eight years, accumulating billions of hours of field experience in automotive applications, such as LiDAR (light detection and ranging) and radar for autonomous cars, 48V–12V DC–DC converters, and high-intensity headlamps for trucks. These are the first EPC products to have completed AEC Q101 qualification testing.

The EPC2202 is an 80V, 16mΩ enhancement-mode FET with a pulsed current rating of 75A in a 2.1mm x 1.6mm chip-scale package. The EPC2203 is an 80V, 73mΩ device with a pulsed current rating of 18A



in a 0.9mm x 0.9mm chip-scale package. The eGaN FETs are many times smaller and achieve switching speeds 10–100 times faster than their silicon MOSFET counterparts, it is reckoned. Both products are designed for a wide range of emerging automotive applications including: LiDAR; high-intensity headlights; 48V–12V DC–DC converters; and ultra-high fidelity infotainment systems.

To complete AEC Q101 testing, EPC's eGaN FETs underwent rigorous environmental and bias-stress testing, including humidity testing with bias (H3TRB), high-temperature reverse bias (HTRB), high-temperature gate bias (HTGB), temperature cycling (TC), as well as several

other tests. EPC's WLCS packaging passed all the same testing standards created for conventional packaged parts, demonstrating that the superior performance of chip-scale packaging does not compromise ruggedness or reliability. The eGaN devices are produced in facilities certified to the Automotive Quality Management

System Standard IATF 16949.

"These two initial automotive products will be followed by a constant stream of transistors and integrated circuits designed to enable autonomous driving and improve fuel economy and safety," says CEO & co-founder Alex Lidow. "Our eGaN technology is faster, smaller, more efficient and more reliable than the aging silicon power MOSFET used in today's vehicles."

Pricing is \$1.57 each for the EPC2202 and \$0.44 each for the EPC2203, in 1000-unit quantities. Both are available for immediate delivery from Digi-Key.

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

## Spirit Electronics made distributor for defense & aerospace markets

To support its accelerating growth in the defense & aerospace markets, 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 appointed Spirit Electronics as a distribution partner focusing on these key market segments.

Operating since 1979 and located in Phoenix, Arizona and Irvine,

California, Spirit Electronics supplies products and services to the US Department of Defense, aerospace and telecom industries.

"Spirit Electronics' knowledge of the market, along with their extensive history and proven successful track record for working with defense and aerospace customers, make them a perfect partner for representing EPC's industry-leading, off-the-shelf eGaN FET and IC product line,"

comments EPC's VP of sales & marketing Nick Cataldo.

"Our new partnership with EPC is an exciting addition to our portfolio of products and will allow us to bring the superior performance of eGaN power transistors and ICs to defense and aerospace customers, so they can design leading-edge power system solutions," says Spirit Electronics' CEO Marti McCurdy.

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

## ROHM and GaN Systems collaborate

Power semiconductor maker ROHM of Kyoto, Japan and GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) have announced a GaN power semiconductor collaboration, with the goal of contributing to the continuing evolution of power electronics.

The strategic partnership leverages GaN Systems' capabilities in power GaN transistors along with ROHM's footprint in semiconductors and resources in the design and manufacture of electronic components. The firms have agreed to jointly develop form-, fit- and function-compatible products using GaN semiconductor dies in both GaN Systems' GaNPX packaging and ROHM's traditional power semiconductor packaging. GaN Systems and ROHM say that their customers will have the advantage of having two possible sources for package-

compatible GaN power switches, presenting what is claimed to be the widest selection of dual-sourced GaN devices.

Customers will also benefit from greater access to GaN products and resources globally, especially in Asia (one of the fastest-growing market for GaN).

In addition, GaN Systems and ROHM will work together on GaN R&D activities to propose new solutions for the industrial, automotive and consumer electronics fields. Also, to contribute to greater energy savings and increased power densities in the power electronics market, both firms will continue to collaborate to expand their line-up of GaN products and broaden the range of choices.

"Gallium nitride has rapidly made its ascent into power electronics applications and this partnership exemplifies how important GaN has become in a complete power electronics offering," says GaN Systems'

CEO Jim Witham. "By combining our joint expertise and capabilities, we're enabling more businesses to access and experience the benefits of GaN in achieving higher-power, more efficient, smaller and lighter power electronics," he adds.

"ROHM has targeted the power device business as one of our growth strategies," says ROHM Semiconductor's senior managing director Katsumi Azuma. "We offer leading-edge products such as silicon carbide power devices and provide power solutions that integrate control technologies, including gate drivers that maximize device performance. We are also developing GaN for next-generation power devices," he adds. "By leveraging the superior technologies and expertise of both companies, we are able to accelerate the development of high-performance solutions to solve the needs of the power market."

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

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

## Power engineers from Chinese universities compete for 2018 'GaN Systems Cup'

In support of global innovation in the power electronics industry, GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) is once again sponsoring the annual China Power Supply Society (CPSS) design competition, which is currently underway with many engineering teams participating from leading universities throughout China. The fourth 'GaN Systems Cup' continues to promote the advancement of power electronic systems leveraging the benefits of GaN transistors.

GaN Systems has supported this annual competition for several years, helping to accelerate and proliferate the learning of and development of high-performing

system designs with GaN transistors to address the applications needs of the most demanding industries, including data centers, renewable energy systems, automotive, and consumer electronics.

"We're experiencing a revolution in power electronics driven by growing requirements for smaller, lighter, lower-cost, and more efficient power systems," says CEO Jim Witham. "It's an exciting time to be a power engineer challenged by the opportunities to create new or to improve on existing design approaches with GaN transistors," he adds. "We look forward to seeing their design creativity in November."

The contest allows students to not only compete for prizes but gain real-world, hands-on experience with GaN power transistors

from design to build. This year's challenge is to design a low-cost, high-efficiency and high-power-density bi-directional DC converter with 400W output power, 95% minimum efficiency, and greater than 20W/in<sup>3</sup> power density using GaN Systems' transistors.

The China Power Supply Society will announce the finalists on 25 August and announce the winning teams at the live finals and awards ceremony during its annual conference in Shenzhen, China on 4-7 November.

The contest is conducted in partnership with CPSS, the China Power Society Science Popularization Committee, and Nanjing University of Aeronautics and Astronautics.

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

[www.cpss.org.cn/cn/xinwendongtai/tongzhigonggao/8908.html](http://www.cpss.org.cn/cn/xinwendongtai/tongzhigonggao/8908.html)

## Transphorm launches Gen III 650V GaN FETs

Transphorm Inc of Goleta, near Santa Barbara, CA, USA has made available its third-generation (Gen III) 650V GaN FETs. Power transistors built on Gen III technology yield lower electromagnetic interference (EMI), increased gate noise immunity, and greater headroom in circuit applications, claims the firm.

The platform's latest evolution stems from knowledge gained from working with customers on end-product designs now in production. Gen III devices being released include the TP65H050WS 50m $\Omega$  FET and TP65H035WS 35m $\Omega$  FET, both available in standard TO-247 packages, priced at \$8.86 and \$11.55 respectively (in 1000-unit quantities). Optimal output ratings are for 1.5–5.0kW, depending on design criteria. Markets include industrial applications, data centers, merchant power supplies, and renewables.

Transphorm says that, since it has control over each critical stage of FET development, insight gained in customer development projects,

along with Gen I and II platforms, can be applied to the GaN-on-Si technology to increase transistor quality, reliability and performance. Data is often gathered that also informs development techniques that can simplify design complexity, increase safety margin and/or positively affect power system performance, adds the firm.

Transphorm says research that led to Gen III yielded both opportunities: increased benefits now inherent to the GaN technology itself and new design methods augmenting the FET's performance. Further, the design and fabrication innovations enable it to reduce device price.

Also, incorporation of a new MOSFET along with other design modifications enable Gen III devices to deliver:

- an increased threshold voltage (noise immunity) to 4V from 2.1V for Gen II, eliminating the need for a negative gate drive; and
- a gate reliability rating of  $\pm 20V$ ; an 11% increase versus Gen II.

As a result, switching is quieter,

and the platform delivers performance improvement at higher current levels with simple external circuitry, says Transphorm.

Regarding learned design techniques, Transphorm published solutions for oscillation suppression in its app note 0009: 'Recommended External Circuitry for Transphorm GaN FETs'. Example recommendations include the use of DC-link RC snubbers and switching-node RC snubbers that add further stability without adverse impact on efficiency. The solutions can benefit half-bridge and bridgeless totem-pole PFC topologies.

"It is important to us to evolve our GaN technology based on customer need and real-world experience," says Philip Zuk, VP of technical marketing. "Gen III FETs exemplify what's possible when we adhere to that basic philosophy," he adds. "We've brought forth a safer, more cost-effective high-voltage GaN FET," says Dr Yifeng Wu, senior VP of engineering.

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

## HV GaN FETs used in Seasonic's high-efficiency 1.6kW PFC platform

Transphorm's HV GaN FETs are being used by Seasonic Electronics of Taipei, Taiwan in its new 1600W bridgeless totem-pole power factor correction (PFC) platform. The 1600T is the power supply manufacturer's highest-performing PFC platform to date (>99% efficiency). The introduction of GaN delivers a 2% efficiency increase and 20% power density increase over Seasonic's silicon-based platform.

The 1600T platform will be scaled and deployed in catalog products targeting the charger (e-scooters, industrial, etc), gaming, server and PC power markets.

"When researching semiconductor technologies that would enable us to reach world-leading efficiency levels, gallium nitride stood out as an attractive alternative to silicon," says Seasonic's director of R&D Paul Lin. "We knew the bridgeless

totem-pole PFC was the topology we would use in our first high-voltage GaN power platform. So, we needed power semiconductors capable of successfully capitalizing on that," he adds. "We wanted a GaN solution that could be backed by our standard warranty. We ultimately opted for Transphorm's FETs within the 1600T given their proven performance and reliability."

The 1600T employs Transphorm's TP65H035WS device, a 650V GaN FET with an on-resistance ( $R_{DS(on)}$ ) of 35m $\Omega$  in a standard TO-247 package. The transistor achieves increased efficiency in hard- and soft-switched circuits, providing power systems engineers options when designing products. Further, the TP65H035WS pairs with commonly used gate drivers to simplify designs while controlling costs. Also, Transphorm claims its GaN

typically delivers greater headroom and noise immunity than other GaN FETs. The TP65H035WS' typical gate threshold is 4V with a maximum gate voltage of  $\pm 20V$ .

Given GaN's relative newness in high-voltage applications, Transphorm offers field application support and hands-on training. Seasonic leveraged the firm's experts to strengthen the design while speeding time to market. Transphorm's guidance helped Seasonic's team ramp on use of a simple, low-cost DSP to control the totem-pole PFC. Transphorm also aided in the platform's component selection and system layout. Ultimately, the co-development directly impacted Seasonic's ability to drive up thermal efficiency while increasing power output, says Transphorm.

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

## VisIC raises \$10m to expand GaN power device portfolio and address more market segments

### Firm to increase technical support team to assist growing worldwide customer base

VisIC Technologies Ltd of Nes Ziona, Israel – a fabless developer of power conversion devices based on gallium nitride (GaN) metal-insulator-semiconductor high-electron-mobility transistors (MISHEMTs) – has closed a \$10m Series D round of financing led by a private investor.

The electrification of automotive vehicles has been growing at an unprecedented pace recently and will continue to grow for the foreseeable future, says the firm. GaN power devices get the maximum performance out of high-power, high-voltage power conversion systems inside hybrid and electric vehicles (HEV/EV). The improved size, weight, efficiency and heat management of the on-board charger and the DC/DC converter,

designed with GaN power devices, all contribute to faster charging and longer driving range. High-performance power supplies for telecom systems and datacenters are using GaN power devices to reach new levels of density and efficiency, notes VisIC, bringing down the electricity costs of the operators significantly.

“GaN technology opens a new space in power electronics — from shifting the performance envelope up to the point of new topologies development. We are delighted to see VisIC offering specifically rugged GaN devices with negligible fast transient dynamic RDSon,” comments Ivan Feno, principal power design engineer at Bel Power Solutions. “The insulated thermal pad is another welcome feature

enabling the increase of the power-stage reliability and density,” he adds. “Ultimately, 1200V-rated GaN devices might be an attractive alternative in the 1200V segment dominated by SiC technology today.”

VisIC says that its technology, in combination with ongoing R&D designs by large players in the power electronics industry, made it possible to close this round of funding on favorable terms.

“With the new funding, we can expand our portfolio further to address more market segments,” says founder & CEO Tamara Baksht. “Furthermore, we will increase our technical support team to assist our growing worldwide customer base,” she adds.

[www.visic-tech.com](http://www.visic-tech.com)

## Exagan launches G-FET power transistors and G-DRIVE intelligent fast-switching products for consumer, industrial and automotive applications

At PCIM Europe 2018 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (5–7 June), gallium nitride technology start-up Exagan of Grenoble and Toulouse, France (founded in 2014 with support from CEA-Leti and Soitec) launched its G-FET power transistors and G-DRIVE intelligent fast-switching solution, featuring an integrated driver and transistor in a single package. The firm claims that the GaN-based devices are easy to design into electronic products, paving the way for fast chargers that comply with the USB power delivery (PD) 3.0 type C standard while providing exceptional power performance and integration.

At PCIM Europe, Exagan showcased the use of its high-power-

density GaN-on-silicon devices to create ultra-fast, efficient and small 45–65W chargers, including demonstrating its electrical-converter expertise and how both the G-FET and G-DRIVE can benefit new converter product designs and their applications.

“The market potential for our products is enormous including all portable electronic devices as well as homes, restaurants, hotels, airports, automobiles and more,” reckons president & CEO Frédéric Dupont. “In the near future, users will be able to quickly charge their smart phones, tablets, laptops and other devices simply by plugging a standard USB cable into a small, generic mobile charger.”

The ability of USB type C ports to serve as universal connections for

the simultaneous transfer of electrical power, data and video is leading to tremendous growth. The number of devices with at least one USB type C port will multiply from 300 million units in 2016 to nearly 5 billion by 2021, forecasts market research firm IHS Markit.

Aiming to accelerate the power electronics industry’s adoption of cost-effective GaN-based solutions for the charger market, Exagan uses 200mm GaN-on-Si wafers, achieving highly cost-efficient high-volume manufacturing. The firm is now sampling its fast, energy-efficient devices to key customers while ramping up production to begin volume shipments of G-FET and G-DRIVE products.

[www.exagan.com/en/products/gfet-family](http://www.exagan.com/en/products/gfet-family)

# WIN extends GaN power process capabilities to 0.45 $\mu$ m-gate technology for 5G applications

## NP45-11 process provides 50V operation with superior power density and efficiency

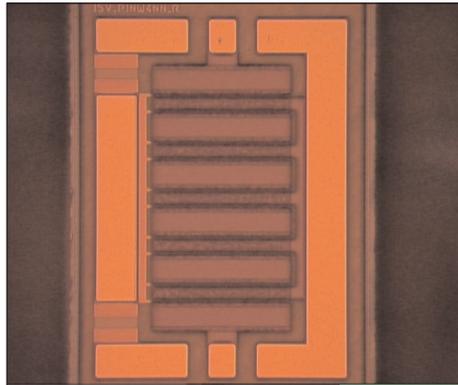
WIN Semiconductors Corp of Taoyuan City, Taiwan — the largest pure-play compound semiconductor wafer foundry — has expanded its gallium nitride (GaN) process capabilities to include a 0.45 $\mu$ m-gate technology that supports current and future 5G applications.

The NP45-11 GaN-on-SiC process allows customers to design hybrid Doherty power amplifiers used in 5G applications including massive MIMO (multiple-input and multiple-output) wireless antenna systems. Similar to macro-cell applications, MIMO base stations often combine Doherty power amplifiers with linearization techniques to meet demanding linearity and efficiency specifications of today's wireless infrastructure.

GaN devices outperform the incumbent LDMOS technology, offering superior efficiency, instantaneous bandwidth and linearity, particularly in the higher frequency bands utilized in 5G radio access networks, notes WIN.

Suitable for use in sub-6GHz 5G applications including macro-cell transmitters and MIMO access points, the NP45-11 technology supports power applications from 100MHz through 6GHz. The discrete transistor process is environmentally rugged, incorporating advanced moisture protection and meets the JEDEC JESD22-A110 biased HAST qualification at 55V. Combined with WIN's, IP3M-01 environmentally rugged high-voltage passive technology, NP45-11 enables hybrid power amplifiers in a low-cost plastic package, says the firm.

The NP45-11 technology is fabricated on 100mm silicon carbide substrates and operates at a drain bias of 50V. In the 2.7GHz band, it provides saturated output power of



**WIN's NP45-11 GaN foundry process.**

7W/mm with 18dB linear gain and over 65% power-added efficiency (PAE) without harmonic tuning.

"5G radio access networks create several challenges to power amplifier designs used in MIMO systems," says senior VP David Danzilio.

"High output power and linear efficiency are primary design objectives to meet performance specifications and lower total cost of ownership," he adds. "The tradeoff between output power and linearized efficiency is significant because of the high peak-to-average power ratio employed in today's wireless modulation schemes. This tradeoff becomes more difficult in 5G applications due to greater instantaneous bandwidth requirements and higher operating frequency."

NP45-11 sample kits are available and can be obtained by contacting WIN's regional sales managers.

WIN showcased its compound semiconductor RF and mm-Wave solutions at the IEEE MTT-S International Microwave Symposium (IMS 2018) in Philadelphia, PA, USA (10–15 June), where David Danzilio presented a paper at the 5G Power Amplifier Technology Workshop.

[www.ims2018.org](http://www.ims2018.org)

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



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## StratEdge features packages for extreme demands of GaN and GaAs devices at IMS

At the IEEE's International Microwave Symposium (IMS 2018) in Philadelphia (12–14 June), StratEdge of San Diego, CA, USA (which designs and manufactures packages and provides chip assembly & test services for microwave, millimeter-wave and high-speed digital devices) featured its new line of packages that meet the extreme demands of gallium nitride (GaN) and gallium arsenide (GaAs) devices. StratEdge packages meet the critical requirements of the telecom, mixed signal, VSAT,

broadband wireless, satellite, military, test & measurement, automotive, down-hole, and MEMS markets.

StratEdge showcased its complete line of post-fired and molded ceramic semiconductor packages operating from DC to 63+GHz. These packages have electrical transition designs that ensure low electrical losses and operate efficiently, even at the highest frequencies. All packages are lead-free and most meet RoHS and WEEE standards. In addition, Strat-

Edge offers complete automated assembly & test services for these packages, including gold-tin solder die attach.

"5G and its high-power infrastructure, the Internet of Things, and advanced cellular technologies requiring RF and microwave frequencies will make package selection critical," comments president Tim Going. "IMS is a great opportunity for those involved to visit our booth and discuss their packaging requirements."

[www.ims2018.org](http://www.ims2018.org)

## High-temp and high-rel packages at CS ManTech and IMAPS HiTEC

StratEdge exhibited its latest high-reliability package families at the International Conference on Compound Semiconductor Manufacturing Technology (CS ManTech 2018) in Austin, TX (7–9 May) and its latest packaging

technology for high-temperature applications — including silicon, GaAs and GaN devices — at the IMAPS International Conference on High Temperature Electronics (HiTEC 2018) in Albuquerque, NM (8–9 May).

"Attending these shows enables us to work with engineers to build packages that enable proper functioning of their chips," comments StratEdge's president Tim Going.

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

## INEX selects Keysight's Advanced Design System to deliver GaN PDK

Semiconductor and MEMS device maker INEX Microtechnology Ltd of Newcastle-upon-Tyne, UK (which was formed in 2014 to provide micro/nano-fabrication services to emerging technology supply chains globally) has selected the Advanced Design System (ADS) electronic design automation software of Keysight Technologies Inc of Santa Rosa, CA, USA to deliver its gallium nitride (GaN) process design kit (PDK).

INEX says that the ability to support customers with PDKs is integral to its quality commitment and to enable customers to achieve right-first-time success.

"Our GaN HEMT process addresses a strong and growing UK space and defence customer base," says INEX's chief technology officer

Dr Matthew O'Keefe. "The process developed over the last two years enables a unique UK sovereign supply," he adds. "The technical capabilities of the Keysight solution — from simulation to layout to data presentation and manipulation as well as the support to INEX — are key factors in our choice, ensuring we provide a solution that meets our specific customers' needs."

INEX provides a range of technologies including gallium nitride, gallium arsenide, indium phosphide and diamond for RF and microwave power applications. Its foundry services' GaN process is said to provide high efficiency, power and ruggedness and the ability to operate over a wide bandwidth.

"Our customers design chips for their systems. Simulating the

design at the chip level and up the chain in the overall system is an essential part of their approach," says O'Keefe. "By providing Keysight-based PDK's we aim to be completely aligned with our customers' requirements," he adds.

"INEX is a rather unique microfabrication foundry with a collaborative business model," comments Keysight ADS product manager Joe Civello. "Time-to-success is critical for all business but especially so for a leading-edge specialist like INEX. Their selection of Keysight to enable right-first-time customer engagements is a reflection of Keysight's approach to quality, from product specification to end-customer experience."

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

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

# EpiGaN showcases RF power and power switching GaN epi technology at IMS and PCIM Europe

EpiGaN nv of Hasselt, near Antwerp, Belgium — which supplies gallium nitride on silicon (GaN-on-Si) and gallium nitride on silicon carbide (GaN-on-SiC) epitaxial wafers for power switching, RF and sensor applications — highlighted the latest enhancements of its GaN epiwafer solutions for RF power and power switching at the IEEE International Microwave Symposium (IMS 2018) in Philadelphia, MA, USA (10–15 June) and at PCIM Europe 2018 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (5–7 June).

EpiGaN has previously developed 200mm GaN-on-Si 650V epiwafer solutions for power management systems that have entered the mainstream CMOS manufacturing lines of silicon-based integrated device manufacturers (IDMs) and foundries. Recently, for 5G applications, EpiGaN has developed 200mm versions of its HVRF GaN-on-Si as well as 150mm GaN-on-SiC epiwafer solutions. The firm claims that its RF power products have excellent dynamic behavior, the highest power densities at mmW ranges and the lowest RF losses (<0.8dB/mm up to 110GHz) for the GaN-on-Si version of its HVRF product family.

EpiGaN says that a key advantage of its GaN-on-Si epiwafer technology is the in-situ silicon nitride (SiN) capping layer. This feature is said to provide superior surface passivation and device reliability, and enables contamination-free processing in existing standard silicon CMOS production infrastructures.

Also, in-situ SiN structuring allows the use of pure aluminium nitride (AlN) layers as barrier materials, which results in lower conduction losses and/or the design of smaller-size chips for the same current rating.

For ultimate RF performance in the 5G-related 30GHz and 40GHz millimeter-wave bands, EpiGaN has developed high-electron-mobility transistor (HEMT) heterostructures featuring pure AlN barrier layers in combination with an in-situ SiN capping layer to complement the typical AlGaN counterparts. This allows the transistor's gate to be located very close to the densely populated channel, maximizing the electrostatic coupling between the two (i.e. improving gate control). This will result in the far superior RF transistor characteristics needed for 5G MMIC developments, says EpiGaN.

"EpiGaN has supplied industry-leading GaN epiwafer solutions for power switching and RF power applications to the global semiconductor industry for several years now," says co-founder & CEO Dr Marianne Germain. "In particular, we are proud about our GaN-on-Si epiwafers that show the lowest RF loss in the market up to 100GHz," she adds. "This is a timely answer to the increasing demands in wireless communication such as the introduction of 5G and the Internet of Things," concludes Germain.

At PCIM Europe, Germain participated in a panel discussion 'GaN — Devices for the Future Design' at the show's Fach Forum, organized by Bodo's Power Systems. Also, at the Exhibitor Forum, chief marketing officer Dr Markus Behet gave a presentation 'How GaN Will Dislodge Si-based Technologies in Power & RF'.

In addition, at IMS 2018, chief technology officer Dr Joff Derluy presented 'Development of Epitaxial Processes for GaN-on-Si for RF Applications'.

[www.ims2018.org](http://www.ims2018.org)  
[www.mesago.de/en/PCIM/main.htm](http://www.mesago.de/en/PCIM/main.htm)  
[www.epigan.com](http://www.epigan.com)



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## Eta Research develops free-standing GaN substrates 2–3” GaN wafers available soon, before re-tooling for 100mm by 2019

Eta Research of Shanghai, China, which was founded in 2015 to develop free-standing gallium nitride (GaN) wafers, is now able to produce 100mm GaN wafers.

CEO Troy Baker has been working on hydride vapor phase epitaxy (HVPE) growth of GaN and AlN since 2002 while studying at the University of California, Santa Barbara (UCSB). Eta uses HVPE to produce GaN wafers and has self-developed both its HVPE equipment and production process.

A key process technology is the method of GaN separation from the substrate. Eta has developed a unique method, not used by other companies in the industry it is

claimed, which is said to greatly improve the yields and enhance the crystal quality. Additionally, the firm uses high-quality polishing equipment purchased from a vendor that has experience of polishing GaN wafers.

The current production equipment can produce entire uncracked 100mm GaN wafers but, due to edge effects, the finished wafers must be cut to a smaller size. The firm will soon offer 2” and 3” GaN wafers for sale. It plans to retool to a larger size to produce 100mm finished GaN wafers by 2019.

Eta’s R&D lab is located in Shanghai, but construction is already underway on a high-capacity pro-

duction facility in Tongling, Anhui Province.

“Our goal is to improve the energy efficiency and performance of GaN-based devices by using GaN substrates,” says Baker. “For that to happen on a large scale, GaN substrates must become widely available for a reasonable price,” he adds. “We intend to control the cost through our new high-yield separation process and the large scale of our new factory, while delivering a product with the characteristics – size, crystal quality, lattice curvature, electrical conductivity, and surface finish – that our customers require.”

[www.eta-research.com](http://www.eta-research.com)

## Silvaco’s device simulator selected by FLOSFIA for developing gallium oxide power devices

Yokohama-based Silvaco Japan Co Ltd — a branch of technology computer-aided design (TCAD) and electronic design automation (EDA) software provider Silvaco Inc of Santa Clara, CA, USA — says that Kyoto-based FLOSFIA Inc has selected its device simulator for the development of GaO power devices using gallium oxide (Ga<sub>2</sub>O<sub>3</sub>) made with its proprietary technology.

Great growth in demand is expected for wide-bandgap semiconductors in the future, and in this sector there are high expectations for practical applications of gallium oxide, which has a bandgap exceeding that of silicon carbide (SiC) and gallium nitride (GaN).

FLOSFIA was spun off from Kyoto University in 2011 and specializes in R&D and commercialization of β-Ga<sub>2</sub>O<sub>3</sub> thin films formed by mist chemical vapor deposition (CVD).

By using its MISTEPITAXY method — which takes a proprietary approach to improving the MISTDRY method — FLOSFIA has formed corundum-structured gallium oxide (β-Ga<sub>2</sub>O<sub>3</sub>)

semiconductor layers on sapphire substrates, creating extremely good quality single crystals, and has developed GaO power devices.

Critical for proceeding efficiently in developing new devices, Silvaco’s device simulators — exemplified by the Atlas/Victory Device — provide broad support for many applications such as leading-edge devices, compound semiconductors and thin-film transistors (TFTs). Silvaco says that FLOSFIA’s decision to use its device simulator was based on their confirmation of its effectiveness in developing power devices using gallium oxide.

“We are developing gallium oxide devices with a completely new pro-

proprietary manufacturing method,” says FLOSFIA’s chief technology officer Takashi Shinohe. “Utilizing a device simulator will become impor-

**We are developing Ga<sub>2</sub>O<sub>3</sub> devices with a completely new proprietary manufacturing method**

tant in order to efficiently develop such new devices. For the decision to use Silvaco’s device simulator, the deciding factors were Silvaco’s extensive track record with wide-bandgap semiconductors and Silvaco’s depth of knowledge of power devices. We expect to see even more progress in our development of GaO power devices as we move toward practical applications,” he adds.

“There are high expectations for more compact and more efficient power conversion circuits through the use of wide-bandgap semiconductors, which are expected to be used in various applications including power devices for in-vehicle applications,” says Silvaco’s general manager Naoto Kameda. “Our developers and engineers will be greatly encouraged by the contribution of Silvaco’s device simulator to FLOSFIA’s proprietary technology, which is highly regarded both within and outside of the industry.”

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

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

# Sillectra's new patents extend SiC process to split substrates with sub-100µm material loss

Sillectra GmbH of Dresden, Germany, which provides wafering technology solutions and services, has added three new patents to its global portfolio of intellectual property (IP).

The first patent covers new technical capabilities relating to the firm's COLD SPLIT laser process and extends the approach to non-polymer applications. The second patent secures COLD SPLIT for all substrate materials. The third patent covers an extension of the firm's silicon carbide (SiC) process capability to split materials with sub-100µm material loss, regardless of vendor-specific SiC crystal-growing processes.

Sillectra says that its effort to drive down SiC material loss aims to help accelerate adoption of the substrate for power devices and other ICs. Up to now, high cost has inhibited fast adoption. Cost reductions enabled by Sillectra's technology could speed deployment of SiC for a broader range of applications, such as electric vehicles (EVs) and 5G technology, reckons the firm.

Sillectra's IP portfolio now consists of 70 patent families with 200 patents. Collectively, the patents cover every innovation associated with the firm's laser-based wafer-thinning process.

The growth of Sillectra's IP portfolio reflects its progress toward commercializing its solution. The firm says that COLD SPLIT can thin wafers to 100µm and below in minutes with high precision and virtually no material loss. For thinning wafers, integrated device manufacturers (IDMs) have previously relied on grinding, which is a slower, less precise process that generates material loss and reduces overall yield. In contrast, COLD SPLIT is a much faster laser-based thinning approach with higher yield and strong cost-of-ownership benefits, claims the firm.

In a development announced in February, Sillectra reported a new capability for COLD SPLIT that increases the value of the technology for cost-sensitive IDMs, it is said. Due to the novel adaptation of 'twinning', the firm demonstrated that COLD SPLIT can reclaim substrate material generated (and previously wasted) during backside grinding and create a second fully optimizable bonus wafer in the process. Sillectra validated the development by producing a gallium nitride (GaN) on SiC high-electron-mobility power transistor (HEMT) device on a split-off (twinned) wafer at its new facility in Dresden. The HEMT showed results superior to a non-COLD-SPLIT-enabled HEMT when measured for CMP characterization, as well as GaN epi, metal layer and gate layer outcomes.

The developments have drawn interest from IDMs as well as substrate manufacturers and even providers of certain process technologies, claims Sillectra.

"Like all technology companies, Sillectra's leadership and future growth depend on continually innovating to extend our capabilities and further enrich the value of our solution," says CEO Dr Harald Binder. "Naturally, therefore, it's a strategic priority to protect the innovations along the way so that our competitive differentiation and enabling advantages remain strong in all regions where customers are located. Our robust IP portfolio reflects this priority," he adds.

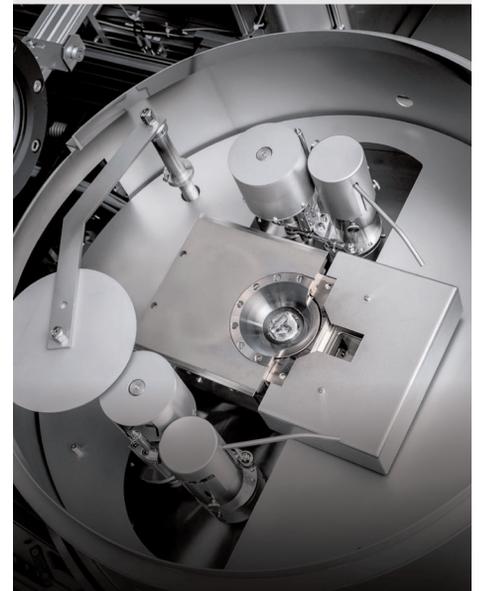
"Our R&D team is relentlessly pushing the limits of our COLD SPLIT technology to fulfill its enormous potential," says chief technology officer Dr Jan Richter. "Additional patents further strengthen our market position, while enabling us to drive COLD SPLIT's material loss far below 50µm."

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



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# AXT's Q1 revenue falls 7.2% after China government-ordered factory shutdown days

## Q2 rebound to be driven by GaAs, InP and Ge substrate growth, despite weakness in gallium raw materials

For first-quarter 2018, AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials in Beijing, China — has reported revenue of \$24.4m, down 7.2% on \$26.3m last quarter and below the initially forecasted \$26–27m.

Of total revenue, \$5.1m came from raw material, down 12% on \$5.8m last quarter, due mainly to weakness with one of the firm's raw material joint venture businesses. "We are seeing a price increase in raw gallium but, because of the prolonged decline in gallium raw material pricing, this particular joint venture has continued to struggle," says CEO Morris Young.

Substrate sales contributed \$19.4m, down 5.4% on \$20.5m last quarter.

"The shortfall to our guidance given on 21 February was a result of government-ordered mandatory factory shutdowns in Beijing, caused by severe air pollution that occurred late in the quarter," notes VP & chief financial officer Gary Fischer. From 27 February to 31 March more than 300 manufacturing companies were intermittently shut down for a total of ten days (30% of the calendar days in this period). "Periodic shutdowns are not uncommon, but the concentration of shutdowns at the end of the quarter was unusual," comments Young.

The shutdown affected sales in every substrate category, although InP revenue was down only slightly, less than for GaAs and Ge.

In spite of this, Q1/2018 revenue was still up 18.4% on \$20.6m a year ago. "We continued to see positive demand for AXT products," notes Young.

Of total revenue, revenue from North America was 8%, Asia Pacific was 66% and Europe was 26%. Again, just two customers gener-

ated more than 10% of revenue (one for GaAs and one for InP), while the top five customers generated about 38% of total revenue, reflecting continuing diversification of both products and customers.

Due to good manufacturing yields and a favorable product mix (with higher-margin InP revenue falling less than that for GaAs and Ge), gross margin has risen further, from 30.5% a year ago and 37.2% last quarter to 39.2%.

Operating expenses were \$5.6m, cut from \$6.1m last quarter but up from \$4.9m a year ago.

Net income was \$2.9m (\$0.07 per diluted share), down from \$3.1m (\$0.08 per diluted share) last quarter but up from \$0.7m (\$0.02 per diluted share) a year ago. This was within the \$0.07–0.09 per share guidance range — despite the revenue shortfall — due to continued operational execution.

Depreciation & amortization was again steady at \$1.1m. Capital expenditure (CapEx) has risen back up from \$4.7m last quarter to \$11.8m. Accounts receivable (net of reserves) fell from \$22.3m to \$21.3m.

During the quarter, cash and cash equivalents and investments fell from \$77m to \$67m, due to spending on the firm's new GaAs manufacturing facility in Dingxing, China (about 90 miles south of the existing Beijing plant).

"Regarding our Dingxing facility, we completed the first phase of

**We are seeing a price increase in raw gallium but, because of the prolonged decline in gallium raw material pricing, this particular joint venture has continued to struggle**

facilitization, installed wafer processing equipment and produced initial wafers that can be used for qualification," says Young. "This was a much anticipated milestone for our investors and an important indication of our progress in the relocation of our gallium arsenide manufacturing [from Beijing to Dingxing]," he adds.

Net inventory rose from \$45.8m to \$51.1m (consisting of 50% in raw materials, 47% in work-in-progress and 3% in finished goods). "Both WIP and raw materials increased, and this is intentional as we see raw material prices increasing and as we build inventory during the relocation," notes Young.

Regarding further government-ordered mandatory factory shutdowns in Beijing: "To help mitigate the issue going forward, we are adjusting our operating procedures to build more units to forecast rather than building to order," says Young. "There is no Chinese New Year holidays in China in Q2, so we are getting off to a good start," he adds. "We are also adding capacity to indium phosphide and gallium arsenide to allow us more flexibility to ramp production as needed. Finally, we are working closely with the local government in Beijing and appreciate their responsiveness."

Despite continued weakness from the gallium raw material joint venture, for second-quarter 2018 AXT expects revenue to rise to \$25.5–26.5m (due to growth for all substrates — GaAs, Ge and InP), with net profit of \$0.07–0.09 per share.

"We are seeing a recovery in the PON [passive optical network] market... 2018 will be a growth year. This is likely due to growing international demand, particularly in China as well as new technologies in the PON arena and emerging

new applications such as business groups, 5G backhaul and in building networks," says Young.

Despite this, InP revenue is expected to grow less strongly than recent quarters due to some near-term market softness in silicon photonics applications for data-center connectivity, after it became apparent that the main customer had more inventory to rebalance. "We are likely to see a stronger second half for our indium phosphide business for data-center applications," believes Young. "Our market position and customer relationship in this application remains solid and we are encouraged by the fact that most experts see a long and bright future for silicon photonics," he adds. "By many analysts accounts, the technology has passed the tipping point, with silicon photonics-based products now shipping in volume and successfully competing with more established technologies. Silicon photonics resolves key issues such as latency, bandwidth, power dissipation and signal integrity, which is critical in hyperscale cloud and large enterprise data centers. Silicon photonics will continue to see an increasing role in the optical component market, with most of the key components and modules suppliers actively participating and the growing interest for semiconductor foundries."

"5G wireless applications are also likely to provide opportunities for silicon photonics," believes Young. "At the Mobile World Congress this year, several key suppliers demonstrated 100G optical transceivers designed specifically for 5G in short-haul and metro deployment. Other potential meaningful applications for indium phosphide include high-performance computing, medical, autonomous cars, aeronautics and defense... we are selling into many emerging applications that are working towards volume productions or are in the early stage of it," he adds.

Regarding gallium arsenide, AXT continues to focus on high-end applications where its vertical gra-

dient freeze (VGF) process technology can produce substrates for the most challenging specifications, including wireless devices, thin-film solar cells, in processors, virtual and augmented reality, retinal recognition and automotive sensing as well as more traditional markets for high-end lighting (e.g. in automobiles, signage and displays). "We continue to provide strong support to one of our LED customers during the quarter [Q1]," says Young. "They rewarded us with an order above our expectation that increases our shipment to them over the next six months," he adds.

"Low-EPD [etch pit density] requirement in many of these applications limits the number of competitors that can meet the inherently stringent specifications," continues Young. "These low-EPD applications also provide us an ongoing opportunity to refine our process and improve our yields as we prepare our business for the market adoption of 3D sensing. We are currently selling into a number of development programs which are steadily increasing in their contribution to our revenues. We view this as a positive indicator of the opportunity with a number of end customers," he adds. "While AXT is not yet participating in the largest example of mass production for consumable commercialization of 3D sensing technology, we view the increasing adoption of 3D sensing as an opportunity for high-end substrate manufacturers because of the stringent technical requirements of the technology. That provides a strong barrier to entry

**The increasing adoption of 3D sensing is an opportunity for high-end substrate manufacturers because of the stringent technical requirements of the technology. That provides a strong barrier to entry**

new lower-end players. Today, only three competitors including AXT are capable of providing low-EPD substrates in sufficient volume for production ramp."

"Our focus now is to further enhance our own readiness to support increasing demand for very low-EPD wafers as the technology is commercialized by multiple end-customers in the mobile market and beyond. As a result, we are taking the appropriate conservative view that our revenue for 3D sensing applications in 2018 will come primarily from development programs. However, that opportunity for selling into production-level 3D sensing programs beginning 2019 is very exciting. AXT will continue to ramp up our capacity for these applications over the course of 2018, preparing our business to support broad-based customer demand."

"Our process technology has enabled us to produce low-EPD substrates for the emerging 3D sensing application, signifying an important early step in a long-term opportunity for our business," says Young.

"We are pleased with these accomplishments and believe our continued progress positions us very well for the balance of the year and beyond."

Regarding germanium substrates, Young says that the demand environment for satellite solar cells remains positive. "We will see growth in this area of our business in 2018. AXT is one of only two suppliers into this market and our VGF substrates perform very well in one of the most unforgiving environments for specialty materials."

"We continue to make progress with our strategic plan preparing our business for a number of exciting opportunities unfolding in 2018 and beyond," summarizes Young. "We are expanding indium phosphide capacity to meet future demand for our products and we are executing a methodical staged relocation of our gallium arsenide manufacturing."

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

## Cardiff University opens refurbished £4m cleanroom at Institute for Compound Semiconductors

### South Wales businesses to benefit via CS Connected compound semiconductor cluster

In the presence of Welsh Government's Economy Secretary Ken Skates and local business leaders, Cardiff University has opened the new refurbished £4m cleanroom at the Institute for Compound Semiconductors (ICS), which assists businesses across South Wales as part of CS Connected — the world's first compound semiconductor cluster.

Sited in the university's Queen's Building, the 225m<sup>2</sup> cleanroom has undergone a £600,000 refit to improve room conditioning in preparation for new equipment.

In addition, with support from both the Engineering and Physical Sciences Research Council (EPSRC) and the Welsh Government via European Regional Development Funds totalling £3.3m, ICS has invested in new equipment to bring online a small area dedicated to 6-inch fabrication capability.

ICS will see further improvements, including laboratory space and an increased 8-inch fabrication capability, when it moves into the new Translational Research Facility on Maindy Road (part of Cardiff Innovation Campus).



"The ICS cleanroom is an outstanding example of a leading-edge facility being developed with Welsh Government support," said Skates. "The project helps to bridge the gap between research and commercial solutions, taking ideas from the lab bench into our boardrooms and on to the shop floors of companies across Wales, so that the economic benefits are felt in communities across Wales. It is encouraging exactly the kind of cutting-edge innovation and technology that Wales needs in order to compete globally and thrive," he adds.

"The Institute for Compound Semiconductors provides cutting-edge facilities that help researchers and industry work together to translate the science into a commercial production environment,

and the cleanroom is a critical part of that," stated professor Peter Smowton, ICS director. "The EPSRC funding allows ICS and its partner companies to continue to develop technology that enables emerging trends, such as self-drive vehicles and 5G communications."

ICS turns its laboratory research into products and services by working with commercial partners, along with the Compound Semiconductor Centre (CSC) — a joint business venture founded in 2015 with Cardiff-based epiwafer foundry and substrate maker IQE plc that forms part of CS Connected.

"The upgrade and new equipment has transformed the ICS cleanroom into a robust, fit-for-purpose facility that is well placed to meet the requirements of academic-driven research projects and also meet the demands of our commercial customers and project partners," states cleanroom manager Dr Angela Sobiesierski.

[www.cardiff.ac.uk/innovation/campus-investment/translational-research-facility](http://www.cardiff.ac.uk/innovation/campus-investment/translational-research-facility)  
[www.iqep.com](http://www.iqep.com)

## SemiGen announces new foundry capabilities and high-reliability screening services

SemiGen Inc of Manchester, NH, USA — an ISO- and ITAR-registered RF/microwave assembly, automated PCB manufacturing, and RF Supply Center — says that, after moving into its new facility, it has increased its foundry and screening capabilities significantly.

The company is now offering processing of 100–150mm silicon wafers, as well as alumina and aluminium nitride substrates up to 4.25-inches. Services provided

include any combination of photolithography, wet etch, dry etch, metallization, grinding, polishing, and in-process metrology.

Recent investments in RF test and high-reliability environmental test capabilities have also enabled SemiGen to offer solutions for high-reliability (hi-rel) screening of amplifiers, FETs, MMICs, transistors, diodes and other active and passive circuits and components.

Tests are performed and are deliv-

ered with full documentation in accordance with MIL-PRF-19500, MIL-PRF-38534 and MIL-PRF-38535 requirements. Element evaluation and screening options from Class H, Class K, TX, TXV, S-level, as well as custom SCD driven requirements are available.

SemiGen exhibited at the IEEE International Microwave Symposium (IMS 2018) in Philadelphia, PA, USA (12–14 June).

[www.semigen.net](http://www.semigen.net)



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Visible LEDs APDs PiN detectors long-wavelength PiNs  
Multi-junction CPV cells  
HBTs pHEMTs BiFET/BiHEMTs

## IQE wins Innovation, Science, Technology title at St David Awards

At the St David Awards 2018 during a gala ceremony at the Senedd in Cardiff, IQE won the Innovation, Science, Technology title, presented by First Minister of Wales Carwyn Jones, in recognition of IQE's close work with the Welsh and UK Governments, Cardiff University and other partners to develop a manufacturing capability in Wales with the vision of establishing the world's first Compound Semiconductor Cluster.



**IQE's CEO Dr Drew Nelson.**

"I would like to take this opportunity to thank them for their continued hard work and dedication in making

IQE the world leader global supplier of advanced semiconductor wafers," said IQE's president & CEO Dr Drew Nelson (who co-founded IQE in 1988). "IQE is also pleased to be a key member of the world's first Compound Semiconductor Cluster, which is based in Wales, and which will help drive the high-tech manufacturing capabilities for the development and commercialization of next-generation semiconductors."

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

## IQE's Infrared division presents invited papers at SPIE DCS

At the SPIE Defense and Commercial Sensing conference (DCS 2018) in Orlando, FL, USA (15–19 April), IQE presented two invited papers on recent key developments in advanced infrared technologies.

1. The joint paper 'Monolithic integration of quantum cascade lasers onto a lattice-mismatched substrate' with the University of

Central Florida on InP-based QCLs reflected IQE's work in commercializing next-generation mid-infrared lasers that have wide-ranging mass-market applications.

2. 'Bulk characterization and surface analysis of epitaxy ready cadmium zinc telluride substrates for use in IRFPA manufacturing for IR imaging' covered its development

of cadmium zinc telluride (CdZnTe) substrates, an infrared material that is widely used in infrared detectors.

Collectively, these developments enable IQE to offer a range of infrared materials providing full - spectrum coverage across a wide and diverse range of detector and sensing applications.

## Riber appoints Philippe Ley as CEO and board member

Riber S.A. of Bezons, France — which makes molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — says that its Supervisory Board (chaired by Didier Cornardeau) has appointed Philippe Ley as CEO and a member of the management board, as proposed by the Appointments and Compensation Committee as part of the drive to further strengthen the management board (which now has three members,

including chairman Michel Picault and Guillaume de Bélair).

Ley is an Ecole Nationale Supérieur d'Arts et Métiers (ENSAM) engineer. After starting his career with Assystem in 1994, he held executive positions with Renault Automation (1997–2001) then Comau France (2001–2007). From 2007 to 2015, he was production director, operations director and a management board member with Riber. Since 2015, he has been managing director and a

corporate officer at ERCA (a subsidiary of the IMA industrial group).

Together with his knowledge of Riber and a track record of implementing his capabilities in various executive roles to date, Ley's experience and entrepreneurial approach represent assets to continue building the firm's future, reckons Riber. His mission will be to support the firm's development in a buoyant market environment.

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

## Repeat order for system from Indian Institute of Technology Bombay

Riber has received an order from the Indian Institute of Technology Bombay for a Compact 21T research MBE system (for delivery in 2019).

The system will contribute to further strengthening IIT Bombay's

research capabilities for developing new optoelectronic devices using quantum dot lasers.

This repeat order is the fourth Riber system operated at IIT Bombay. Riber says that this commercial

success is part of its continued expansion into India's growing market, where it already has an installed base of 16 systems (64% of the total in India).

[www.iitb.ac.in](http://www.iitb.ac.in)

# II-VI opens compound semiconductor material center of excellence in Champaign, Illinois

## New manufacturing facility expands epiwafer production capacity

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has opened its new compound semiconductor material center of excellence in Champaign, Illinois, with a ribbon-cutting ceremony attended by Illinois Governor Bruce Rauner.

II-VI says this represents a milestone in its ongoing investment in its manufacturing footprint to ramp up its production capacity for compound semiconductor epitaxial wafers (e.g. for 3D sensing, optical networking, wireless communications and power electronics). Since the groundbreaking for this expansion in November 2016, II-VI continues to recruit managers, engineers and technicians to join its team.

"I would like to express my thanks to the Illinois Department of Commerce & Economic Opportunity for its ongoing support and unwavering commitment to our success," says Quesnell Hartmann, general manager & co-founder of II-VI EpiWorks. "Completion of this



**Ribbon-cutting ceremony. From right to left: Illinois Governor Bruce Rauner, II-VI Inc's president & CEO Dr Chuck Mattera, II-VI EpiWorks' general manager & co-founder Dr Quesnell Hartmann, and co-founder Dr David Amari.**

phase in our expansion provides us with the critical infrastructure to scale our production, advance our technology, and enable us to serve the rapidly growing demand from our global customer base," he adds.

"II-VI and the State of Illinois have formed a strong partnership,

sharing a vision that businesses with leading-edge technology and advanced manufacturing capabilities are the most competitive over the long-term," says II-VI Inc's president & CEO Dr Chuck Mattera. "With support from Illinois, we expect to continue to invest in this Champaign facility, by adding state-of-the-art manufacturing capacity, improving process capabilities, broadening the product portfolio, and recruiting and developing a lot of talent to fill the anticipated growth in jobs and opportunities for career growth."

The opening "showcases how local industry, strong university systems and state government can partner to realize a bold vision for a globally competitive semiconductor manufacturing center of excellence," comments Rauner.

[www.ii-vi.com](http://www.ii-vi.com)

# Riber's Q1 revenue down 21.7% year-on-year due to staggering of evaporator deliveries

## Production MBE system orders double year-on-year

For first-quarter 2018, Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has reported revenue of €7.2m (84.2% from Asia, 12.2% from Europe, 3.4% from the USA, and 0.2% from other regions), down 21.7% on €9.2m a year ago.

This was due to revenue for Evaporators (cells and sources) falling by 29% from €7.3m a year ago to €5.2m, reflecting a staggering of deliveries for the photovoltaic and screen industries over the first and second quarters of 2018.

System revenue was €0.8m, down only slightly from €0.9m (with, again, one research system delivered). Services & accessories revenue maintained a strong growth rate, rising by 26% from €1m to €1.3m.

The order book at end-March has more than doubled, up 112% from €17m a year ago to €36.1m, due to good performance across all business lines.

Specifically, Systems orders rose by 110% from €10.5m to €22m (13 MBE systems, including nine production systems, compared with just four production systems and three research systems a year ago). Services & accessories orders

rose by 28% from €4.5m to €5.8m, confirming the development of production and research MBE activities. Evaporator orders more than quadrupled, rising by 308% from €2m to €8.3m, factoring in the high level of repeat orders spanning end-2017 to early 2018.

Riber is hence targeting year-on-year revenue growth of at least 15% for 2018.

● Since the end of Q1/2018, Riber has received a European order for a MBE research system (for delivery this year) to be used in developing passivation for high-power lasers.

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

# Veeco's revenue grows 14% in Q1 to \$158.6m, driven by MOCVD system shipments to China

## Shift in MOCVD revenue from LED to photonics and RF device applications to boost margins in second-half 2018

For first-quarter 2018, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported a seventh consecutive quarter of revenue growth, to \$158.6m (well above the midpoint of the \$140–165m guidance). This is up 14% on \$139.7m last quarter (adjusted from \$143.4m after adopting the ASC 606 revenue recognition standard on 1 January) and up 68% on \$94.5m a year ago.

"2018 is off to a great start with strong sequential and year-over-year revenue growth," says chairman & CEO John R. Peeler. "Sales growth in the first quarter was driven primarily by shipments of our lithography systems into the advanced packaging market, and shipments of MOCVD systems for LED applications."

Of total revenue, the LED Lighting, Display and Compound Semiconductor segment hence comprised 57%, growing to \$90m, reflecting strong 2018 opening metal-organic chemical vapor deposition (MOCVD) backlog (delivering systems to five customers in China).

The Advanced Packaging, MEMS & RF Filter segment jumped from 9%

of revenue last quarter to 17% (more than doubling to \$27m), as Veeco saw MEMS device makers add to their etch production capacity and tier-1 OSAT (outsourced assembly & test) customers add capacity for fan-out wafer-level packaging and copper pillar applications (shipping multiple lithography tools).

The Front-End Semiconductor segment (formerly part of the Scientific & Industrial segment, before the acquisition in May 2017 of lithography, laser-processing and inspection system maker Ultratech Inc of San Jose, CA, USA) fell to \$9m, comprising 6% of revenue (down from 9%). However, this includes revenue from STT-MRAM and 3D wafer inspection systems (two areas of growth for Veeco).

The Scientific & Industrial segment was flat at \$32m (mainly sales for data storage as well as optical coatings), falling from 24% of revenue last quarter to 20%.

Geographically, of total revenue, China rebounded further, from just 18% last quarter to 47% (including 39% from MOCVD sales for blue LEDs), while the USA remained at 15%, Europe, Middle East & Africa

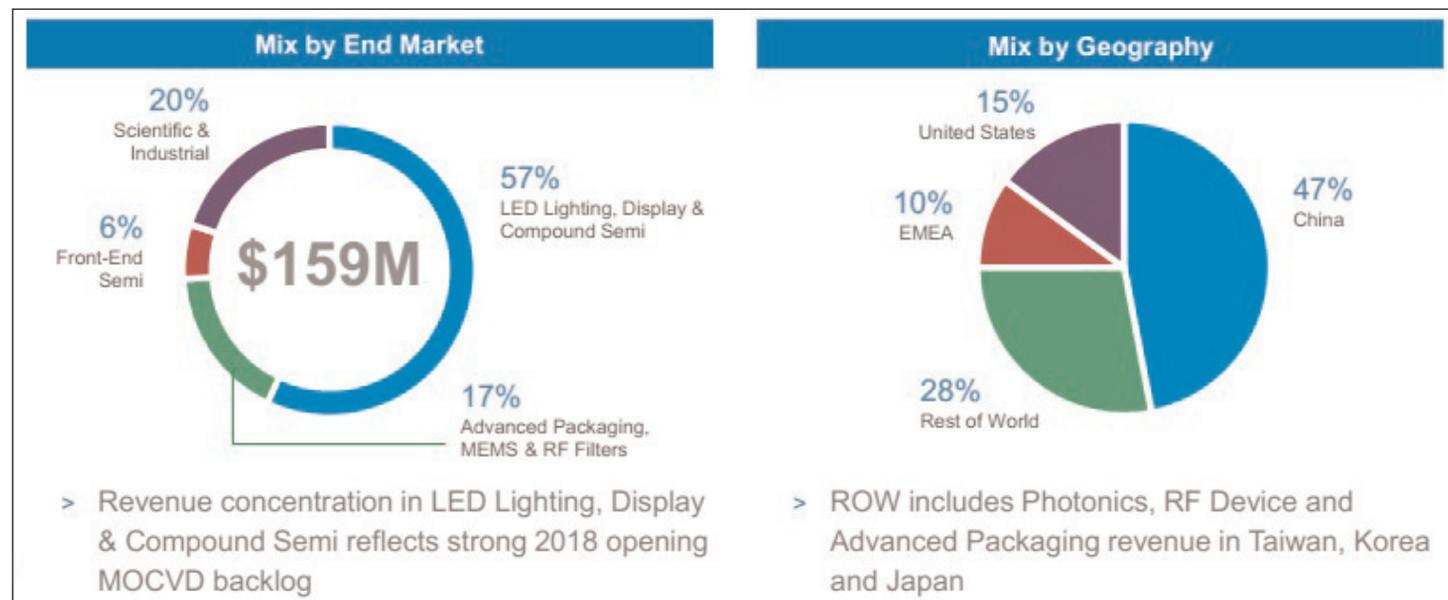
(EMEA) fell from 14% to 10%, and the rest of the world (including Photonics, RF Device and Advanced Packaging revenue in Taiwan, Korea and Japan) fell from 53% to 28%.

"Our non-GAAP gross margin, operating income, net income and EPS all exceeded our guided ranges," Peeler notes.

Gross margin was 36.5%, down from 37.3% a year ago, but higher than the 34–36% guidance due to higher sales volume, better product mix and favorable service costs.

Operating expenditure (OpEx) was \$46.5m, cut from \$49m last quarter. Operating income has risen further, from \$4.8m a year ago and \$7.5m last quarter to \$11.3m. Likewise, net income rose further, from \$4.2m (\$0.10 per diluted share) a year ago and \$6.2m (\$0.13 per diluted share) last quarter to \$9.2m (\$0.20 per diluted share, above the forecast ranging from a loss of \$0.04 to a profit of \$0.14).

However, due to investments in working capital, cash and short-term investments fell by \$16.9m during the quarter, from \$327.5m to \$310.6m. Long-term debt was \$278m, representing the carrying



value of the \$345m in convertible notes.

Order bookings were \$155m, down 13% on \$179m last quarter but up 45% on \$107m a year ago. "As we work towards our goal of being a more diversified company, we are pleased to see orders grow in the Front-End Semi and Advanced Packaging, MEMS & RF Filter markets," says Peeler.

Of total bookings, Advanced Packaging, MEMS & RF comprised 19%, including multiple lithography and wet etch systems for fan-out wafer-level packaging, as well as multiple systems for MEMS. LED Lighting, Display & Compound Semiconductors comprised 34%, including multiple EPIK 868 MOCVD systems from a large LED lighting customer in China). "Separately, consistent with our expectations for growth in Compound Semi outside of general lighting, we received orders for GaN power as well as photonics application," notes chief financial officer Sam Maheshwari. Front-End

Semiconductor was up sharply to 21% (as customer interest in the superfast 3D inspection system accelerates). Scientific & Industrial comprised 26% of orders. "This profile is consistent with our expectations of a more diversified company from second half of 2018 onwards," says Peeler.

Order backlog at the end of Q1 was \$331m, down only slightly on last quarter's record \$334m and well above \$221m a year previously.

For second-quarter 2018, Veeco expects revenue of \$145–170m (contributing to revenue for first-half 2018 up 15% year-on-year).

Gross margin is expected to fall to 33–35% (although gross margin for first-half 2018 should still be higher

**Blue LED MOCVD system sales in China generated low margins for us, and we expect these revenues to reduce in the second half of the year**

than forecasted, above 35%). With OpEx of \$46–48m, operating income should be \$2–11m and net income \$1–10m (\$0.01–0.20 per diluted share).

"We are on track for strong growth in 2018 sales over 2017, with year-over-year growth expected in all four of our market segment," says Maheshwari. "Blue LED MOCVD system sales in China generated low margins for us, and we expect these revenues to reduce in the second half of the year," he adds. "On the other hand, sales from the rest of our businesses are expected to grow in the second half, substantiated by our Q1 booking. This shift in revenue mix should help improve gross margin for the company."

"With our current visibility, we see Q3 revenue tracking flat to Q2 revenue, but with higher gross margin," says Maheshwari. "Additionally, we continue to target gross margin of 40% as we exit the year [due to higher margin in second-half 2018]."

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

## Aledia chooses Veeco's Propel GaN MOCVD system for large-wafer 3D LED production

Aledia S.A of Grenoble, France, a developer and manufacturer of 3D LEDs for display applications based on its gallium nitride (GaN) nanowire-on-silicon platform, has selected the Propel GaN metal-organic chemical vapor deposition (MOCVD) system of epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA to support its R&D. Aledia noted Propel's large process window, single-wafer reactor technology and defect stability as key factors in its decision.

"The opportunity for our breakthrough nanowire-LED display technology on large-area silicon is very large, and we need the best and most scalable technology available to support our continued R&D around 3D display applications — we believe Veeco is best positioned," says Aledia's CEO, chairman & co-founder Giorgio

Anania. "Veeco's cutting-edge Propel system delivers unsurpassed results, and very good homogeneity throughout the entire wafer, making it the best choice and one we know will help us continue to push the limits of innovation," he comments.

Designed for GaN applications like power, RF, laser diodes and advanced LEDs, the Propel system's single-wafer reactor platform enables the processing of 6- and 8-inch wafers or 2- to 4-inch wafers in a mini-batch mode. In addition to Veeco's proprietary TurboDisc technology, the system also includes Veeco's IsoFlange and SymmHeat technologies, which provide homogeneous laminar flow and uniform temperature profile across the entire wafer.

"On the heels of the company's previous adoption of Veeco's K465i MOCVD system, Aledia's decision

to turn to Veeco once again to support future generations of nanowire-LED technologies for mobile displays is a testament to our shared commitment to excellence," says Peo Hansson Ph.D., senior VP & general manager of MOCVD at Veeco. "We look forward to our continued partnership and to support Aledia as it continues to innovate new discoveries in the LED space."

Innovators in display technology are focusing on the next big technological shifts such as micro-LED and 3D LED. Industry analysts predict a scenario where the market for advanced LED displays could reach 330 million units by 2025. This is fueled by the promise of sub-100µm LEDs, which is considered to be the critical enabler to achieving the ultimate display.

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

# Aixtron's orders grow 20% in Q1, driven by MOCVD systems for lasers in 3D sensing and datacoms

## Revenue and EBIT expected to be close to upper end of full-year guidance range

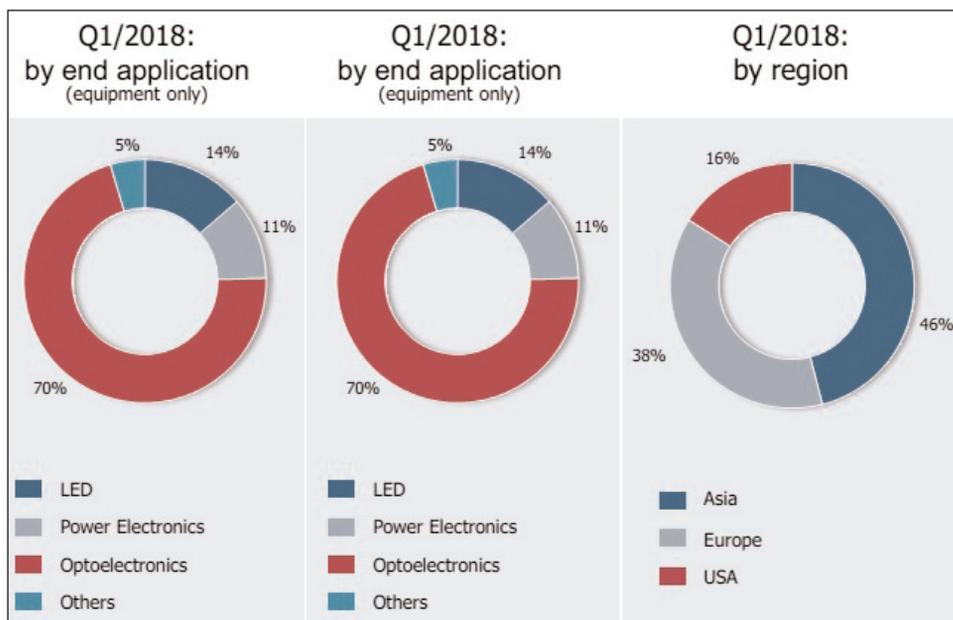
For first-quarter 2018, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €62.4m, up 15% on €54.1m last quarter and 16% on €53.6m a year ago, driven by demand for metal-organic chemical vapor deposition (MOCVD) systems for making lasers such as vertical-cavity surface-emitting lasers (VCSELs) in 3D sensing as well as lasers for optical datacom applications.

Specifically, equipment revenue was €50.8m, up 17% on €43.5m a year ago (remaining 81% of total revenue). Meanwhile, revenue from spare parts & services has grown by 15% from €10.1m a year ago to €11.6m.

Of equipment revenue, the proportion from MOCVD systems for the production of LEDs (including red–orange–yellow 'ROY' and specialty LEDs) shrank from 52% to just 14% (after selling its inventory of AIX R6 gallium nitride blue LED systems) and Power Electronics fell from 19% to 11%, while systems for the production of Optoelectronics (excluding LEDs) have proliferated from just 7% to 70%. This is after systems for Silicon comprised 20% of revenue a year ago, including the atomic layer deposition/chemical vapor deposition (ALD/CVD) product line for memory chip production (based at US subsidiary Aixtron Inc in Sunnyvale, CA, USA) that was sold to Eugene Technology Inc in November.

Correspondingly, on a regional basis, Asia has plummeted from 81% of revenue a year ago to 46% (from €43.5m to €29m), while Europe has leapt from 8% to 38% (€4.1m to €23.5m) and the USA from 11% to 16% (€6m to €9.9m).

"We have gone through a successful reorientation of our technology portfolio, and now have a durable and focused product portfolio in



growth areas, such as the specialty LEDs, lasers and power electronics," says president Dr Bernd Schulte.

Reflecting the absence of low-margin AIX R6 MOCVD system sales that the firm had in Q1/2017, gross margin has risen further, from 25% a year ago and 39% last quarter to a higher-than-expected 43%, driven by the increased sales and favorable product mix.

Operating expenses were €18.9m (30% of revenue), down by 28% from €26.4m (49% of revenue) a year ago. This is due mainly to R&D spending falling from €19.7m to €13.7m after divesting the memory business and the new developments in III–V–on–silicon (TFOS) for microprocessor logic in order to focus development of optoelectronics, power electronics and LEDs.

As a result of the increased sales volume, increased margins and lower operating expenses, the operating result (EBIT) was €7.9m (13% of revenue), an improvement compared with –€12.7m a year ago. This was down from €24.4m last quarter, but that included €23.9m profit from the disposal of the ALD/CVD product line.

Compared with €34.6m a year ago and €13.6m last quarter, operating cash flow was –€21.1m, due mainly to agreed payments related to the sale of the ALD/CVD product line in Q4/2017. Capital expenditure (CapEx) was €1.6m (up from €1.1m a year ago). Total cash flow was –€23.2m. During the quarter, cash and cash equivalents (including cash deposits with a maturity of more than 90 days) hence fell from €246.5m to €223.2m.

Order intake (including spare parts and service) was a higher-than-expected €78.6m, up 20% on €65.7m last quarter and 27% on €61.9m a year ago, due mainly to continued strong demand for MOCVD systems for laser applications such as VCSELs for 3D sensor technology or optical data transmission.

Equipment order backlog at the end of March was €114.9m, up 6% on €108.6m last quarter and 31% on €87.6m a year ago. "This gives us a good visibility for the remainder of the year," says VP of finance & administration Charles Russell.

"Q1/2018 was Aixtron's strongest first quarter since 2011, with further increases in revenues and

order intake, as well as in order backlog," says Schulte.

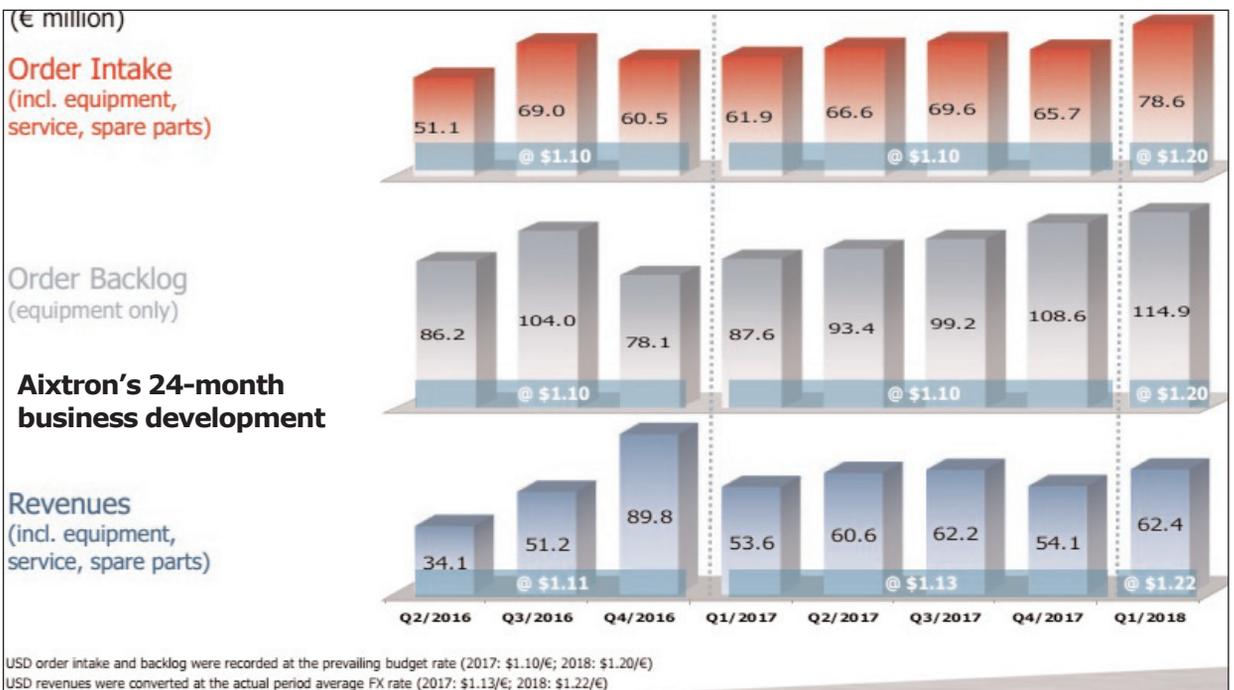
Hence, based on Q1's revenue of €62.4m supplemented by 2018-shippable order backlog of €115m, a forecasted €20–50m of further 2018-shippable equipment order intake plus a forecasted €30m of spares & service revenue (at an internal budgeted

exchange rate of \$/€1.20 for 2018), Aixtron confirms its full-year 2018 guidance (given in February) for revenue and order intake of €230–260m. This is up 20–35% on 2017's revenue of €191.6m for continuing business (excluding €38.8m from the divested ALD/CVD product line in 2017). Gross margin is expected to be 35–40% and EBIT 5–10% of revenue. However, based on Q1/2018 and internal assessment of the development of demand, both revenue and EBIT are now expected to be close to the upper end of the guidance ranges. Operating cash flow for 2018 is expected to be positive, but lower than 2017's €70.1m.

Aixtron says that it remains committed to its annual goal of a sustainable return to profitability for 2018, supported by continued market demand for MOCVD equipment for VCSEL and other laser applications, red–orange–yellow and specialty LEDs, and power electronics, as well as higher margins and lower costs.

"Aixtron benefits from the robust demand for MOCVD tools as well as the successful realignment of its product portfolio," comments Schulte.

"Aixtron currently has a very good market position in laser and specialty LED applications as well as promising equipment technologies for power



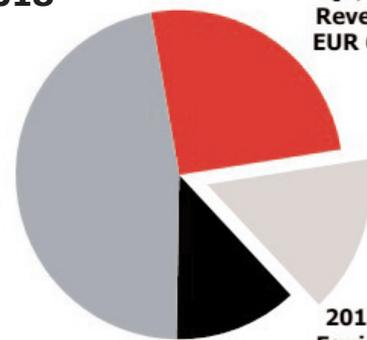
electronics," believes president Dr Felix Grawert. "With our comprehensive roadmap for technology and product development, we ensure the continuous, market-oriented further development of our MOCVD systems for optoelectronics as well as the improvement of our offering in the field of power electronics," he adds. In the medium term, we expect power electronics based on gallium

nitride and silicon carbide in particular to offer significant potential for the company."

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

### Aixtron's 2018 guidance

2018 Shippable Order Backlog: EUR 115m



Q2-Q4/2018 Estimated Spares & Service Revenues: ca. EUR 30m

Q1/2018 Revenues: EUR 62.4m

2018 Shippable Equipment Order Intake: EUR 20 ~ 50m

### VPEC chooses AIX 2800G4 MOCVD systems

Aixtron is to deliver multiple AIX 2800G4 MOCVD cluster systems in 8x6" wafer configuration to long-standing customer Visual Photonics Epitaxy Co Ltd (VPEC) of Ping-Jen City, Taiwan.

The pure-play foundry, which specializes mainly in wireless and optical device epiwafers, plans to ramp up its epitaxy production to meet the growing global demand for various photonic and electronic applications.

"Aixtron is the leading provider of high-volume manufacturing equipment for arsenide phosphide (AsP) based materials," says VPEC's senior VP Neil Chen. "As a proven tool for high-volume production in the area of photonic applications, the AIX 2800G4 system delivers exactly the outstanding uniformity and reproducibility but also flexibility and versatility that we require," he adds.

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

## EVG begins construction of Manufacturing III building to expand production capacity

### Space doubled for final assembly of systems

EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — has started construction on the next phase of expanding its corporate headquarters. The new building will house its 'Manufacturing III' facility, which will provide about 4800m<sup>2</sup> of additional space for manufacturing and other departments, more than doubling floor space for final assembly of EVG's systems.

This follows the opening last December of a new building that allows a significant expansion of warehouse space and provides more than 50% additional test room space for final system assembly as well as technical source inspection of the systems by the firm's customers.



The new Manufacturing III facility.



From left to right: Paul Lindner, Hermann Waltl, Erich Thallner, Aya Maria Thallner, Dr Werner Thallner.

"With our innovative manufacturing solutions for the high-tech industry as well as new biomedical applications, we operate in very dynamic markets with great future prospects," says executive operations and financial director Dr Werner Thallner.

"In light of the high capacity utilization in all areas of our existing facilities, as well as the positive market outlook, we decided to implement our plans for building our Manufacturing III facility this year," he adds. "This will support our long-term growth targets at our corporate headquarters in St Florian am Inn," concludes Thallner.

Construction of the new Manufacturing III building is set to be completed in early 2019.

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

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## VCSEL makers select ClassOne electroplating systems

ClassOne Technology of Kalispell, MT, USA says that in recent months it has sold Solstice electroplating systems to leading providers of vertical-cavity surface-emitting laser (VCSEL) devices.

"We're observing unprecedented demand for VCSEL manufacturing capacity to support 3D sensing, fiber-optic communications, and laser-based materials processing," says ClassOne Group CEO Byron Exarcos. "At the same time, we see that compound semiconductor manufacturers are migrating production from wet benches to automated single-wafer plating. The strong upturn in our Solstice sales reflects this," he adds. "Our Solstice platform provides state-of-the-art automation and control, with industry-leading uniformity and throughput," he claims. "At half the cost of competitive products, Solstice has

become the platform of choice for manufacturers who use smaller substrates."

ClassOne has developed several proprietary high-performance Solstice processing chambers of particular interest to VCSEL manufacturers who require high-speed, high-quality cost-cutting plating using materials such as gold, nickel or copper.

"Compound semiconductor makers are looking for maximum flexibility," notes Exarcos. "They like the fact that Solstice can run multiple wafer sizes simultaneously, and that the platform can be configured for a wide variety of wet processes beyond electroplating. These include metal lift-off, resist strip, gold deplate, UBM [under bump metallization] etch, KOH etch, anodizing, and more — all from a single automated platform," he

adds. "We call this Plating-Plus, and it can eliminate the need to purchase additional downstream tools."

Exarcos says that, in addition to system performance, VCSEL manufacturers are attracted to Solstice's affordability. The ≤200mm Solstice systems are priced at roughly half the cost of comparable 300mm systems from the large equipment manufacturers, it is reckoned.

The Solstice family of electroplating tools includes Solstice S8 and S4, which are 8- and 4-chamber systems that can deliver throughputs of up to 75 wafers per hour. Multiple wet-process chambers enable the tools to perform multiple processes in-line simultaneously. ClassOne also offers the semi-automated Solstice LT specifically for process development and low-volume applications.

[www.classone.com/products](http://www.classone.com/products)

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## Thermco Systems partners with vertical thermal reactor supplier Hitachi Kokusai Semiconductor Europe

Thermco Systems (a division of Tetreon Technologies Ltd of Washington, West Sussex, UK) has announced a strategic partnership with Hitachi Kokusai Semiconductor Europe GmbH of Erkrath, Germany, boosting its position as a manufacturer of horizontal thermal reactors.

Founded in 1962 and having one of the largest installed bases of over 30,000 horizontal tubes worldwide, Thermco makes atmospheric and LPCVD furnaces for the semiconductor, MEMS, nanotechnology, LED and photovoltaic markets.

The partnership makes available to Thermco's European customers the feature-rich 'Vertron Revolution' vertical thermal reactors for the first time. Hitachi Kokusai Semiconductor

Europe's products will complement Thermco's established range of horizontal thermal reactors, CSD epitaxy reactors, chemical wet benches and next generation control systems, offering a broader range of high-tech solutions.

Thermco's European customers will now also have access to the new Hitachi Kokusai plasma batch ashing tool, 4-point probe and other key pieces of metrology equipment. In parallel, Hitachi Kokusai and Thermco Systems will also start working on a program of joint technical product developments.

"Throughout our 56-year history Thermco has offered customers the best in terms of quality engineering, reinforced by the highest level of

technical competency and end-to-end customer support," says Thermco Systems' managing director Andrew Conning. "Our partnership with Hitachi Kokusai now enables us to extend our proposition to existing and new customers with a range of complementary quality products backed by our strong service proposition," he adds.

"We have built a strong affiliation and together we look forward to developing our strategic relationship in a variety of areas to offer solutions tailored to meet our European customer needs," comments Hitachi Kokusai European president Yoshio Kitahara.

[www.thermcosystems.com](http://www.thermcosystems.com)  
[www.hitachi-kse.com](http://www.hitachi-kse.com)

## VPEC chooses LayTec for VCSEL manufacturing

LayTec AG of Berlin, Germany says that its in-situ metrology products have been chosen by pure-play foundry Visual Photonics Epitaxy Co Ltd (VPEC) of Ping-Jen City, Taiwan for its vertical-cavity edge-emitting laser (VCSEL) production.

Supporting worldwide VCSEL chip demand for 3D sensing and other rapidly growing applications, LayTec's dedicated VCSEL Add-On to its EpiTT and EpiCurve TT systems provides additional in-situ spectral reflectance sensing and can be customized in wavelength ranges for gallium arsenide (GaAs)-based

and indium phosphide (InP)-based near-infrared/infrared (NIR/IR) VCSEL processes, enabling high-yield manufacturing of these very complex multi-layer device structures.

The VCSEL Add-On is also available as an upgrade to existing EpiTT or EpiCurve TT systems. Equipped with advanced real-time analysis algorithms, it monitors distributed Bragg reflector (DBR) stop-bands and cavity dip position during VCSEL epitaxy in addition to the EpiTT's wafer temperature and growth rate, as well as the EpiCurve

TT's wafer bow measurements.

"VPEC has chosen LayTec's market-leading in-situ process technology for VCSEL wafer manufacturing as an essential part for accomplishing our high standards in quality and yield," comments VPEC senior VP Neil Chen. "Combining existing control of wafer temperature, wafer bow and growth rates with the new spectral monitoring capabilities is a key for VCSEL foundries in terms of process transfer, rapid recipe changes and scaling up," he adds.

[www.laytec.de/VCSEL](http://www.laytec.de/VCSEL)  
[www.vpec.com.tw](http://www.vpec.com.tw)

## Axus adds senior process engineer & account manager

Axus Technology of Chandler, AZ, USA (which provides CMP, wafer thinning and wafer polishing surface-processing solutions for semiconductor, MEMS/nanofabrication and substrate applications) says that Catherine Bullock has joined it as senior process engineer and account manager, providing support to its process development

and foundry facility as well as strategic account management for customers using the process lab. Responsibilities include process development and support for CMP technology, substrate thinning, bonding, and cleaning technologies.

Bullock has held CMP process engineering posts at Applied Materials (AMAT), Motorola and National

Semiconductor.

"As a certified project manager and technical instructor for 200 and 300mm Mirra, Mirra Mesa, Reflexion and Reflexion LK AMAT product lines, she is already well versed in our equipment and processing systems," says Dr Peter Wrschka, director of process technology.

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

# ALD pioneer Suntola wins Finland's 2018 Millennium Technology Prize

On 22 May in Helsinki, Finland's president Sauli Niinistö presented Technology Academy Finland's eighth biennial Millennium Technology Prize (worth €1m) for 2018 to Finnish physicist Dr Tuomo Suntola.

Suntola pioneered atomic layer deposition (ALD) technology, which allows the fabrication of complex structures one atomic layer at a time, even on three-dimensional surfaces. ALD is used worldwide to manufacture ultra-thin material layers for microprocessors and digital memory devices.

Suntola's innovation is cited as being one of the key factors in sustaining Moore's Law (i.e. that the number of transistors per integrated circuit doubles roughly every two years) and that "the extremely thin isolating or conducting films needed in microprocessors and computer memory devices can only be manufactured using the ALD technology developed by Suntola".

Suntola previously (in 2004) received the European SEMI Award, honoring "the pioneer in Atomic Layer Deposition techniques ... that paved the way for the development of nanoscale semiconductor devices".

Suntola developed ALD technology and equipment for manufacturing thin films in the 1970s and then acquired corresponding international patents, enabling the industrial production of thin films on a mass scale. Fundamental research that underlies ALD technology had also been conducted in the former Soviet Union by professors Valentin B. Aleskovsky (1912–2006) and Stanislav I. Koltsov (1931–2003).

"Suntola's innovations led to the large-scale commercial utilization of the ALD method," notes Päivi Törmä, chair of the board of the Millennium Technology Prize Selection Committee. "He saw the huge potential of atomic layer deposition and thin-film technology in micro-



electronics and information technology," he adds.

"When the semiconductor sector came to understand the significance of ALD technology in the early 2000s, its use exploded," says Suntola. "The super-efficient everyday electronics of today are based on ALD," comments Kustaa Poutiainen, chairman & CEO of ALD thin-film technology firm Picosun of Espoo, Finland. Suntola joined Picosun a couple of years after the firm was founded in 1997, first as a technology advisor but then also as one of the owners and a board member.

"Being awarded the Millennium Technology Prize is a great honour for me, especially because the innovation has proved useful in so many applications," says Suntola.

ALD can be used to improve the efficiency of solar panels, LED lights and lithium batteries for electric cars and its use has also been researched for environmentally friendly packaging materials. The global market for equipment and chemicals used in manufacturing ALD films is estimated to be about \$2bn, and the market value of consumer electronics relying on ALD technology is at least \$500bn, it is reckoned.

ALD films are used in optical applications, as well as on watches and silver jewellery to prevent corrosion. "The health technology is taking giant leaps forward with ALD, and we will see the same happening to many other branches of industry in the near future," comments Poutiainen.

<https://taf.fi/millennium-technology-prize>  
[www.picosun.com](http://www.picosun.com)

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# Plasma-Therm completes acquisition of CORIAL

## Acquisition enhances support infrastructure for European customers

Plasma-Therm LLC of St Petersburg, FL, USA (which makes plasma etch, deposition and advanced packaging equipment for specialty semiconductor and nanotechnology markets) has acquired plasma etch and deposition equipment maker CORIAL of Bernin, France.

"It is a great opportunity for CORIAL to consolidate its future and accelerate the development of innovative stand-alone equipment based on joint CORIAL and Plasma-Therm expertise and advance our commercialization initiatives globally," comments CORIAL's chief research officer Andrei Uvarov.

Offering technologies including RIE, ICP, DRIE, ICP-CVD, PECVD and ALE/ALD, CORIAL addresses

end-market applications including optoelectronics, failure analysis, MEMS, power devices, advanced packaging, wireless communication and integrated optics.

"This transaction is expected to produce significant cost savings from operational synergies while increasing the group's top-line revenue by leveraging the combined sales and service network," says Plasma-Therm's CEO Abdul Lateef. "This acquisition enforces PlasmaTherm's commitment to the European market by further enhancing our support infrastructure for the European customer base. With this acquisition we take one more step in the execution of our vision of a Technology Center of

Excellence and Research in the Grenoble ecosystem," he adds.

"CORIAL is a strategic acquisition that strengthens our presence in the R&D market space and for all other markets requiring small-footprint and technology-rich equipment," notes Plasma-Therm's director of marketing Thierry Lazerand. "We are also excited about the addition of the experienced team of engineers with differentiated know-how for product development," he adds. "The combination will leverage Plasma-Therm's award-winning service, as recognized by the VLSIresearch Customer Satisfaction Survey."

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

## Plasma-Therm wins 'RANKED 1st' awards in VLSIresearch survey

For the 20th year, Plasma-Therm has won multiple awards in the annual Customer Satisfaction Survey of market analyst firm VLSIresearch.

Plasma-Therm earned five awards, including two 'RANKED 1st' awards for having the highest scores of all firms in the categories 'Etch & Clean Equipment' and 'Focused Suppliers of Chip Making Equipment'.

In 'THE BEST Suppliers of Fab

Equipment' (which includes specialized manufacturers as well as the largest equipment makers), Plasma-Therm ranked higher than every other firm apart from ASML (the largest photolithography equipment maker). It was also second only to ASML in 'THE BEST Suppliers of Fab Equipment to Specialty Chip Makers'.

"While we continue to expand our

product and application portfolio, we never lose our focus on providing the best service and support," says CEO Abdul Lateef. "We are working harder than ever to ensure success for all our customers, from small institutions and start-ups to specialty fabs and high-volume manufacturers."

Plasma-Therm has now received a total of 42 awards over 20 years.

## AMEC first Chinese firm to be ranked by VLSIresearch

Advanced Micro-Fabrication Equipment Inc (AMEC) of Shanghai, China has achieved high scores in the 2018 Customer Satisfaction Survey (CSS) conducted annually by VLSIresearch. AMEC is the only China-based firm to be recognized in the list of winners.

AMEC earned second place in the '10 BEST Focused Suppliers of Chip Making Equipment' category, with customers citing it as a trusted and recommended supplier. AMEC also came third in 'THE BEST Suppliers of Fab Equipment' and fourth in 'THE BEST Suppliers of Fab Equipment to Specialty Chip Makers'.

"Customers recognize AMEC's value and benefit from the performance, productivity, quality and cost advantages of our etch and MOCVD [metal-organic chemical vapor deposition] technology and products," says CEO Dr Gerald Z. Yin. "AMEC is still a young and fast-growing company, however. As we journey to maturity we must work harder and smarter to continuously innovate and improve so that we may become an even better supplier," he adds.

"We are impressed by the quality feedback shared by customers on

AMEC's behalf, as well as their enthusiasm for the technology solutions and support they receive from their supplier," comments VLSIresearch's president Risto Puhakka. "This is the first time that a China-based company has ranked in the CSS," he adds. "It is an indication of China's fast-growing semiconductor manufacturing industry, which is being well served by leading indigenous process technology companies like AMEC, as well as other global players."

[www.amec-inc.com](http://www.amec-inc.com)  
[www.vlsiresearch.com](http://www.vlsiresearch.com)

# SPTS wins Queen's Award for Enterprise in Innovation

Orbotech Ltd of Yavne, Israel says that its company SPTS Technologies Ltd of Newport, Wales, UK — which manufactures etch, physical vapor deposition (PVD) and chemical vapor deposition (CVD) and thermal wafer processing solutions for the MEMS, advanced packaging, LED, high-speed RF on GaAs, and power management device markets — has been honoured with the Queen's Award for Enterprise in Innovation 2018, recognizing its development of novel PVD process solutions for fan-out wafer-level packaging (FOWL).

In addition to assessing the degree of innovation, the judging panel also evaluated SPTS on its corporate responsibility, which included employee affairs, customer and supplier relationships, and its impact on the environment and contribution to society.

"We provide advanced wafer processing equipment to the world's leading semiconductor and microelectronics manufacturers, and an

ongoing program of research and development coupled with our ability to commercialize our innovation has been key to building and sustaining a profitable business," says Kevin Crofton, corporate executive VP at Orbotech and president of SPTS Technologies. "This award belongs to our entire global organization — from those directly involved in the development of our advanced PVD solutions for the fast-growing FOWL application sector, to those who sold, manufactured, installed and supported the many 300mm Sigma systems that we've shipped into our customer base."

"The success of our wafer processing solutions for advanced packaging is a testament to the quality and competitiveness of UK developed technologies and products in the global markets," Crofton continues. "We are also very pleased to share credit for this award with the Welsh Government who demonstrated their commitment with the R&D grant that

helped fund this and other advanced packaging development programs here at SPTS."

"SPTS is a prominent global business in South East Wales and an increasingly successful exporter," comments Wales' Economy Secretary Ken Skates. "Companies like SPTS are increasingly vital to our economy, which is why my Economic Action Plan, which was published in December, seeks to support businesses to innovate, introduce new products and services and rise to the challenges of the future."

Previously known as the Queen's Awards to Industry, the Queen's Awards for Enterprise were introduced in 1966 to acknowledge businesses with outstanding performance in three categories — International Trade, Innovation and Sustainable Development. The awards are open to any company operating in the UK and are announced annually on 21 April, The Queen's birthday.

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

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Qty	ID	Diam	Type
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22	2483	25.4mm	Undoped
500	444	50.8mm	P
267	446	50.8mm	N

## BluGlass appoints Mike Krames as advisor to aid RPCVD technical development and commercialization

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 — has appointed Dr Mike Krames as advisor, serving in a strategic and technical capacity to provide expert guidance on the technical development and commercialization plans of RPCVD.

BluGlass is commercializing its proprietary low-temperature remote-plasma chemical vapor deposition (RPCVD) process for manufacturing indium gallium nitride (InGaN)-based LEDs, power electronics and solar cells, offering advantages including higher performance and lower cost, it is claimed.

Krames has more than 20 years of leadership experience in the

compound semiconductor industry, especially in LEDs and their applications to lighting and displays. In 2015, he established US-based Arkesso LLC, an independent advisory and technology development consultancy. Previously, he was chief technology officer at LED firm Soraa Inc (founded by Nobel Prize winner Shuji Nakamura) and executive VP at Philips Lumileds. There, he ran the Advanced Laboratories and pioneered programs in LEDs and related materials, including leading the development of the technology necessary to enable LEDs to serve as automotive headlights for the first time.

"The appointment of Mike to advise BluGlass at this pivotal stage

of our development represents a fantastic opportunity for the company to gain expert technical and commercial guidance from one of the recognized nitride industry leaders," comments managing director Giles Bourne.

Krames has served on numerous roundtables and panels for the US Department of Energy (DOE) and its Basic Energy Sciences (BES) program. He is an IEEE fellow and chair of the SPIE Photonics West conference on Light-Emitting Diodes. He is author of over 80 peer-reviewed publications and more than 100 granted US patents and has served on several boards of directors/advisors.

[www.bluglass.com.au](http://www.bluglass.com.au)

## AMO uses Oxford Instruments process solutions to fabricate ultrafast photonics devices

UK-based Oxford Instruments Plasma Technology (OIPT) says that its fabrication solutions have been used by researchers at AMO GmbH, a non-profit SME based in Aachen, Germany, to develop a graphene-based photonics device capable of operating at a data rate of 25Gb/s per channel.

The devices convert optical modulation data into an electrical signal that can be interpreted by existing IT systems, and they have the potential to become key enablers for next-generation mobile communications unlocking data streams at ultrafast speeds with wide bandwidths.

Advances in Big Data and Internet of Things technologies are driving development of long-range data centers with kilometers of data links. Keeping up with these ever increasing demands will require the development of faster and more efficient data links, says OIPT. Devices developed by AMO, within the European Graphene Flagship project, have set the bar in terms

of high-speed photodetectors operating at telecom wavelengths. At this year's Mobile World Congress (MWC) in Barcelona, Spain at the end of February, AMO — along with collaborators with the Graphene Flagship project — demonstrated the world's first graphene data communication link operating at 25Gb/s per channel. As such, the detector developed at AMO can reach speeds of up to 130GHz

"The latest results on high-speed graphene-based data communication are very encouraging," says AMO's managing director professor Max Lemme. "They are a positive testament to AMO's mission: to identify new materials and to demonstrate new technologies for future applications in electronics and optoelectronics, such as IoT and 5G. We can only achieve such results through our state-of-the-art R&D process line, which includes a large number of tools for scalable nanotechnologies, such as Oxford Instruments' RIE, ALD and CVD tools."

Devices were developed on AMO's 6" fabrication pilot line, which is equipped with Oxford Instruments fabrication solutions including ICP RIE, ALD and PECVD tools. Oxford Instruments offers solutions for the datacoms market sector for both scaled-up production as well as novel device R&D. The detector's fabrication involved: waveguide fabrication, III-V/2D materials mesa etching, and graphene/2D/novel materials deposition. The firm also offers solutions for devices such as the indium phosphide (InP) edge-emitting lasers and vertical-cavity surface-emitting lasers (VCSELs) that are also key components of photonic data communications.

"We continue to invest in further developing and improving our cutting-edge device fabrication processes for datacoms and photonics through feedback from such impressive success stories," says OIPT's innovation and solutions director Frazer Anderson.

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

# BluGlass raises AUD\$9.2m in share placement plus AUD\$2m in share offering

**Firm to buy MOCVD equipment to demonstrate RPCVD retrofitting, expand infrastructure to speed RPCVD development, and exploit market opportunities**

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 — has completed its share purchase plan, announced to the Australian Stock Exchange (ASX) on 21 May.

Shareholders with registered addresses in Australia and New Zealand (as of 18 May) were offered the opportunity to apply for up to AUS\$15,000 worth of new ordinary shares at a price of AUS\$0.37 per share — an 8.6% discount to the closing share price on 16 May and an 11.4% discount to BluGlass' 5-day volume-weighted average price (VWAP) ending on 16 May. The firm has subsequently raised a total of AUS\$2,030,000, resulting in the issue of 5,486,353 fully paid ordinary shares.

"I would like to sincerely thank all of our shareholders for their continued support of the company as we develop and commercialize our unique RPCVD technology," says

managing director Giles Bourne. BluGlass' proprietary low-temperature remote-plasma chemical vapor deposition (RPCVD) process for manufacturing indium gallium nitride (InGaN)-based LEDs, power electronics and solar cells is said to offer advantages including higher performance and lower cost.

Previously, in late May, BluGlass received commitments from institutional, professional and private investors to purchase 24,864,865 fully paid ordinary shares at AUD\$0.37 per share to raise AUD\$9.2m under a placement.

"We are very pleased to see the significant cornerstone support from global institutional funds," says Bourne. "These funds have invested alongside domestic institutional and retail investors," he adds. "BluGlass is delighted with the strong participation that we received in our capital raise, in both the placement and the share purchase plan."

"Proceeds from the placement will

enable BluGlass to expedite its technical and commercial goals with our collaborative partners and deliver commercial outcomes for our proprietary RPCVD technology," says Bourne.

The funds raised will be used to:

- acquire additional metal-organic chemical vapor deposition (MOCVD) equipment to build and demonstrate applications by retrofitting MOCVD equipment with RPCVD on commercial platforms;
- undertake a major facilities upgrade to expand existing infrastructure to assist in accelerating RPCVD development; and
- strengthen BluGlass' balance sheet to exploit market opportunities and help to fund the planned increase in activity.

Work has already begun on the upgrade. "We look forward to keeping investors updated as we make progress with our key technical and commercial milestones," the firm adds.

## BluGlass appoints Stephe Wilks as director

BluGlass has appointed Stephe Wilks to its board of directors.

Wilks is a professional director, with a long record of leading global technology companies in high growth and disruptive industries. He has headed several Australian and international technology firms, including as regional director (Asia & Japan) – Regulatory Affairs for BT Asia Pacific, managing director of XYZed Pty Ltd (an Optus company), chief operating officer of both Nextgen Networks and Personal Broadband Australia, and as consulting director of NM Rothschild & Sons.

Wilks is chair of Australia's largest private IT services company Inter-



active. He also serves as non-executive director of Sirion Global (part of the HeliosWire IoT satellite group) and of DataDot Technology. BluGlass reckons that his finance, strategic management, M&A and public affairs experience will add significant value to its board.

Wilks also has Science and Law degrees from Macquarie University and a Master of Laws from the University of Sydney.

"Stephe's extensive technology

leadership, strategic finance, M&A and governance expertise will make an important contribution to the development and implementation of our commercialization strategy," believes chairman William Johnson.

BluGlass has also announced the retirement of Chandra Kantamneni as non-executive director. Kantamneni has been a director since the firm's initial public offering and listing in 2006. "On behalf of the entire board and management, I would like to thank Chandra for his significant contribution to the development of the company over the last 12 years," says Johnson.

[www.bluglass.com.au](http://www.bluglass.com.au)

# AMICRA becomes part of ASM Pacific Technology as ASM AMICRA Microtechnologies

## AMICRA's die bonders for advanced packaging and silicon photonics gain distribution network in Asia

AMICRA Microtechnologies GmbH of Regensburg, Germany (a vendor of back-end processing equipment for advanced packaging applications and silicon photonics assembly) is to become part of Singapore-based ASM Pacific Technology Ltd (ASMPT), the world's largest back-end equipment supplier and surface-mount technology (SMT) solutions provider (which is listed on the Hong Kong Stock Exchange).

In April, AMICRA was renamed ASM AMICRA Microtechnologies GmbH. It will be integrated into ASMPT's back-end equipment segment. AMICRA's corporate structure and global organization will remain in place, as well as its management team (consisting of Dr Johann Weinhändler, Rudolf Kaiser and Horst Lapsien).

The acquisition is expected to expand and strengthen AMICRA's strategic position. As a strategic investor in the electronics manufacturing industry with a distribution network in Asia, ASMPT complements AMICRA's technology position and

worldwide business activities.

The transaction will serve the fast-growing silicon photonics assembly equipment market in particular, as well as the general high-precision flip-chip and die bonding markets.

AMICRA was founded in 2001 with five staff. It has since developed into a supplier of high-precision die bonders for the advanced packaging and photonics assembly market. The firm now employs 130 in Regensburg and in 12 sales and tech support offices worldwide. AMICRA products are expected to now constitute an important growth factor for ASMPT.

ASMPT currently invests about 10% of its revenues in R&D, making it a suitable partner for a photonics and optical device packaging firm such as AMICRA.

Following its penetration of worldwide markets for high-precision die-attach equipment (especially in the rapidly growing silicon photonics assembly segment), AMICRA says that it saw an opportunity to merge with a strategic partner to better

support its growing international customers base. With ASMPT's economic scale and established supply chains and customer support capabilities, AMICRA aims to take the next step in its business development.

"The expanded operational base offered by ASMPT is very important to us," comments Weinhändler, a member of the AMICRA executive management team. "We will continue to be a reliable partner to our existing and new customers focused on their specific needs and requirements," he adds. "AMICRA's sub-micron high-accuracy die bonder product is complementary to the ASMPT group's existing portfolio, and AMICRA's leading position in the photonics assembly market gives a high growth potential for AMICRA and ASMPT... This joining of forces will further strengthen our growth opportunities and deliver even higher added value to our common customers," he believes.

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

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

## Ichor appoints McGregor as sales director

Ichor Systems Ltd of Blantyre, Scotland, UK has appointed Iain McGregor as sales director, focusing on sales of Lam Research Corp legacy products.

Ichor Systems Ltd is part of NASDAQ-listed Ichor Systems Inc of Fremont, CA, USA, which supplies gas, chemical and liquid delivery systems to semiconductor manufacturers. With 46 staff at a European headquarters facility in Hamilton International Technology Park, the company says it has an innovative approach to reducing technical obsolescence in engineering equipment.

An engineering graduate of



**Iain McGregor.**

Glasgow College of Technology (now Glasgow Caledonian University), McGregor worked with NEC, Digital Equipment Corp and Seagate as a production engineer then progressed to European technical support manager for Tokyo Electron Ltd and to Thermco as business director before joining Ichor.

"The latest and greatest technologies in semiconductors are used in

spheres that are at the forefront of new science, but the legacy products keep our homes, our cars and our lives running and we couldn't do without them," comments McGregor.

"As well as semiconductor equipment manufacture and refurbishment, we are looking at rolling out innovative engineering solutions to a much wider range of sectors targeting, in effect, the entire range of UK and European manufacture, and Iain will be at the heart of this initiative," says managing director John Spence.

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# Kulicke & Soffa partners with Rohinni on design, commercialization and distribution of micro- and mini-LED technologies

## K&S to scale development and production of Rohinni's high-speed placement technology

Singapore-based chip assembly & packaging equipment and materials supplier Kulicke and Soffa Industries Inc (K&S) has entered into a licensing agreement with Rohinni LLC of Coeur d'Alene, ID, USA (which has developed a proprietary method for transferring semiconductor devices) to facilitate the design, commercialization and distribution of micro- and mini-LED solutions, which it says have the potential to enhance the performance, improve the efficiency and reduce the size of existing lighting technologies.

High-volume end-markets including automotive, display, consumer electronics and general lighting are expected to drive adoption. Despite the benefits of micro- and mini-LEDs, high-volume production challenges must be addressed prior to widespread market adoption, K&S adds.

Rohinni has developed solutions that directly address such production

challenges, enabling greater design flexibility in end-use applications. In parallel, it has also established a network of partnerships in several key segments poised to benefit from this technology.

Kulicke & Soffa says that its existing market positions, R&D competencies, supply chain and manufacturing capabilities provide scale to further extend Rohinni's leadership and its effort in driving adoption of new LED technologies.

"K&S has recently taken a much more proactive approach in targeting and identifying complementary partnerships with a clear path to value creation," says Chan Pin Chong, senior VP of the Wedge Bond and EA/APMR business unit.

"Our team has spent the past several years developing precise, high-speed placement technologies for micro- and mini-LED products," notes Rohinni's CEO Matt Gerber.

"This agreement with K&S provides capabilities to quickly scale development and global production."

LCD displays incorporating these latest developments in LED backlighting technologies for High-Dynamic-Range (HDR) viewing are significantly brighter than organic light-emitting diodes (OLEDs). To produce an HDR LCD display with over 10,000 LEDs in a backlight assembly requires a completely new generation of high-speed production technologies, says K&S. With an estimated 220 million square meters of flat-panel displays estimated to be produced in 2018, the growth potential of new backlighting technologies is significant. The complementary contributions of both K&S and Rohinni are expected to accelerate global adoption of micro- and mini-LED-based solutions.

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

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

# HexaTech launches 2" AlN substrate product line

## Technology development sets stage for continued diameter expansion and increased process yields

In conjunction with the International Conference on UV LED Technologies & Applications (ICULTA-2018) in Berlin, Germany (22-25 April), HexaTech Inc of Morrisville, NC, USA launched its 2"-diameter aluminum nitride (AlN) substrate product line (available with standard lead times).

"This achievement is the result of our intense, focused research and development activities, producing critical breakthroughs in AlN crystal growth performance," says CEO John Goehrke. "Together with strong support from our strategic partners, including Osram (as announced last year), we have

again raised the bar for AlN substrate technology," he adds.

"This capability is the leading edge of a long-term, production-oriented product portfolio, which will enable our customers to quickly and easily transition deep-ultraviolet (UV-C) optoelectronic/electronic device development and production to an AlN substrate platform, delivering superior device performance coupled with cost-effective production scaling, process integration, and accelerated time to market," says Gregory Mills, VP of business development.

"By challenging perceived constraints and aggressively pursu-

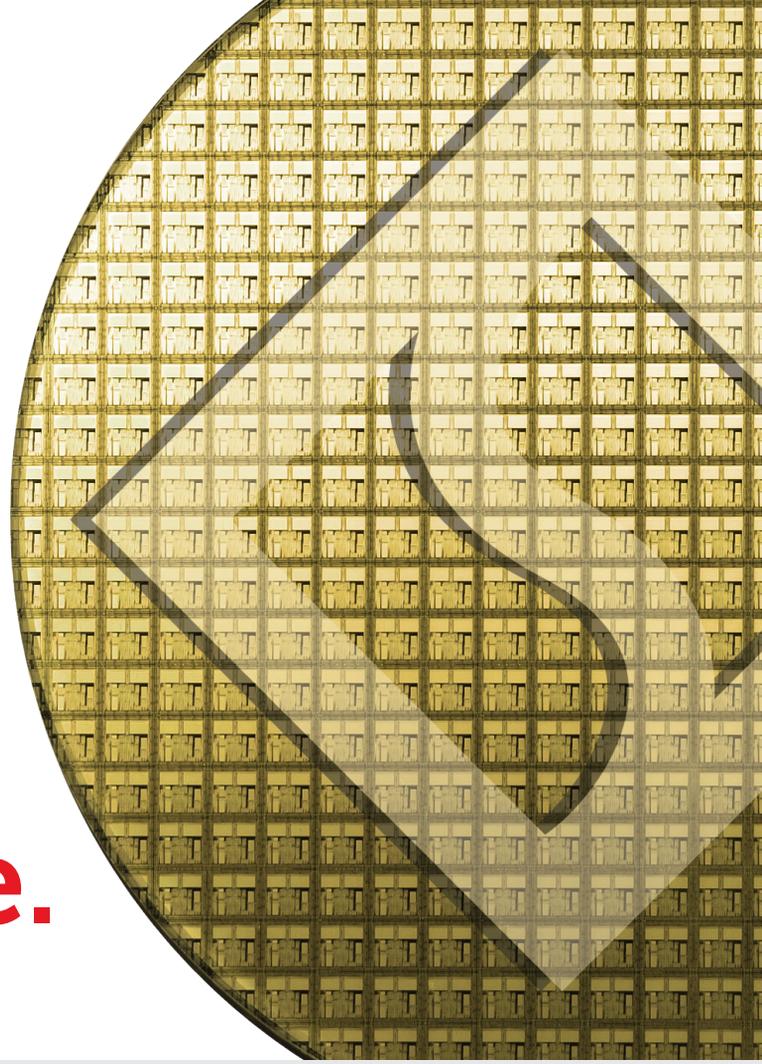
ing solutions at each step of the crystal growth process, we have developed a significant shift in capability which breaks previously observed limitations," reckons Dr Raoul Schlessler, co-founder & VP of crystal and wafer development. The achievement "sets the stage for both continued diameter expansion and increased process yields, ultimately rivaling the price:performance ratio of other mature compound semiconductor technologies, such as silicon carbide and gallium arsenide," he adds.

[www.iuva.org/BerlinConference](http://www.iuva.org/BerlinConference)

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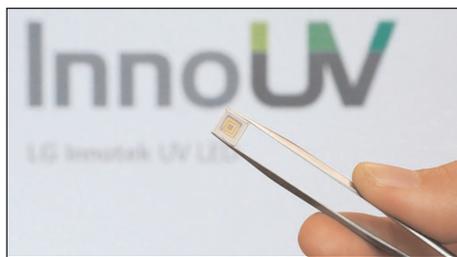


## LG Innotek launches UV LED brand InnoUV

Seoul-based materials and component manufacturer LG Innotek (a subsidiary of South Korean electronics company LG Group) plans to launch the brand InnoUV (combining 'innovation' and 'ultraviolet'), applying the name to all 40 types of UV LED packages and modules that it has developed (with varying UV wavelengths and light outputs, depending on application).

UV LEDs eliminate germs and viruses (depending on their wavelength) and are used for water, air and surface disinfection, medicine, biotechnology and curing and light exposure equipment because of their ability to chemically react with particular substances.

UV LEDs are eco-friendly because



they emit light without using any chemical substances or heavy metals. They also offer high usability, due to their long lifespan, high durability and small form factor (under 1cm).

LG Innotek says that InnoUV reflects its aim to make increase the sterilizing power of UV LEDs. The firm's record-output 100mW UV-C LED (unveiled last November) can wipe out 99.9% of Salmonella

(a cause of food poisoning) in just 3.4 seconds, it is reckoned.

LG Innotek says that companies can use the InnoUV brand logo on the exterior, packaging and promotion materials of their finished UV LED products after they go through a prior negotiation process with LG Innotek.

According to market research firm Yole Développement, the UV LED market is expected to grow more than sevenfold from \$151.9m in 2016 to \$1.1178bn in 2021.

LG Innotek held a UV LED Forum on 27 June at the Kyobashi Trust Tower in Tokyo (the third forum, following others in Seoul in March and Shenzhen in May).

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

### LG Innotek introduces UV LEDs at RadTech

At RadTech 2018 (North America's largest UV trade show) in Chicago, IL, USA (7-9 May), South Korea's LG Innotek introduced about 30 different kinds of LED packages with UV wavelengths and light outputs optimized for different applications. The firm plans to introduce UV light sources, including UV-A, 305nm UV-B and 278nm UV-C LED packages in a wavelength range of 365-415nm.

LG Innotek also showcased what are claimed to be the world's highest 100mW UV-C LEDs, its proprietary sterilization modules, and curing and light exposure packages as well as medical and biotech packages.

Meanwhile, LG Innotek held a UV LED Forum in Seoul in March before the forum to be held in China. The forum was attended by about 1000 people including

people from the related industries, such as home appliances, sanitation facilities, and medical and manufacturing equipment, as well as people from various universities and associations.

In addition, on 29 May the firm held a UV LED Forum in Shenzhen, China, aimed at speeding up cooperation with local companies and discover new partners.

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

## Luminus adds white LEDs to horticulture portfolio spanning UV to Far Red

Luminus Devices Inc of Sunnyvale, CA, USA has expanded its horticulture LED portfolio with new SST-20 series white LEDs to complement its range of discrete wavelengths from UVA (365nm) to Far Red (730nm).

Incorporating white light in horticulture fixtures provides illumination in the greenhouse and makes it easier to observe crops for signs of disease. Also, in many cases, white LEDs can replace blue LEDs as they provide similar photosynthetic photon flux (PPF), potentially reducing production costs. With a flexible range spanning 2700-7000K,

users can now select the light most appropriate to their needs.

"The need for improved crop yields and more sustainable food supplies is more important than ever and our horticulture LED advances enable innovative luminaires that directly address the market's needs," says Yves Bertic, senior director of global product marketing.

As the horticulture and farming research community discover productivity and crop quality gains through wavelength and spectrum engineering, Luminus says it is continuing to expand its range by

adding new wavelengths to its portfolio so that growers and farmers can maximize production yields, become more sustainable and reduce costs.

"With this addition to our SST series, we now offer a comprehensive horticulture product portfolio that delivers the highest performance and efficacy with competitive lead times of 12 weeks or less," says Bertic.

Luminus horticulture LED products are globally available in volume directly or through the firm's distribution network.

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

# Luminus enters UV-C LED disinfection & sterilization market with two 280nm emitters

Luminus Devices Inc of Sunnyvale, CA, USA — which designs and makes LEDs and solid-state light sources for the global illumination market — has expanded its ultra-violet (UV) LED portfolio with two new 280nm devices for the medical and health & well-being markets.

The standard-footprint 3535 surface-mount emitter is a 350mA device with peak output up to 60mW. The second ultra-compact emitter is 1.3mm by 1.3mm and only 0.85mm tall, and delivers 3mW at 20mA and peak output of 11mW at 100mA.

“Air, surface and water disinfection



**Luminus' 3535 and 1313 UV-C LEDs.**

markets will see a significant number of new products and new product categories over the next 36 months,” says Stephane Bellosguardo, VP of specialty lighting marketing. “Just as the computer industry was driven by ever smaller and faster processors, so will be the

innovation in markets like air and water purification with miniature products like our 1313 UV-C LED.”

The new UV-C LEDs are just the latest additions to a UV portfolio that offers both surface-mount devices and modules in the UV-A spectrum for horticulture, curing, additive manufacturing and medical instrumentation applications.

“UV-LED-based industrial applications are already growing rapidly and represent an increasingly important segment of our non-visible specialty products alongside infrared emitters,” says Bellosguardo.

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

## Luminus' spectrally tuned LED light sources target new market opportunities in human-centric lighting

Luminus Devices has released its third proprietary spectral technology, PerfectWhite, which is said to closely replicate the visual characteristics of halogen lamps (3000K).

Luminus says that, compared with halogen, PerfectWhite was preferred by lighting designers in testing at both the Light + Building and Lightfair events. Though the spectrums are a virtual match — Luminus filled the cyan gap — PerfectWhite's color point is slightly below the black-body locus and, as a result, there is no green/yellow tint that is common to halogen. A better halogen has long been a wish of the lighting design community, and PerfectWhite delivers without infrared, without green/yellow tint, and without ultraviolet radiation, says Luminus.

“The spectral characteristics of light from a halogen lamp are what make it so appealing, particularly in hospitality and museum applications,” says Tom Jory, VP of illumination. “Unlike other full-spectrum LEDs that emit harmful near-UV radiation, PerfectWhite

delivers the visual effect of a halogen lamp by filling the cyan gap that exists in traditional LED technology,” he adds.

Luminus' portfolio of unique LED spectrums also includes AccuWhite and Sensus spectral technologies, which can be applied to virtually any of the firm's chip-on-board (COB) LEDs.

AccuWhite is spectrally engineered to maximize color rendering index (CRI) performance, and it delivers the firm's highest color-rendering products, with a guaranteed CRI minimum of 95 and a typical CRI of 98. With lighting designers and visual display managers continuing to seek the very highest CRI and TM-30-15 ratings for the most demanding interior lighting applications, AccuWhite LEDs offer TM-30-15 values as high as 95 for  $R_f$  (fidelity) and 100 for  $R_g$  (gamut) while still achieving luminous efficacy as high as 125 lumens per watt at a case temperature of 85°C.

Sensus spectral technology addresses demands in retail shops to inspire shoppers with light that creates more dramatic,

vibrant and exciting environments where whites are whiter, and saturated colors like blue and red are richer and more vibrant, says Luminus.

Sensus' engineered spectrums in 3000K and 3500K produce a large gamut area index (GAI BB15 as high as 120) and chromaticity below the black-body curve, allowing people to see pure, bright whites and deeper colors with greater contrast. While other LEDs might also produce pure whites, Luminus claims that Sensus achieves this without sacrificing efficacy, as demonstrated with up to 148lm/W at 85°C.

“Our three spectral technologies serve as the foundation for additional spectral tuning that is specifically targeted at human centric lighting,” says Jory. “Though there's much still to be discovered, we are already working with industry partners to provide light that serves dual purposes of illuminating beautifully so people can see well and being healthy for people.”

[www.luminus.com/products/cobarrays/perfectwhite-cob](http://www.luminus.com/products/cobarrays/perfectwhite-cob)

## Soraa expands collaboration program for 'white light' LED disinfection

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology fabricated on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has announced the availability of an expanded collaboration program for its patented white-light disinfection technology. This technology is based on Soraa's violet LEDs, which can be used to provide disinfection while also

delivering natural white light.

CEO Jeff Parker cites Soraa's portfolio of patents in bactericidal LEDs used for white-light generation and disinfection, a portfolio that includes patents dating back to at least 2009. The program is further buttressed by Soraa's recent acquisition of foundational GE patents on GaN LEDs, dating back to 2001.

"We are extremely proud of our

early inventions in this space, and are actively engaged in partnerships with key players in the field that will leverage our expertise with violet LEDs," says Parker. "These unique lighting solutions give us the ability to help usher in a new era of 'white light' disinfection in an effort to create healthier environments."

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

## Nichia expands direct mountable chip LED series with royal blue, green, amber and red single-color options

Nichia Corp of Tokushima, Japan has expanded its Direct Mountable Chip series by introducing discrete color options, a similar technology to chip-scale packaging (CSP). Along with its previously released white options, the Direct Mountable Chip color lineup — consisting of royal blue, green, amber and red — enables lighting customers to take advantage of Nichia's unique Direct Mountable Chip technology in a wide range of applications.

Nichia says that, with over 50 years of experience in phosphors and 25 years of experience in LEDs, it has capitalized on its history to launch an innovative color solution that utilizes Nichia's own phosphor

and blue die technology, bringing benefits to fixture manufacturers and designers.

By using the same wavelength die in each color, Nichia has harmonized the forward voltage across the entire Direct Mountable Chip family, simplifying electrical circuit designs. Additionally, unlike other discrete color technologies, the internal structure of each Direct Mountable Chip color is the same. So, the directivity and height are also the same, making optical design much easier to manage. Finally, with the phosphor-converted red Direct Mountable Chip, the thermal droop characteristics are significantly improved from tra-

ditional red AlInGaP LEDs, it is claimed. This allows for much better in-situ performance and overall color and stability.

Nichia claims its Direct Mountable Chip family was the first lighting CSP-type to incorporate unique technology allowing for a single-sided 120° lambertian optical pattern, eliminating cross-talk in lumen dense applications. The firm says that, by developing an innovative color lineup, its now expanded Direct Mountable Chip portfolio provides flexibility to all lighting applications, including color tuning, architectural lighting and other commercial and residential markets.

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

## Plessey's CTO presents at Display Week following UK National Technology Award

At the Society for Information Display (SID) Display Week 2018 event in Los Angeles on 24 May, Dr Keith Strickland — chief technology officer of Plessey Semiconductors Ltd of Plymouth, UK — presented a paper on the future of microLED displays using next-generation technologies and highlighting the benefits of Plessey Semiconductors' proprietary gallium nitride on silicon (GaN-on-Si) technology.

"Holding a growing number of patents for the implementation of GaN-on-Si technology in microLED display design and manufacturing, Plessey is very close to announcing some major partnerships and the launch of new photonic solutions to enable OEMs to develop truly wearable augmented reality devices," says Strickland.

Plessey's participation at Display Week 2018 (20–25 May)

follows the firm winning the Tech Company of the Year category at the National Technology Awards, which celebrates technology pioneers and encourages excellence in the UK. Winners were revealed at an awards ceremony on 17 May at the Waldorf Hilton hotel in London with over 300 guests in attendance.

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

# Everlight demonstrates portfolio of horticulture LEDs

At the LIGHTFAIR International 2018 trade fair in Chicago, IL, USA (8–10 May), Taiwan-based Everlight Electronics Co Ltd demonstrated its comprehensive range of horticulture LEDs and diverse lighting application products as well as relevant lamps such as horticulture luminaires and fishing lamps.

LEDs have been extensively applied for horticultural lighting in recent years. Monochromatic LEDs have not only replaced traditional high-pressure sodium lamps but, due to their color combination, also effectively meet the requirements of specific spectra and optical functions. Everlight has developed various series of products to completely cover PAR 450–745nm for horticulture.

According to the required performance, Everlight offers its

SHWO 3535-ELB (high), 3030-ELB and 2835-ELB (low) LEDs.

The new 2835 PC Red-ELB (2.8mm x 3.5mm x 0.7mm) has an exceptional color temperature of 5% blue intensity which can achieve a wall-plug efficiency (WPE) of 35% (0.5W) and replace two light sources, Royal Blue & Deep Red, at once with its luminous efficacy of 15lm. The 3535-ELB (3.5mm x 3.5mm x 2.03mm) series is said to have an edge in high luminous efficacy, cost-performance ratio and 65% WPE. Products with different colors are all LM-80 standard certified to satisfy demand for LED service life-time. Everlight also demonstrated a horticulture luminaire and a fishing lamp based on the 3535-ELB. The firm says that its complete, diversified agricultural LEDs can meet the needs of various growing environ-

ments to improve animal and plant growth as well as achieve energy conservation.

A 560mm x 20mm x 1.0mm horticultural bar demonstrated at LIGHTFAIR complies with Zhaga standards. The 12W LEDs emit at wavelengths of 660nm and 450nm and reach 3129mW or 16.377 $\mu$ mol by using medium-power LEDs for indoor farming. The Zhaga Consortium is a standard in the LED industry that is suitable for luminaire manufacturers to rapidly adopt their LED lighting technology through the use of interchangeable parts for their products. Developed in accordance with Zhaga standards, Everlight's 2ft bar is a high-quality light source for horticultural luminaire that helps to reduce development cycle time in that market.

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

# Samsung offers LED products optimized for horticulture

South Korea's Samsung Electronics Co Ltd is now offering LED components that optimized for horticulture lighting.

The new horticulture LED lineup features a newly developed 'red LED' package, as well as additions to key existing Samsung 'white LED' package and module families to include horticulture lighting specifications.

"Our horticulture LED solutions are based on LED technologies that deliver proven levels of performance and reliability across an extensive range of lighting applications," says Yoonjoon Choi, VP of the LED business team. "By broadening our lineup to include horticulture LEDs, we are providing global luminaire manufacturers with a one-stop resource for these solutions as well as for our many other LED technologies."

The new LH351B Red horticultural LED is a high-power package providing a wavelength of 660nm with a photosynthetic photon flux (PPF) value of 2.15 $\mu$ mol/s (350mA),



**Top row (from left to right): Q-series, H inFlux. Bottom row (left to right): LH351B Red, LM301B, LM561C.**

making it optimal for most types of horticulture lighting. The 660nm wavelength helps to accelerate the growth of plants including their photosynthesis, as well as enrich the blooming of flowers. The package also features a very low thermal resistance of 2.0K/W, allowing for easier heat dissipation within LED luminaires. Moreover, the LH351B Red uses the same electrode pad design as its LH351 series counterparts, enabling greater PCB design flexibility in luminaire manufacturing.

Beyond its new LH351B Red offering, Samsung has added horticultural

specifications to its mid-power packages (LM301B and LM561C) and two linear modules — (the Q-series and H inFlux). These LED component families now include PPF values of 0.52 $\mu$ mol/s (65mA), 0.49 $\mu$ mol/s (65mA), 24 $\mu$ mol/s (0.45A, 21.9V) and 114 $\mu$ mol/s (1.38A, 46.9V), respectively.

In addition, the white LED packages and modules feature extremely high light efficacy of 2.92 $\mu$ mol/J (65mA), 2.72 $\mu$ mol/J (65mA), 2.43 $\mu$ mol/J (0.45A, 21.9V) and 1.76 $\mu$ mol/J (1.38A, 46.9V), respectively, while the LH351B Red delivers 3.13 $\mu$ mol/J (350mA). These high efficacy levels minimize the impact of lighting on ambient temperatures, allowing growers to better control temperatures in almost any greenhouse environment and save on energy costs.

Showcased at the LIGHTFAIR International 2018 trade fair in Chicago, IL, USA (8–10 May), samples of Samsung's horticulture LEDs are available now.

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

# KAIST team develops mass transfer of flexible blue vertical micro-LEDs on plastic

Professor Keon Jae Lee of the Department of Materials Science and Engineering and his team at Korea Advanced Institute of Science and Technology (KAIST) have developed a low-cost production technology for thin-film blue flexible vertical micro-LEDs (f-VLEDs) that could advance the commercialization of micro-LEDs, it is reckoned (Chang Wan Kim et al, 'Monolithic Flexible Vertical GaN Light-Emitting Diodes for a Transparent Wireless Brain Optical Stimulator', *Advanced Materials*, June 2018 issue).

At January's Consumer Electronics Show (CES 2018) in Las Vegas, the micro-LED TV was spotlighted as a candidate for replacing the active-matrix organic light-emitting diode (AMOLED) display.

The micro-LED is a sub-100µm light source for red, green and blue,

which has outstanding output, ultra-low power consumption, fast response speed, and excellent flexibility.

However, the display industry has been utilizing the individual chip transfer of millions of LED pixels, making production costs high. The initial market for micro-LED TVs is hence forecasted to be just a hundred thousand dollars for the global premium market.

For the widespread commercialization of micro-LEDs for mobile and TV displays, the transfer method for thin-film micro-LEDs requires a one-time transfer of 1 million LEDs. In addition, the highly efficient thin-film blue micro-LED is crucial for a full-color display.

The team has developed thin-film red f-VLEDs in previous projects, and is has now realized thousands of thin-film blue vertical micro-LEDs

(with a thickness <2µm) on plastics using one-time transfer.

The blue GaN f-VLEDs achieved optical power density of about 30mW/mm<sup>2</sup> (three times higher than that of lateral micro-LEDs) and a device lifetime of 100,000 hours (about 12 years) by reducing heat generation. The blue f-VLEDs could be conformally attached to curved skin and brain for wearable devices, and stably operated by wirelessly transferred electrical energy.

"For future micro-LEDs, the innovative technology of thin-film transfer, efficient devices, and interconnection is necessary," says Lee. "We plan to demonstrate a full-color micro-LED display in smart watch sizes by the end of this year."

<https://doi.org/10.1002/adma.201800649>  
[www.kaist.ac.kr](http://www.kaist.ac.kr)

## Epistar to mass produce mini-LEDs in second-half 2018

Taiwanese LED epitaxial wafer and chip maker Epistar in 2017 went through a financial turnaround and reported a share dividend of NT\$0.8. In the wake of lukewarm market demand, second-quarter 2018 results showed declines. It plans to mass produce mini LED products for smartphone backlighting and ultra-fine pixel pitch displays in second-half 2018, according to a report by LEDinside. Mini LED-based applications are estimated be rolled out in Q3 or Q4 2018 at the earliest.

Affected by the traditional slow season, Epistar's first-quarter 2018 revenue fell 10.23% year-on-year to NT\$5.14bn (US\$172.8m). Demand from lighting markets was tepid in Q2. The LED backlight market rebounded but momentum was weak. However, judging by orders received, Epistar said overall demand in Q2 seems to be stronger than in Q1.

Epistar started collaboration talks with clients last year to develop mini-LED products for applications including smartphone, laptop, and

indoor digital signage. Production of Mini LED products is set to run anytime its clients place orders.

When adopted in displays, mini-LEDs can improve color contrast and saturation and reduce production costs and thickness of devices.

Epistar expects demand for mini-LED display technology to surge in 2019 when the market should respond with high acceptance after one or two lanches of new mini-LED-based applications.

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

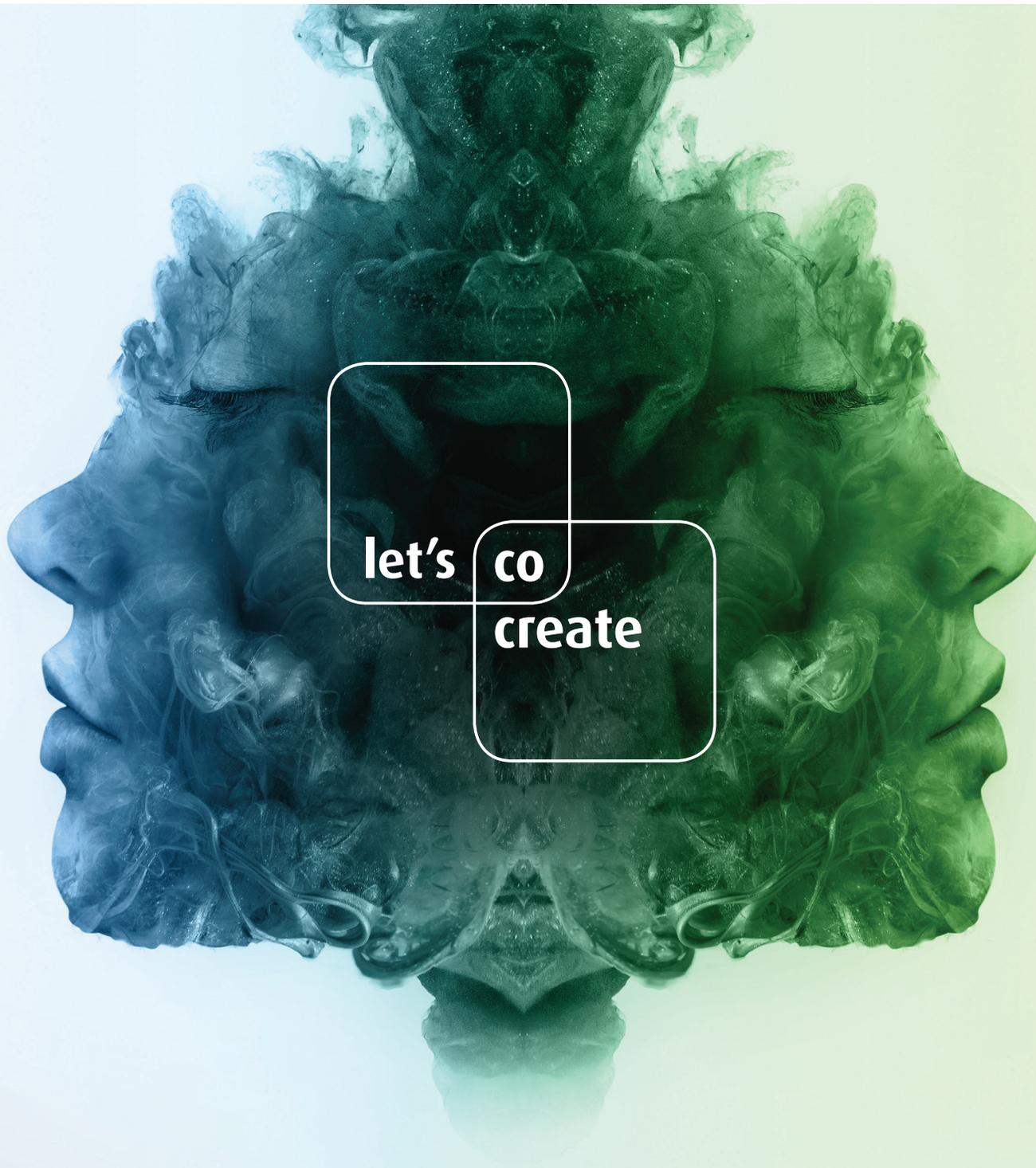
## Epistar files US patent infringement lawsuit against V-TAC USA

Epistar has filed a patent infringement lawsuit against V-TAC USA Corp in the United States District Court for the Central District of California. The complaint asserts that V-TAC's LED filament bulbs infringe seven Epistar patents and seeks injunctive relief to halt further sale of the infringing products.

Epistar alleges that the V-TAC's LED filament bulbs such as the VT-5115D Light Bulbs (P/N: 215), VT-5100D Light Bulbs (P/N: 200) and VT-5133 Light Bulbs (P/N: 283) infringe one or more claims of its US patents 6,346,771 ('High Power LED Lamp'), 7,489,068 ('Light Emitting Device'), 7,560,738 ('Light-Emitting

Diode Array Having An Adhesive Layer'), 8,240,881 ('Light Emitting Device Package'), 9,065,022 ('Light Emitting Apparatus'), 9,488,321 ('Illumination Device With Inclined Light Emitting Element Disposed On A Transparent Substrate'), and 9,664,340 ('Light Emitting Device').

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



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# Seoul Semiconductor launches series of AC LED modules

South Korean LED maker Seoul Semiconductor Co Ltd has introduced a new series of AC LED modules. Offered in designs from 200lm to 10,000lm in round, rectangular and linear formats, the modules integrate the firm's patented Acrich AC driver technology with the firm's advanced LEDs, enabling the design of compact light fixtures.

"Lighting designers who are looking to significantly reduce the size, weight, and volume of their luminaire designs can select one of our standard round, rectangular, or linear AC module designs to develop a complete light engine ready to be incorporated into their fixtures," says executive VP Keith Hopwood. "These modules are available through distribution, with availability in small quantities. Previously, modules designs were only available as custom solutions that required significant quantities."



**Acrich AC LED modules, available in round, rectangular and linear formats.**

Seoul Semiconductor's Acrich AC modules provide a fully integrated reference design for lighting fixture designers. They are available in a wide range of power and light output ratings, and can be readily applied to any lighting fixture design.

The modules are available in 120V or 230V versions, with many designs with efficacy higher than 100lm/W, meet Title 24 low flicker requirements and are compatible with Triac dimming.

All the modules have UL or ENEC safety approvals and comply with EMI class B requirements.

Based on the firm's patented Acrich design, Seoul's NanoDriver Series LED drivers enable integration of the AC modules' control circuitry into a miniature driver package, which provides simplified circuit topology and a significantly smaller overall light engine design. The NanoDriver Series devices are the industry's smallest 24W LED driver available, says the firm.

The firm's patented Multi Junction Transistor (MJT) technology enables multiple LEDs to be fabricated on a single die, resulting in higher voltage LEDs without the cost and complexity of multiple dies and wire bonds. High voltage LEDs deliver lower cost, higher reliability and simplified circuit topology.

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

## Seoul Semiconductor's AC LED modules pass 4kV surge testing, extending NanoDriver to industrial and commercial lighting

Using its recently introduced NanoDriver Series LED driver, Seoul Semiconductor has demonstrated a 277V<sub>AC</sub> lighting module that complies with the industry-standard 4kV surge testing.

Previously, AC LED modules have been used only in residential lighting applications due to the technology's limited capability to meet the surge requirements for industrial and commercial use. The demonstration module proves that it is possible to achieve a 277V<sub>AC</sub> module with high surge capability using the firm's NanoDriver Series LED driver.

Seoul Semiconductor says that, prior to its recent product launch, many LED fixture designers perceived AC LED technology as a low-performance, low-cost solution, assuming that AC LED technology had compromised performance which restricted its applicability. The firm says the demonstration module proves that it is possible to

achieve a high-efficiency, low-flicker solution using AC LED technology.

"This demonstration module proves that AC LED and driver technology can be successfully integrated for industrial and commercial lighting, expanding the market for these smaller, simpler, lower-cost fixture designs," says executive VP Keith Hopwood.

"The NanoDriver Series devices are the industry's smallest 24W LED drivers available, enabling lighting engineers to develop luminaire designs with dramatically reduced size, weight and volume. "Expanding the NanoDriver's applications to include commercial and residential lighting brings to customers in those markets the benefits of Seoul Semiconductor's AC LED technology — efficacy, low flicker, simpler topologies and reduced size."

NanoDriver Series LED drivers are suitable for commercial and industrial applications such as bol-

lards, wall sconces, downlights, and flush-mount fixtures. Their small size enables ultra-thin and novel fixture designs, enabling conventional lamp replacement without needing a large volume recess for the driver, or a reduction in the light output, says the firm. NanoDriver Series drivers make it possible to convert many conventional fixture designs to LEDs because the driver's small size allows integration into the fixture housing, adds the firm.

NanoDriver Series devices are suitable for luminaires up to 3000lm, enabling integration of control circuitry and external converter. This allows the addition of commercial lighting 0–10V controls, motion and daylight sensors, and the integration of wireless control. The drivers are also small and lightweight enough to make airfreight economical, reducing lead time and streamlining the supply chain.



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# Cree's quarterly revenue driven by Wolfspeed's SiC materials and Power & GaN RF devices

## Restructuring to right-size Lighting Products while doubling SiC wafer and Power device capacity by end-2018

For fiscal Q3/2018 (ended 25 March), Cree Inc of Durham, NC, USA has reported revenue of \$356m, down 3% on \$367.8m last quarter but up 4% on \$341.5m a year ago. However, this includes just under a month's activities from the Infineon RF Power business (acquired on 6 March). Excluding this, revenue was \$352m, up 3% year-on-year, and towards the upper end of the expected range of \$335–355m.

"From a strategic perspective, our Wolfspeed silicon carbide (SiC) materials, power and GaN RF businesses are the primary growth drivers," notes CEO Gregg Lowe.

Wolfspeed revenue was \$81.9m (23% of total revenue), up 16% on \$70.6m last quarter and 46% on \$56.1m (16% of revenue) a year ago. Excluding revenue from the Infineon RF Power business, Wolfspeed's organic growth was still 10% sequentially (above the targeted 5%) and 38% year-on-year, due to better-than-anticipated factory execution.

Revenue for LED Products (chips and components) was \$143.3m (40% of total revenue), down 6% on \$152.7m last quarter (better than the expected 10%) but up 9% on \$131.3m a year ago, due to strong demand in high-power general lighting, video screen and specialty lighting applications.

Revenue for Lighting Products (LED lighting systems and lamps) was \$130.8m (37% of total revenue), down 10% on \$144.6m last quarter and 15% on \$154m (45% of total revenue) a year ago.

"Wolfspeed's performance in Q3 illustrates the tremendous potential of the business, with organic revenues increasing nearly 40% year-on-year," notes Lowe.

Although down slightly from 48.4% last quarter, Wolfspeed gross margin was an above-target 48%, up from 47% a year ago.

LED Products gross margin has risen further, from 24.7% a year ago and 25.3% last quarter to 26.4%, due to strong demand and a more favorable product mix.

Lighting Products gross margin was 19.1%, down from 23% a year ago but up from 15.9% last quarter due to lower warranty-related costs and incremental factory improvements.

Overall company gross margin has risen from 25.2% last quarter to 27.8%. On a non-GAAP basis, gross margin was 28.3%, up from 25.7% and above the 28% forecast.

Operating expenditure (OpEx) was \$97m, below the targeted \$98m due mainly to R&D expenses being lower (related to timing).

Compared with a net loss of \$0.66m (\$0.01 per diluted share) last quarter, Cree made a net profit of \$3.8m (\$0.04 per diluted share) — exceeding the \$3m (\$0.03 per diluted share) upper end of the targeted range — and up from net profit of \$0.75m (\$0.01 per diluted share) a year ago.

During the quarter, Cree received \$16m from the exercise of employee stock options. Cash flow from operations was hence \$19.6m (down from \$51.7m last quarter). Spending on property, plant & equipment (PP&E) was \$43.2m (down from \$48.8m), while patent spending was \$3m. So, total capital expenditure (CapEx) was \$46m (down from \$51.3m). Free cash flow was hence -\$26.5m (versus +\$461,000 last quarter).

On 6 March Cree spent \$427m to buy the Infineon RF Power business (reported as part of the Wolfspeed segment). This was after Cree borrowed \$316m on its line of credit. So overall (net of line-of-credit borrowings), cash and investments fell from \$526m to \$401m.

Inventory days on hand rose to 109 days as inventory rose by \$37m to \$310m. Of this increase, \$26m relates to the acquired RF Power

inventories (inclusive of a \$5m preliminary purchase accounting basis step up). The remainder is primarily Wolfspeed work in process (WiP) to support business growth as well as finished goods in Lighting Products. Cree aims to exit fiscal Q4/2018 with inventory below 100 days (within the target range of 90–100).

During fiscal Q3, Cree completed a strategic review process, leading to the announcement on 26 February of a new long-term business strategy.

"We adjusted the outlook of our Lighting Products segment to be focused on fixing the business and providing modest growth," says chief financial officer Mike McDevitt. So, during fiscal Q4 Cree is implementing a restructuring plan to right size Lighting Products resources (incurring a \$7m GAAP restructuring charge), to be fully implemented by the end of the September quarter, after which it targets fully realizing \$15m in annual OpEx reductions.

"We've made significant changes to our design and product release methodologies, resulting in great initial revenue traction on new products and lower warranty claims," says Lowe. "We've also improved relationships with our channel and distribution partners, giving us a larger footprint and a better customer-facing presence," he adds.

"We target higher revenue and additional margin improvement in Q4, driven by a combination of factors: continued improvements in quality, better channel engagements, and increasing demand for new products."

The strategic review concluded that the LED Products business could drive value through greater focus.

"We have an incredible brand, a great channel, and a tremendous amount of IP positioning us as a leader in high-power technology," says Lowe. "We're going to take those capabilities and focus them in areas like auto-

motive lighting and application optimize solutions that are stickier and have an opportunity for us to create more value, enabling us to deliver modest revenue growth and gross margin expansion and resulting in great free cash flow generation.”

For fiscal Q4/2018 (to 24 June), Cree targets revenue of \$390–410m. This includes Wolfspeed rising 27%, based on strong organic growth and a full-quarter contribution from the Infineon RF Power acquisition. LED Products will rise by 7% due to growth in high-power LED components, with modest growth in mid-power joint venture (JV) components. Lighting Products will rebound by 9% (back to Q2 levels) as the firm come out of a seasonally slow fiscal Q3.

The Infineon RF Power business will “expand our leadership in RF to increase scale, a broader product offering and additional domain expertise,” says Lowe. “We are still in the early stages of integration.”

Despite the impact of the recent US export ban on China’s ZTE (which comprised about 20% of Infineon Power revenue), Cree still expects Wolfspeed revenue and gross profit to grow sequentially, with earnings of the acquired business now targeted to be dilutive by \$0.01 per share over the next several quarters. “We have inventory that is custom made for ZTE which could become unsellable at some point,” notes McDevitt.

“If we determine the inventory has become impaired, we would need to record a one-time charge equal to about \$0.01 per share,” he adds. “While the sales restriction with ZTE is creating some short-term headwinds in this business, it doesn’t change the long-term strategic benefit of this acquisition.”

Since (1) the acquired RF Power business (component packaging) has lower margin than rest of Wolfspeed and (2) near-term RF Power factory loading is reduced by the ZTE export ban, Wolfspeed margins should be sequentially lower. However, due mainly to higher-margin Wolfspeed being a higher portion of the total revenue mix, Cree expects company gross margin to rise to 29.7%,

aided by Lighting Products margin improving (by a few hundred basis points) and LED Product margin remaining level.

In fiscal Q4, Cree targets OpEx of 27.5% of revenue (similar to fiscal Q3), despite including the full-quarter spend of its acquired RF Power business (related to Wolfspeed R&D, IP illegal cost, semiconductor sales team additions, trade show cost and the higher bearable cost related to higher sales) partially offset by slightly lower Lighting Products OpEx as its begins to implement its right-sizing initiatives.

Cree targets operating income of \$7–11m and net income of \$5–9m (\$0.05–0.09 per diluted share).

“Demand signals for Wolfspeed remain strong with the adoption rate of electric vehicles, the increasing use of SiC and GaN technologies in communications, solar and industrial markets received substantial opportunity for the coming decade,” says Lowe.

“Carrying capital allocation priorities remained focused on expanding capacity in our Wolfspeed business as demand for these products exceeds our current ability to supply,” says McDevitt. “In fiscal 2018 we target capital spending of \$190m, driven primarily by expanding Wolfspeed’s production capacity to support forecasted customer demand,” he adds.

“The team is working hard ramping new production to meet growing demand and engineering and production teams are working together to quickly resolve challenges associated with rapid production expansion,” says Lowe. “The current cash outflow forecast is lower than previously announced due solely to timing. Overall we target fiscal 2018 free cash flow being –\$15m.”

The negative free cash flow is due to accelerating the Wolfspeed capacity investments to support the substantial growth opportunity forecasted over the next several years. “We are on target with our plan to double wafer capacity for external [SiC] materials customers by the end of calendar 2018. We are also on target with our additional Power & RF device capacities starting to come online in

fiscal Q4,” McDevitt says. “This plan is intended to double our power device capacity by the end of calendar 2018 from where we exited fiscal 2017.

As we ramp this new capacity we anticipate we could have some variability in our initial production yields and factory utilization that may reduce our near-term Wolfspeed gross margins,” he adds.

“Our smallest and most profitable business today [Wolfspeed] will become our largest and most profitable business over the timeframe of the long-range plan, roughly quadrupling in revenue by 2022,” expects Lowe. “Our LED business will see modest growth by focusing on stickier segments and our Lighting business will also see modest growth from where we’re at today, with a focus on improving quality and margins,” he adds. “This company-wide mix shift, combined with some efficiency improvements, will enable us to drive significant growth in gross margins — about 1500 basis points of improvement to around 40% (with Wolfspeed in the 50% range and the Lighting and LED businesses both in the low 30s) — establishing a 40/20/20 business model (40% gross margin, 20% OpEx, and 20% operating margin).”

To aid this, Cree has made organizational changes. Semiconductor manufacturing assets (split between Wolfspeed and LED Products) have been combined under Rick McFarland (who has experience from Freescale). “Putting them under one leader will give us an enormous opportunity for efficiency improvements, yield improvements and — equally important — will allow us to capitalize on the fungibility of those assets as we shift towards our higher-margin-type opportunities,” says Lowe.

Cree has also combined its sales team in the Wolfspeed and LED semiconductor organizations under Thomas Wessel (who has experience from TI. and as global sales & marketing lead for Analog Devices), who brings to Cree “experience in automotive, communications, industrial and distribution”.

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

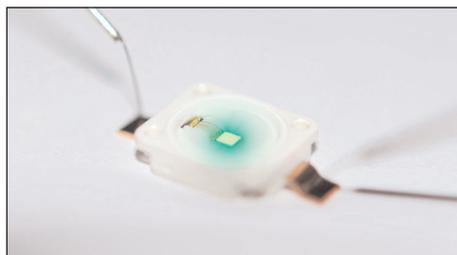
# Osram boosts efficiency of green LEDs by 40%

Typical forward voltage reduced by about 600mV to 2.6V

at power density of 45A/cm<sup>2</sup>

Osram Opto Semiconductors GmbH of Regensburg, Germany has succeeded in reducing the typical forward voltage by about 600mV to 2.6V (at a power density of 45A/cm<sup>2</sup>) in its indium gallium nitride (InGaN)-based green direct-emitting LEDs. With a simultaneous increase in optical output power, efficiency can be instantly improved by up to 40% compared to predecessor products across the firm's entire UX:3 portfolio. The significant drop in light output (the 'green gap' phenomenon) exhibited by green LEDs has often been the cause of efficiency problems and high costs in customer applications.

The benefits can be considerable, particularly for applications in which red, blue and green LEDs used in combination. Because all



three colors now have a voltage of less than 3V, the size of the drivers (previously designed for higher maximum voltages) can now be smaller. This in turn reduces both dissipative power loss and costs. The crucial factors in increasing efficiency were improved charge carrier transport and optimized material quality in the epitaxial layers.

At 350mA, 1mm<sup>2</sup> UX:3 chips achieve efficiencies of 175lm/W and higher at wavelengths around 530nm with the new technology.

Absolute light output in excess of 300lm at a pumping current of 1A opens up new applications, says Osram Opto.

"Until recently, these efficiency values seemed unattainable for green direct-emitting InGaN LEDs," says project manager Adam Bauer. "We are now moving into areas that up to now have been achievable only with phosphor-conversion emitters but with significantly reduced spectral quality," he adds. "Thanks to the success of our development team we have been able to drastically reduce the green gap phenomenon."

The team is now working on further improvements that offer potential that has become evident as a result of the recent findings.

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

## Osram acquires VCSEL firm Vixar

Firm adds to expertise in optical identification technology for security applications such as 3D facial recognition

Osram GmbH of Munich, Germany has added to its expertise in semiconductor-based optical security technology and expanded its product portfolio by acquiring Vixar Inc of Plymouth, MN, USA, a fabless company specializing in vertical-cavity surface-emitting laser (VCSEL) technology that has developed a volume supply chain consisting of merchant foundries serving the optoelectronic market.

While currently known primarily for identification applications in mobile devices, VCSELs can also be used to recognize gestures and measure distances in medical, industrial and automotive applications.

Vixar was founded by pioneers in the VCSEL industry, having first brought VCSEL to the datacoms market in the late 1990s, and more recently by founding Vixar in 2005

to pursue sensing applications. About 20 staff will transfer to Osram. Vixar is profitable both on an operational and net results level. Closing of the transaction is expected in summer.

"The acquisition of Vixar is adding to our expertise, particularly in the fast-growing market for security tech-

**The acquired capabilities pave the way for further security technologies, including ultra-compact 3D facial recognition. As well as unlocking smartphones and other consumer electronics devices, such technologies also can be used for high-security access controls in industry**

nologies," says Olaf Berlien, CEO of Osram Licht AG. Osram has expertise in infrared optical semiconductors and has already brought to market light sources for fingerprint sensors, iris scanners and 2D facial recognition. The acquired capabilities pave the way for further security technologies, including ultra-compact 3D facial recognition. As well as unlocking smartphones and other consumer electronics devices, such technologies also can be used for high-security access controls in industry.

Osram says that the way in which VCSEL technology captures 3D environmental data has applications in everything from gesture recognition, augmented reality, robotics and proximity sensors to autonomous driving.

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

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

## Hella and Audi introduce car featuring dynamic HD matrix LED headlamps with laser high beams

Car maker Audi and Germany-based automotive lighting and electronics firm Hella are introducing several vehicle front-lighting innovations to the market, allowing the illumination of roads even more dynamically and precisely while providing drivers with better vision. With the new Audi A8, an efficient LED lens module in the area of low beams will enter serial production for the first time. The new HD Matrix LED headlamp technology has additionally been further developed and a dynamic laser high-beam realized.

The new Audi A8 headlamp's low beam is equipped with a compact, efficient LED lens module consisting of glass and combining primary and secondary optics in a single body (avoiding most scatter loss). For low beam, three modules are used — one for reach, the others for lighting in front of the vehicle. The latter have an efficiency of up to 70% (the relationship between available LED luminous flux and luminous flux used for low-beam distribution).

For high beam, Matrix headlamp technology has been developed further by increasing the number and performance of individually controllable LEDs and rearranging them. 32 LEDs are now sited in a joint module along two rows. LED control occurs on the basis of front-camera data. When it recognizes other vehicles or road users, the control unit turns off or dims individual LEDs to avoid glaring. Other parts simultaneously operate at high-beam capacity, improving road visibility. The HD Matrix LED high beam is supported by two more LED modules throughout, which also increase both spread width and intensity.

Due to the HD Matrix LED headlamp and the additional LED modules, roads (especially curves) can be lit even more actively and precisely. In low beam, the optical concept of the lens module ensures that each LED can be assigned to a specific area of road. When in curves, the respective light focus will shift.

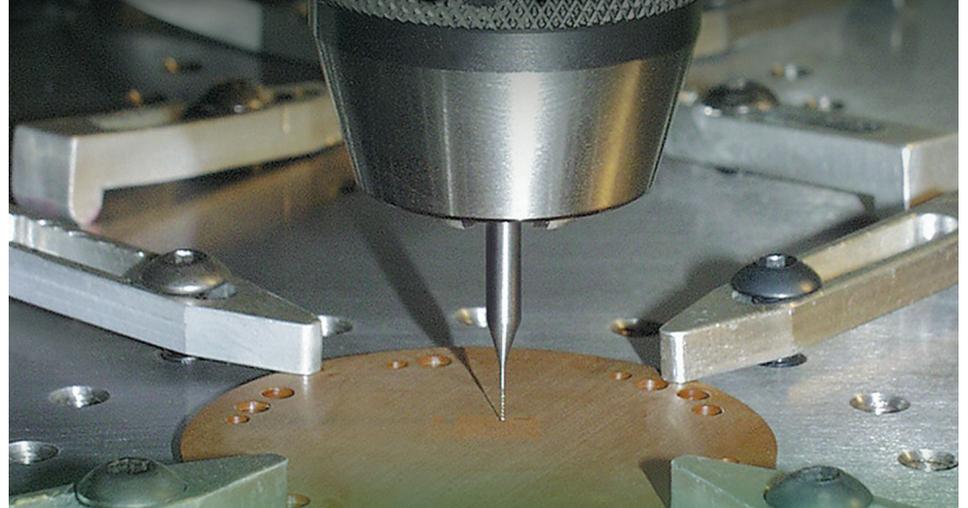
When driving with high beams, the high-beam LEDs will shift light towards the progression of the curve.

The dynamic laser high beams automatically turn on at 70km/h. The laser module will project a light beam whose spot extends several hundred meters. Further, the light

adjusts to the progression of the curve, e.g. on country roads. Also, once the camera recognizes other vehicles in its range, the laser spot automatically dims. The technology provides drivers with a view of the road without glaring oncoming traffic.

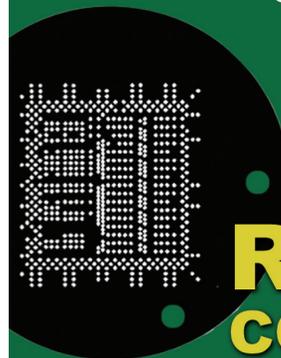
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## Lasertel's parent firm Leonardo commits to \$5m capital investment

### Funding to increase pump module manufacturing capacity for directed-energy programs and boost development of high-power lasers for lidar and material processing

In early May, Lasertel Inc of Tucson, AZ, USA (which makes high-power lasers and integrated systems for platforms including UAVs, space and airborne applications as well as next-generation man-portable systems) announced a \$5m capital investment by its parent company (Italy-based aerospace & defense firm Leonardo) in order to increase manufacturing capacity and advance efforts in developing high-power laser diodes.

The investment, which includes \$3.5m in capital equipment, will:

- increase manufacturing capacity

for low size, weight and power (SWaP) laser diode pump modules in support of high-volume directed-energy programs;

- advance vertical-cavity surface-emitting laser (VCSEL) and edge-emitter brightness for lidar and material processing applications; and
- accelerate development of advanced thermal management and laser diode driver technologies.

The investment "demonstrates the commitment by Leonardo to supporting the continued growth of Lasertel," comments Lasertel's president Dr Mark McElhinney.

With significant advances in the past two years in laser diode pump sources capable of providing high power and low SWaP, and continuing demand for increased power and brightness for applications such as directed energy and lidar, Lasertel says that it can now invest in the research needed to meet the needs of emerging applications. It expects that investments in capabilities and capacity will allow laser diodes to meet the power and cost demands as these technologies approach widespread adoption.

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

## VI Systems reports prototype 599–605nm yellow-orange (In,Ga,Al)P–GaP diode laser

### Average power of 1mW achieved in pulsed mode at 40kHz

VI Systems GmbH of Berlin, Germany (a fabless spin-off of the Technical University of Berlin and the A. F. Ioffe Physico-Technical Institute in St Petersburg, Russia) has reported the results of a novel type of diode laser that emits in the yellow-orange (599–605nm wavelength) spectral range (N. N. Ledentsov et al, 'Room-temperature yellow-orange (In,Ga,Al)P–GaP laser diodes grown on (n11) GaAs substrates', Optics Express volume 26 (number 11) p13985).

Existing commercially available lasers of this spectral range are mostly based on frequency doubling (by means of a nonlinear crystal) of the laser light from an infrared laser diode.

Lasing in the 599–605nm yellow-orange spectral range was demonstrated at room temperature in a laboratory environment. The device is single mode in the vertical direction (fast axis), and the full width at half maximum (FWHM) in the slow axis was measured at a lateral angle of 24° for a 1mm-long

diode laser. Operating in pulsed mode at 40kHz, an average power level of 1mW was achieved.

Target applications include medical use, industrial spectroscopic analysis and ultra-high-precision optical atomic clocks.

VI Systems presented at the 2018 Advanced Research Workshop 'Future Trends in Microelectronics: Vingt Ans Après' (FTM-9) in Sardinia, Italy (10–16 June).

[www.osapublishing.org/abstract.cfm?uri=oe-26-11-13985](http://www.osapublishing.org/abstract.cfm?uri=oe-26-11-13985)  
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## III–V optoelectronics foundry CST Global joins European Photonics Industry Consortium

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK has become a member of the European Photonics Industry Consortium (EPIC), the association responsible for maintaining the largest active network of photonics-related companies in Europe.

EPIC now has 370 member companies, spanning industry sectors including LED lighting; photovoltaic solar energy; photonics integrated circuits (PICs); optical components; lasers and sensor production; imaging, displays and projection; optical fiber communications; and other industries enabled by photonics-related technologies. EPIC is owned and operated by its members, who range from start-ups and SMEs to large corporates, as well as including research organizations, universities and other stakeholders connected to the photonics industry.



EPIC manages several focused LinkedIn Groups and exhibits at events across Europe. It organizes 20–30 events per year, including technology workshops and networking events, providing members with opportunities to meet and network with key suppliers and industry leaders and facilitating press relations and communications opportunities amongst its members.

“It provides a strong network environment for photonics-enabled companies and industries in Europe, with recognition and influence worldwide,” comments Euan Livingston, VP sales & marketing at CST Global. “It is a proactive organization, often acting as a catalyst and facilitator for both technological and commercial advancement. It can help accelerate growth and identify new and emerging photonics markets for research and development,” he adds.

“CST Global brings an exceptional contribution to the consortium through its III-V compound semiconductor technologies for the fabrication of photonics products,” comments EPIC’s director general Carlos Lee. “The company provides both a custom foundry service, as well as a range of high-volume, standard laser products for the optical communications markets.”

[www.epic-assoc.com](http://www.epic-assoc.com)

## CST Global appoints ISO 9001:2015 quality & supply chain manager

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) has appointed John Kane as quality and supply chain manager, reporting to the senior management team and responsible for the ISO 9001:2015 Quality Management System (QMS) at its site in Blantyre, near Glasgow, Scotland, UK. The QMS scope includes all 3” and 4” wafer fabrication and test processes and is a requirement for supplying customers operating in the data-center, cloud and telecoms markets.

“ISO 9001:2015 is the highest quality standard available for company processes. It impacts the entire business and it requires all staff to take responsibility for their individual part in the process,” notes Kane. “My role includes



**Quality and supply chain manager**  
**John Kane.**

developing our existing business systems and processes through Continuous Improvement, which I will extend to our key subcontractors. I will also maintain the management, production and test processes necessary for improved communication and control, both within and outside the company. It is a complex and competitive market with an integrated supply chain, so I must also take responsibility for business risk management,” he adds.

Kane has over 20 years of semiconductor experience in quality,

engineering, management and commercial roles. His quality management experience includes supplier, product and customer quality process implementation to exacting AS9100 and TS16949 standards. He is also ISO9001:2015 Lead Auditor qualified and has led cross-functional teams for continuous improvement, process qualification, new product introduction (NPI) and production transfer projects in tier-1, semiconductor and electronics manufacturing companies.

Kane has held senior quality, engineering and account management positions in Spirit Aerosystems, Jabil, Sumco Europe Sales, MEMC UK, EKC Technology and Motorola. He also has an Applied Physics with Semiconductor Electronics degree.

[www.CSTGlobal.uk](http://www.CSTGlobal.uk)

# Marktech expands West Coast photodetector design and manufacturing capabilities

Marktech Optoelectronics of Latham, NY, USA, a manufacturer of standard and custom optoelectronics components and assemblies, is expanding the photodetector design and manufacturing capabilities of Marktech West, its dedicated second facility in Simi Valley, CA, USA.

Established in 2015, the 3800ft<sup>2</sup> Marktech West facility offers all the necessary infrastructure, technology, and engineering expertise for the design, development and manufacture of photodetectors, in quantities ranging from prototype to OEM volumes, from wafer design stage to complete subsystems, says the firm. Extensive Marktech investments in advanced production technology and equipment, including a Class 1000 (ISO 6) cleanroom, have created a highly controlled manufacturing environment in which to produce both silicon (Si) and indium gallium arsenide (InGaAs) photodetectors. Available products, each with extensive front- and back-end customization capabilities, include:

- UV detectors, with spectral sensitivities from 150nm to 570nm, and further incorporating gallium phosphide (GaP), gallium nitride (GaN) and silicon carbide (SiC) materials, for long-term stability, high device sensitivity and low dark current;
- Silicon photodiodes and silicon phototransistors, with spectral sensitivities from 350nm to 1100nm, for visible and NIR applications requiring low noise, high speed and high sensitivity. Silicon wafers and chips are optimized to ensure uniform, consistent performance and high reliability. Available cost-effective customization capabilities to exacting standards include wavelength specific band-pass filtering, and hybridization.
- Avalanche photodiodes (APD's), featuring higher sensitivities than standard photodiodes, for high-accuracy, low-level light (LLL) detection, short pulse detection, and



applications requiring higher bandwidth or internal gain, as required to overcome high preamplifier noise levels. Standard Marktech APD's offer an internal gain mechanism, fast rise times, low dark current, and high NIR spectral sensitivity. Available cost-effective customization options to exacting standards include operational voltage selection ( $V_{br}$  binning), wavelength specific band-pass filtering, and hybridization. Silicon-based APD's (Si APD's), supporting high-speed and low-light-level NIR optical detection from 400nm to 1100nm, are offered with active area sizes of 230 $\mu$ m and 500 $\mu$ m, and with peak response optimization of either 800nm or 905nm.

- 100% US-based custom silicon chip and wafer design and processing, with designs for long-term stability, radiation hardness and high-reliability against UV and Gamma radiation.
- GaP Schottky photodetectors, specially optimized for high-accuracy UV photodetection up to the visible spectrum, 150nm to 550nm.
- Standard photovoltaic or photoconductive silicon photodiodes, with spectral sensitivities from 350nm to 1100nm, for applications requiring high-broadband sensitivity, moderate-to-fast response speeds, and optimized spectral enhancements.
- InGaAs PIN photodiode chips, in active area sizes from 0.1mm to 3.0mm, with spectral sensitivities from 800nm to 2600nm. Marktech InGaAs PIN photodiode chips offer an optimal balance between low dark current, high speed and light sensitivity. No thermoelectric cooling

is utilized in the manufacturing of Marktech PIN photodiodes, reducing costs and improving overall efficiencies.

- Foundry services, for the epitaxial growth of high-reliability SWIR wafers in the 1.0 $\mu$ m to 2.6 $\mu$ m range, with InP material as the base substrate, in 2", 3" and 4" diameters.

Additional facility capabilities include mask design, custom packaging, and hybrid electronic designs. Front-end customization options include chip geometry design flexibility; responsivity to operating wavelengths; rise times to unique bandwidths; capacitance, for reduced noise and increased speed; dark current, for improved dynamic range; and anti-reflective coatings, for reduced optical losses. Back-end customization capabilities to unique environmental requirements include filter-in packages, for reduced ambient light effects; optical component add-ons, such as optical lenses, scintillators, etc.; light sources, including LEDs or laser dice for assembly miniaturization; integration of heaters, coolers, temperature sensors and op-amps; and custom packaging. Photodetectors are typically packaged within a variety of transistor metal case styles, in sizes from TO-18 to B-1032. Optoelectronic modules are further offered for simplified application integration and evaluation.

"We are pleased to announce our expanded West Coast photodetector manufacturing capabilities... These capabilities now allow us to manufacture a variety of photodetectors with highly competitive lead times, in anywhere from prototype to OEM volumes, using the very latest equipment and manufacturing processes," says president, Bill Moore. "We look forward to continuing to advance our in-house manufacturing capabilities, in response to customer needs."

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

# US DoD funding project to demo waveguide platform transparent throughout MWIR and LWIR bands

## UCSB-led team to develop CMOS-compatible waveguide platform for integrating MWIR & LWIR laser sources into AIM Photonics' capabilities

The Rochester-based consortium AIM Photonics (American Institute for Manufacturing Photonics), an industry-driven public-private partnership advancing the USA's photonics manufacturing capabilities, has announced the awarding of the latest Department of Defense (DoD) government-directed project for photonic integrated circuits (PICs), Integrating MWIR and LWIR Sources.

The \$1,702,000 project will support a consortium of AIM Photonics members led by University of California Santa Barbara (UCSB) and including Northrop Grumman, the US Naval Research Laboratory (NRL), and SUNY Polytechnic Institute. Most development to date has focused on a relatively narrow wavelength range around 1550nm, so the goal is to address opportunities at longer wavelengths.

The plan is to incorporate mid-wave infrared (MWIR) laser sources (nominally  $3.0\mu\text{m} < \lambda < 5.0\mu\text{m}$ ) and long-wave infrared (LWIR) laser sources (nominally  $8.0\mu\text{m} < \lambda < 14.0\mu\text{m}$ ) into the capability that AIM Photonics can offer. The expanded wavelength range will enable a variety of commercial and military applications, such as allowing sensors to be tuned to detect

atmospheric trace gases for air quality evaluation or hazard alerts.

"AIM Photonics continues to expand the PIC ecosystem with our PDK [process design kit], MPW [multi-project wafer], and soon-to-be-available TAP [tuition assistance program] services," says AIM Photonics' deputy CEO Dr John Bowers. "The additional laser research is another example of the exceptional value this institute continues to provide through these research and development partnerships."

UCSB's experience in laser research and integrated photonics, in collaboration with DoD experts and key defense contractors, will target inclusion of these laser sources into the AIM Photonics PDK, MPW, and TAP capabilities, allowing for a wider range of capabilities for the larger integrated photonics community.

"The expansion into longer wavelengths is necessary to ensure our design and development infrastructure we have developed is state of the art, and continues to address the additional requirements and key benefits of our integrated photonics manufacturing ecosystem," says AIM Photonics' CEO Dr Michael Liehr.

"Northrop Grumman regards the

inclusion of MWIR and LWIR into AIM Photonics photonic integrated circuits as a critical part of the development of future DoD imaging systems vital to the nation's security," states Northrop Grumman staff research scientist Dr Loan Le.

"The extension of photonic integrated circuits to MWIR and LWIR wavelengths may be expected to strongly impact Navy systems," says Dr Jerry Meyer, NRL's senior scientist for Quantum Electronics. "They will be particularly valuable in systems requiring such advanced capabilities as IR power scaling, multi-spectral beam combining, high-resolution IR imaging, and chemical threat detection," he adds.

"Aside from Department of Defense interests, there are numerous medical, bioenvironmental, remote sensing, communications, and manufacturing and process monitoring benefits that we hope will be affordably and reliably demonstrated through the outcomes of this work," concludes Dr Thomas R. Nelson Jr, Advanced Development Team lead at the US Air Force Research Laboratory (AFRL), Materials and Manufacturing Directorate.

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

## Firecomms wins German patent infringement case brought by Broadcom

Firecomms Ltd of Cork, Ireland and Tongxiang, China (which manufactures plastic fiber-optic solutions and optical transceiver modules for communications networks) has won a patent infringement action brought against it in Germany by Avago Technologies General IP (Singapore) Pte Ltd (Broadcom). On 13 April, the District Court of Munich issued a judgment stating

that Firecomms' RedLink products FR05MHIR and FR10MHIR do not infringe the German designation of Broadcom's European Patent No. 1 511 198 B1 (patent 198), the charges brought by Broadcom should be dismissed, and that Broadcom should bear the costs of the dispute.

"The Munich Court has upheld Firecomms long-held position that it does not infringe patent 198 and

has rejected Broadcom's arguments to the contrary," says managing director Dr John D. Lambkin. "We have throughout this long process been resolute in defending the veracity of our own technology," he adds. "Firecomms also very much appreciates the steadfast support of key customers during the course of this action."

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

# EU-funded MOICANA project targets heterogeneous integration of InP quantum dot lasers on SiN silicon photonics platform

MOICANA ('Monolithic co-integration of QD-based InP on SiN as a versatile platform for the demonstration of high performance and low-cost PIC transmitters') is a new R&D project that targets the development of fundamental innovations in the field of photonic integrated transmitters, aiming to make them cheaper and more power efficient. Running from January 2018 to December 2020, MOICANA is funded by the European Union (EU) under its Horizon 2020 program H2020 ICT 2016-2017 – Photonics KET (Key Enabling Technology) Call (project number 780537) and the initiative of the Photonics Public Private Partnership.

The project consortium brings together four leading industrial partners and four academic and research institutes in the photonic integrated circuit (PIC) and photonic systems value chain: Greece's Aristotle University of Thessaloniki (project coordinator), Germany's University of Kassel, Technion –

Technical University of Israel, France's III-V Lab, Israel's Mellanox Technologies, Switzerland's Ligentec, Germany's ADVA and Spain's VLC Photonics.

The widespread adoption of optical transceivers in a broad range of application domains urgently demands low-cost, high-power-efficient and large-volume manufacturing integration technology that can meet the different specifications required in every application sector and urgently scale up to serve the growing telecom and datacom markets. The existing solutions for tackling this demand favor silicon photonics-based technologies that still feature a major drawback. They need complex and expensive hybrid integration substrates, since they rely on externally coupled indium phosphide (InP) laser sources for the final assembly, while the redundant testing for the pre- and post-processed coupled laser induces an additional cost-increasing factor.

MOICANA aims to demonstrate breakthrough performance by combining the best in class from the two worlds of photonic integration: quantum dot InP structures as the III-V light source material and silicon nitride (SiN) from silicon photonics for the passive platform.

The project targets the highest possible cost effectiveness in the mass fabrication of optical transmitters by developing technology for the epitaxial deposition of quantum dot InP components directly on silicon by selective-area growth.

MOICANA aims to highlight its versatile and scalable perspective and its credentials for broad market uptake by demonstrating a whole new series of cooler-less, energy-efficient and high-performance single-channel and wavelength-division multiplexing (WDM) transmitter modules for data-center interconnects (DCI) in 5G mobile front-haul and coherent communication applications.

[www.moicana.eu](http://www.moicana.eu)

## MACOM Japan completes sale of LR4 100G long-range optical subassembly business to CIG Shanghai

### CIGTech Japan formed for contract manufacturing of TOSAs & ROSAs

MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for RF, microwave, millimeter-wave and lightwave applications) says that MACOM Japan Ltd has completed the previously reported sale and transfer to communications equipment manufacturing company CIG Shanghai Co Ltd of capital equipment, inventory and other assets associated with MACOM Japan's long-range optical subassembly product line (the LR4 100G product business) and the grant of a non-exclusive license for related intellectual property.

The asset purchase and IP license agreement of 30 April (amended on 10 May) was for the buyer to pay \$5m to MACOM Japan within 30 days following the closing of the transaction, provide it with the opportunity to supply components, and will pay MACOM Japan an additional estimated \$5m and \$12m for certain capital equipment and inventory, respectively, within 60 days, subject to the receipt of required government approvals.

As part of a corporate expansion, CIG (Cambridge Industries Group) Shanghai (which has a subsidiary Cambridge Industries USA Inc in

Santa Clara, CA) is forming the Tokyo-based subsidiary CIGTech Japan Ltd (headed by president & CEO Toshihiro Takada), dedicated to the design and development of transmit and receive optical subassemblies (TOSAs and ROSAs) operating at speeds of 100G and beyond. Leveraging the firm's low-cost, high-volume manufacturing capabilities, CIG aims to pursue contract manufacturing (CM) of TOSAs and ROSAs for customers worldwide.

[www.cigtech.com/  
optical-sub-assemblies](http://www.cigtech.com/optical-sub-assemblies)  
[www.macom.com](http://www.macom.com)

## Broadex to make Kaiam's transceivers in China

Kaiam Corp of Newark, CA, USA (which makes optical transceivers for hyperscale data centers) has agreed a partnership for module maker Broadex Technologies Co Ltd of Jiaxing, Zhejiang Province, China to manufacture and supply high-end transceivers into the China market.

The two firms have signed a memorandum of understanding (MOU) for furthering cooperation on volume production of QSFP28 100G-CWDM4 transceivers based on Kaiam's LightScale2 platform. Kaiam claims that the LightScale2 architecture has fundamental advantages in cost and performance and is suited to high-volume applications. The agreement allows Broadex to manufacture these units in China and directly address Chinese customers who require local production. This also complements Kaiam's in-house manufacturing in the Livingston, Scotland, UK and provides further capacity to address

the high-volume data-center market.

"We anticipate very strong demand for 100G transceivers based on our LightScale2 technology," says Dietmar Zapf, Kaiam's general manager & VP of manufacturing. "In addition to the production lines already running at our Livingston, UK facility, we need to develop and secure further expanded capacity for manufacturing these products in high volume. The MOU signed with Broadex would allow us to leverage Broadex's manufacturing expertise and infrastructure and expand our capacity in the next 3-6 months to meet high demand," he adds.

"We are glad that Kaiam chose to continue working with us for manufacturing its new non-hermetic transceivers for data-center applications," says Broadex VP & chief technology officer Yong Ding PhD. "We have been producing OSA-level components for Kaiam in high

volumes for several years now. The LightScale2 platform is optimized to deliver maximum value and performance in the data-center environment at dramatically lower costs. We will work aggressively to quickly ramp to high volumes with high yields," he adds.

"Kaiam is eagerly anticipating expansion into the China market with the assistance of our valued partners at Broadex," says Jeremy Dietz, Kaiam's VP of global sales & marketing. "The two companies will combine on business growth activities in and around China to strengthen Kaiam and Broadex's market share in optical transceivers for data centers as well as PLCs [planar light-wave circuits] for 5G rollouts."

The MOU includes details of mutual technology cooperation and manufacturing arrangements on timeline, cost roadmap, local sourcing and China market development.

[www.broadex-tech.com](http://www.broadex-tech.com)

## Kaiam launches enhanced 100G 'CWDM4+' LightScale2 transceivers

Kaiam has made available an enhanced series of 100G 'CWDM4+' transceivers that offers substantially higher performance than the CWDM4 standard and is optimized as well as tested for added reliability.

The firm says that multi-source agreement (MSA)-standard transceiver specifications are often inadequate to account for losses due to variations in data-center fiber plant, adding to the cost of deployment. Furthermore, even low failure rates of transceivers add substantial operating cost for data centers. Kaiam says that its new enhanced specification and increased reliability transceiver addresses both concerns without additional cost.

The XQX5600 series of enhanced CWDM4+ transceivers (in the QSFP28 pluggable form factor) provide -1dBm minimum Tx optical modulation amplitude (OMA), 3dB more than required by the

CWDM4 standard. This, in turn, supports 3dB more link budget than the CWDM4 standard requires, supporting more robust links in the face of various real-world data-center link impairments. Similar to a space-grade production process, each fully assembled module undergoes environmental test and burn-in prior to shipment, as well as routine chip-level screening, resulting in higher reliability.

Kaiam claims it can deliver this enhanced CWDM4+ performance at no cost increase over standard CWDM4 due to its superior technology platform. The firm's LightScale2 architecture simplifies both optical and high-speed electrical paths. Based on Kaiam's OWB (optical wire bond) technology, the optical path is said to use far fewer components than competing legacy solutions, resulting in lower optical losses.

Signal integrity is improved by eliminating flex circuits and hermetic gold boxes, enabling very high product yields even under more challenging CWDM4+ specs.

"Kaiam is uniquely positioned to address the data-center deployment issues encountered by our customers," claims Jeremy Dietz, VP of global sales & marketing. "By enabling more link budget and delivering higher reliability than standard products, many of these issues can be avoided," he adds. "We have moved the technology needle considerably, proving that the CWDM4 standard specs are overly conservative in today's world. Our recently expanded production capacity in Livingston, UK — combined with that from our partnership with Broadex — provides customers with quick access to improved value," says Dietz.

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

# Almae to co-develop laser modules based on POET's optical interposer platform for high-speed datacoms

## Firms to provide foundry services for epi supply and device fabrication

POET Technologies has executed an agreement for the co-development of transmit devices with Almae Technologies SAS of Marcoussis, France, a spin-off from III-V Lab (the joint Nokia, Thales and CEA-Leti industrial research laboratory).

Almae is majority-owned by an affiliate of Accelink Technologies Co Ltd of Wuhan, China (a maker of optical components and subsystems for the datacom, telecom and network access markets), which in March entered into a memorandum of understanding (MoU) with POET for the co-development of transceivers for 100/400G markets as well as low-cost single-channel (10/25G) products for telecom applications.

Almae designs and produces indium phosphide epitaxial wafers used to implement photonics circuits integrating semiconductor lasers. Its high-speed buried heterostructure laser technology consists of embedding the semiconductor strip constituting the laser with semi-insulating InP material, enabling good thermal exchange and optimum optical guidance of the beam, as well as low parasitic capacitance and resistance.

This is said to enhance the implementation, stability and performance of integrated lasers. With over 2000m<sup>2</sup> of cleanrooms, Almae has an annual full production capacity of several thousand wafers, incorporating new-generation laser components that support high-speed access over optical fibers.

The purpose of the agreement is to jointly develop, manufacture and sell a series of laser modules based on the POET Optical Interposer platform (unveiled in January) for high-speed data communications.

The firms will collaborate on the design of lasers and modulators to be compatible with POET's Optical Interposer and to provide foundry services for both epitaxial supply and device fabrication. The collective efforts will be undertaken through a series of overlapping projects, spanning the exchange of data and techniques, co-development activities, commercial arrangements, and strategies for pursuing global go-to-market sales.

"We are very pleased to establish a framework for collaboration with Almae, a leading European supplier

of high-performance EML lasers based on a novel buried heterostructure design and an advanced PIC fabrication platform," says POET's CEO Dr Suresh Venkatesan. "In addition to the joint development of Optical Interposer-compatible devices, the agreement outlines an arrangement for sharing expertise and resources to accelerate time-to-market for both companies, while also expanding our collective geographic reach and providing a much larger market opportunity," he adds.

"The framework for collaboration with POET follows closely behind the recent introduction of our 25G integrated laser-modulator (EML), which has broad application in high-performance photonics," says Almae's CEO Dr Jean-Louis Gentner. "The inclusion of our device designs into the POET Optical Interposer platform will expand the applications we can address in both the datacom and telecom markets. We are also pleased to be able to offer our epitaxial foundry services to POET and to take advantage of POET's fabrication capabilities in Singapore."

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

## POET reports first-quarter results

For Q1/2018, POET Technologies Inc of Toronto, Canada and San Jose, CA, USA — a designer and manufacturer of optoelectronic devices, including light sources, passive waveguides and photonic integrated circuits (PIC) for the sensing and datacom markets — has reported revenue of US\$673,229, down on US\$717,692 last quarter and US\$712,550 a year ago. Revenue primarily comprises sales of DenseLight photonic sensors for test & measurement applications.

Gross margin rose to 60.2%, up from 46.3% last quarter and 59.6% a year ago. Net loss before taxes was US\$3,249,292 (\$0.01 per share),

down from US\$3,590,648 (\$0.01 per share) a year ago but up on US\$2,915,240 (\$0.01 per share) last quarter.

In March, POET completed a 'bought deal' public offering, yielding gross proceeds of US\$10.7m (C\$13.8m). It hence ended Q1 with cash and short-term investments of US\$13.2m, despite capital investment in plant, equipment and patents rising from US\$129,531 a year ago to US\$1,064,693.

During Q1, POET demonstrated a high-frequency waveguide-integrated PIN photodiode targeting 100G and 400G optical transceivers for data-center applications.

In January the firm announced the POET Optical Interposer platform, which leverages the firm's dielectric waveguide technology to enable the co-packaging of electronics and optics in a single multi-chip module. POET also signed a memorandum of understanding (MOU) with Accelink for the co-development, qualification and sales of a family of transceiver products based on the Optical Interposer platform.

Chief financial officer Thomas R. Mika presented at the 8th Annual LD Micro Invitational Conference in Los Angeles on 4 June.

[www.poet-technologies.com](http://www.poet-technologies.com)

## POET gives business and technology update

POET Technologies says that, during 2017, it began focusing its resources on developing photonic solutions using a hybrid integration approach, which combines its indium phosphide (InP)-based photonics chips and its dielectric-based waveguide devices into a single package.

Its approach to hybrid integration using the Optical Interposer Platform was borne by the unique capabilities acquired through its acquisitions of DenseLight Semiconductor and BB Photonics in 2016. This new approach targeted the same objective, i.e. replacing discrete high-cost passive optical components with lower-cost embedded devices and proven wafer-level semiconductor process and assembly technologies.

Using embedded dielectric passive devices and advanced packaging techniques, POET says that it can lower the cost of datacoms transceivers for data-center operators and telecom applications. By late 2017, the firm had validated the potential to dramatically reduce the cost of conventional transceivers via wafer-scale integration of photonics devices and passive waveguides into a single multi-chip module (MCM) package, leading to the announcement of POET's Optical Interposer platform in January.

"During 2017, we made significant progress across several areas of the business," says CEO Dr Suresh Venkatesan. "We increased revenue 50% year-over-year with the increased shipments of light sources for sensing applications. Additionally, we recorded about \$1.7m in credits from the Singapore Economic Development Board (EDB) in support of our ongoing R&D efforts at our DenseLight facility," he adds.

"From a technology perspective, we achieved a real breakthrough in designing and demonstrating key elements of the POET Optical Interposer. It is a true platform technology that is readily scalable for

applications in data communication transceivers that undergo rapid evolutions in standards and generations. It is also flexible enough to address critical applications in other markets such as automotive LIDAR and high-performance computing. Placing photonic components in close proximity to data generators like ASICs and microprocessors has been an industry objective for decades. Among the many difficult challenges, thermal management and reliability are ones that the Optical Interposer platform can potentially address," continues Venkatesan.

"While using the POET Optical Interposer platform for photonics assembly provides thermal management and reliability advantages, its primary advantage is cost, which is the basis for competition in a standards-driven industry. We achieve low cost by employing proven semiconductor 'known good die' assembly, testing & packaging techniques to the optical components of the transceiver. Our architecture is unique, allowing us to both manufacture the passive interposer assembly platform at low cost in a factory that is compatible with mainstream silicon semiconductor fabrication and to place active devices on this platform without requiring complex alignment and expensive micro-optical components. Further, our waveguides embedded in the interposer function as multiplexers/demultiplexers, spot-size converters and guides, and are independent of the active devices that determine the speed of the device. The waveguides for a 100G optical engine are the same low cost as those for a 400G optical engine. Furthermore, there is little incremental cost in adding additional communication channels to the platform. This is one example of the scalability of the POET Optical Interposer," he adds.

"Most recently, we've taken additional meaningful steps toward

commercializing POET's interposer technology, including our announced master collaboration agreement with [Malaysia-based wafer foundry] SilTerra for the co-development of the waveguide manufacturing process flow, consignment of equipment and entry into a wafer purchase agreement. We did this in order to establish a reliable and consistent manufacturing resource for the supply of wafers incorporating the Optical Interposer devices. We also entered into a memorandum of understanding (MoU) with Accelink Technologies to become 'Preferred Co-Development Partners' on the collaborative development, qualification and sales of a family of advanced multichannel (100/400G) transmit and receive devices based on POET's Optical Interposer platform. These strategic engagements with a leading foundry and global supplier of transceivers represent significant milestones in the commercialization process, as they each position the firm to engage more credibly in discussions with additional prospective customers," Venkatesan believes.

"We continue to be on schedule to deliver receive optical engine prototypes to Accelink this summer, with our main challenges to that schedule being the logistics of installing and bringing up new tools and processes at 8-inch wafer foundry. We are very pleased with the cooperation and support that we are receiving from SilTerra and our equipment vendors. Beyond the short-term goal of prototypes for receive optical engines, we are working on the more complex transmit side of the transceiver and look forward to some announcements on that front later in the year. We see a very significant opportunity in the Optical Interposer platform applied to a number of application areas and vertical markets," Venkatesan concludes.

[www.poet-technologies.com](http://www.poet-technologies.com)

# Finisar's quarterly revenue falls 6.7% due to lower demand from Chinese OEMs

## Return to growth in June quarter to drive improvements in margins and EPS

For full-year fiscal 2018 (ended 29 April), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of \$1316.5m, down 9.2% on fiscal 2017's \$1449.3m, due to lower demand from Chinese OEM customers.

In particular, Datacom product sales fell by 1.2% to \$12.8m, while Telecom product sales were fell by 29.5% to \$120m.

Fiscal fourth-quarter revenue was \$310.1m, down 6.7% on \$332.4m last quarter and down 13.3% on \$357.5m a year ago.

Datacom product sales were \$248m, down 6.8% on \$266.1m last quarter, due mainly to the expected decline in revenue from vertical-cavity surface-emitting laser (VCSEL) laser arrays for 3D sensing applications. Telecom product sales were \$62.1m, down by 6.4% on \$66.3m last quarter (due mainly to the full three-month impact of the annual telecom price reductions) but also down 31.7% on \$90.9m a year ago.

Like last quarter, Finisar had two 10%-or-greater customers. The top 10 customers represented 61.1% of total revenue (down from 63.3% last quarter).

On a non-GAAP basis, gross margin has fallen further, from 36.2% a year ago and 28.6% last quarter to 24.7% (well below the expected 27–28%). This is due to the impact of the full three months of the telecom price reductions, under-absorption of fixed manufacturing expenses in the VCSEL laser fab in Allen, Texas, and an increase in non-cash inventory reserves. Full-year gross margin hence fell

from 35.9% to 29.7%.

Full-year operating expenses rose from \$280.3m (19.3% of revenue) to \$292.2m (22.2% of revenue). Although up from \$71m a year ago, fiscal Q4 operating expenses were \$72m, cut slightly from \$72.4m last quarter.

Despite this, operating income fell further, from \$58.4m (operating margin of 16.3% of revenue) a year ago and \$22.7m (6.8% margin) last quarter to \$4.6m (1.5% margin, well below the expected 4%). Full-year operating income was hence down from \$240.6m (16.6% margin) to \$99.2m (7.5% margin).

Likewise, net income has fallen further, from \$57.5m (\$0.50 per diluted share) a year ago and \$22.8m (\$0.20 per diluted share) last quarter to \$5.8m (\$0.05 per diluted share, below the expected \$0.09–0.15). Full-year net income hence fell from \$231.7m (\$2.03 per diluted share) to \$100.4m (\$0.86 per diluted share).

Capital expenditure (CapEx) was \$55.2m (above the forecasted

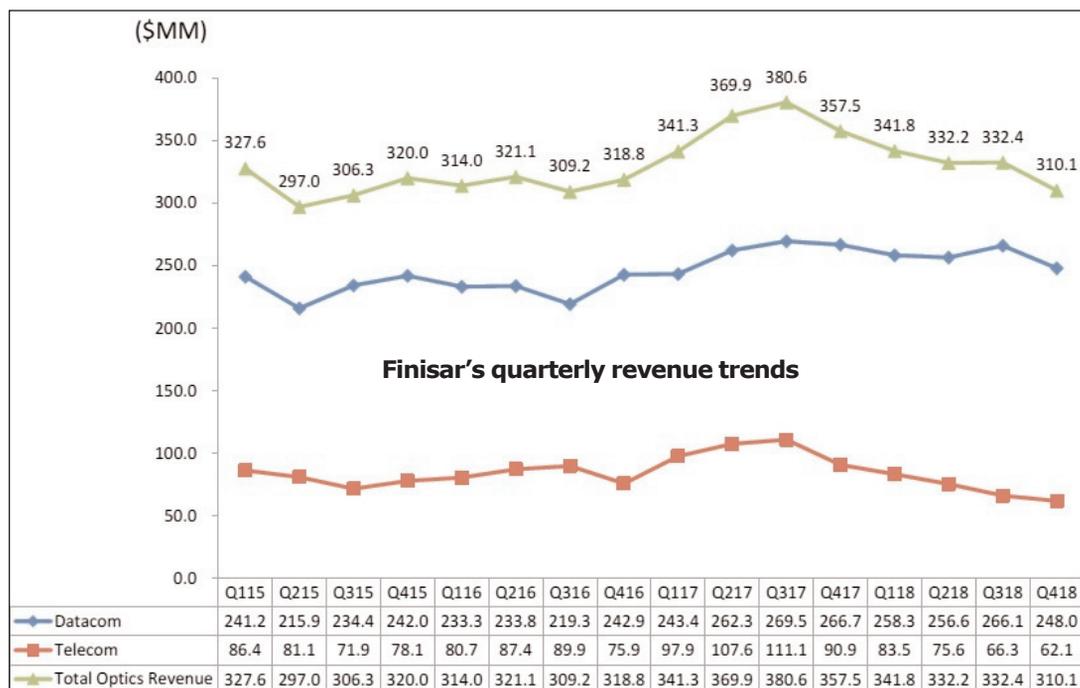
\$45m). This included \$4.4m for ongoing construction of the third building of Finisar's manufacturing site in Wuxi, China (due for completion in calendar second-half 2018) and \$27m on uplift of the new 700,000ft<sup>2</sup> facility in Sherman, Texas (purchased recently in order to expand manufacturing capacity for VCSELs using 6-inch wafers) and the initial deliveries of capital equipment for that site.

During the quarter, cash and short-term investments hence fell from \$1.216bn to \$1.197bn.

"While we are disappointed in last quarter's results, we do expect both revenues and gross margins will increase in our fiscal first quarter," says CEO Michael Hurlston.

For fiscal first-quarter 2019, Finisar expects revenue to grow slightly to \$305–325m. There should be improvements in gross margin to 26–27%, operating margin to 4–5%, and earnings per fully diluted share to \$0.10–0.16.

Excluding \$100m for the uplift of the building and additional equip-



ment at the Sherman facility, CapEx should be \$30m. This includes \$5m related to the construction and fit out of the third building in Wuxi.

"We expect to see an increase in demand for our VCSEL laser arrays for 3D sensing applications in the second fiscal quarter in connection with the expected timing of the new product introductions by our customers," notes Hurlston. "In addition, we have closed a number of design wins for our VCSELS in consumer and automotive applications," he adds. "Our opportunity funnel will continue to increase in areas beyond automotive and handsets. We continue to make progress with respect to uplift of the building and the ordering and receipt of capital equipment for VCSEL laser fab in Sherman, Texas for 3D sensing applications and still expect to be qualified and in

production using 6-inch wafers by the end of the calendar year, which we expect to significantly increase our production capacity."

"In our core business, we're seeing increased demand for ROADMs [reconfigurable optical add/drop multiplexers] as India and China deploy more advanced networks. In our datacom transceiver business, we're seeing increased unit volumes in the data-center market, but this is being offset by continued ASP [average selling price] pressure. We have a set of cost reductions and process to provide greater pricing flexibility," Hurlston says.

"We have begun to make changes at Finisar that I believe will not only bring more focus to our product development efforts, but will lead to better execution and efficiency, allowing the company to reduce

relative expense levels," says Hurlston. "We can ultimately get to a sustainable operating margin of 12–15%. We plan to do this by ramping in new markets, changing our product mix and focusing R&D priorities," he adds. "Fundamental to achieving this objective will be managing our operating expenses to 18–20% of revenue... We'll take multiple quarters to implement, but we have already begun taking steps to execute a plan consistent with these objectives."

"On the horizon, we believe we are well positioned with the major 5G wireless OEMs on 25G and 100G data rates for both short- and long-reach applications," reckons Hurlston. "We also believe we are well positioned for the 400G transition starting in calendar year 2019."

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

## Finisar demonstrates VCSEL and diffractive optics technology for 3D sensing applications at Sensors Expo

Finisar gave several demonstrations and product displays at the Sensors Expo 2018 in San Jose (27–28 June).

Finisar is demonstrating vertical-cavity surface-emitting lasers (VCSELS) arrays and diffractive optics technology used in a wide range of 3D depth-sensing and infrared (IR) imaging applications, such as 3D facial recognition in consumer mobile devices. It will also have samples of a highly integrated 1550nm coherent transmitter and receiver module for next-generation LiDAR applications.

### VCSEL technology demo

A live demonstration of IR illumination for 3D sensing using VCSELS and diffractive optics technology will show IR light-field measurements made in real-time for 3D time-of-flight (ToF) and 2D IR imaging applications. Advantages of VCSEL technology including high output power, high uniformity across an extended source area, stable wavelength

across temperature and high reliability, which are important for both IR illumination and stringent automotive applications. Finisar says that its VCSEL expertise stems from over two decades of research, design and manufacturing innovation.

"VCSEL technology is now being deployed in a wide range of exciting applications from biometric authentication to 3D mapping for augmented reality to automotive LiDAR," comments Craig Thompson, VP of marketing & business development for 3D Sensing.

### Diffractive lenses and beam converter demo

Finisar is also demonstrating all-dielectric diffractive lenses and beam converters that use a proven deep ultraviolet (DUV) photolithography patterning process. Applications include aberration corrected microlenses, top-hat generators, phase converters and computer-generated holograms. The diffractive elements are etched directly into a substrate

and contain no organic materials, which allows them to withstand high optical power and extreme temperatures up to 550°C.

### LiDAR coherent optical engine display

Finisar is showcasing a LiDAR coherent optical engine that is designed to enable long-distance resolution up to 300m for applications such as autonomous driving vision systems. The small package integrates a wavelength-tunable laser, a transmitter phase modulator and a coherent receiver. The laser can be tuned across 4THz, allowing solid-state beam steering to replace less reliable rotating mirrors and microelectromechanical systems (MEMS). The phase modulator and coherent detection enable the distance and velocity of an object to be determined from a single scan using the Doppler effect.

During the Sensors Expo, Finisar also displayed several partner reference designs leveraging VCSEL technology.

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

# NeoPhotonics' Q1 revenue falls 4% year-on-year, as ZTE loss counteracts growth in North America

## Targeted inventory reduction delayed from Q2 to Q3, but return to profitability still expected in second-half 2018

For first-quarter 2018, NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of hybrid photonic integrated optoelectronic modules and subsystems for high-speed communications networks) has reported revenue of \$68.6m, down 4% on \$71.7m a year ago and 11% on \$76.9m last quarter due to slightly lower volume and the full implementation of annual price reductions (which, together with the Chinese New Year, makes Q1 typically the seasonally softest quarter).

"Continuing our focus on 100G-and-above High Speed Products, which reached the highest proportion of revenue in our history at 86% in the quarter [versus 84% last quarter], we introduced and demonstrated new products for 400G and 600G coherent and data-center applications," says chairman & CEO Tim Jenks.

"We saw strength in metro and DCI deployments, driven by North America, and we have accelerating demand for these segments going into the remainder of the year," he adds. "At the same time, while demand in China had stabilized, the recent regulatory and trade actions have introduced new uncertainty in that region, we continue to monitor and adjust plans accordingly."

"As noted in our 17 April press release on the impact of the US Department of Commerce Denial Order related to [China-based] ZTE, we had expected up to 5% of annualized revenue from ZTE and its suppliers, which will now not be realized as planned," says Jenks. "Further, we held certain products in inventory for ZTE that were valued at approximately \$1.2m that have been written down."

Despite being up 9% year-on-year, China was down 5% on last quarter (61% of revenue). The Americas comprised 21% of total revenue.

Huawei Technologies (including its affiliate HiSilicon Technologies) was again the largest customer, at 48% of revenue (up from 42% last quarter). The next four customers represented 36% of total revenue (down from 41%), including 19% from US-based Ciena.

"We did see a slightly lower volume and a different mix of products than expected, resulting in gross margin at the lower end of the range and inventory that was slightly higher than expectations," says senior VP & chief financial officer Beth Eby. Net inventory rose from \$67m to \$69m (from 99 days to 104 days of inventory on-hand). "We remain committed to the goal of 90 days of inventory," notes Eby.

On a non-GAAP basis, gross margin has fallen further, from 26.3% a year ago and 21.3% last quarter to 14.7% (below the forecasted 16–20%) due mainly to the ZTE write-down of \$1.2m, as well as the amortization of \$3m lower output from the firm's Japan fab (where full qualification and integration of new equipment for laser manufacturing lines took longer than expected); the full impact of annual price negotiations; and \$0.9m in higher-than-expected costs for additional testing to support new customer requirements.

Operating expenses (OpEx) have been cut further, from \$30.2m a year ago and \$24.1m last quarter to \$22.9m (better than the expected \$23–24m) due to the absence of one-time charges (officer severance costs) from last quarter plus partial recovery of last quarter's \$0.5m bad debt write-off.

Net loss has worsened further, from \$10.7m (\$0.25 per diluted share) a year ago and \$11.7m (\$0.27 per diluted share) last quarter to \$14.6m (\$0.33 per diluted share), worse than the forecasted \$0.32–0.22 per diluted share, due to the annual

price reductions and the impact of the ZTE-related write-down.

Compared with positive operating cash flow of \$8m last quarter, in Q1/2018 NeoPhotonics used \$3.5m of cash in operations. Capital expenditure (CapEx) was \$8m (up from \$6m) after paying for the newly qualified fab equipment. Free cash flow was hence –\$12m (compared with +\$2.5m last quarter). During Q1, cash and cash equivalents, short-term investments and restricted cash fell from \$93.9m to \$86.9m.

For second-quarter 2018, NeoPhotonics expects higher volume to yield a return to revenue growth, to \$70–76m. Q2 gross margin should rebound to 18–22%. With operating expenses of \$22–23m, net loss per share should be \$0.26–0.16.

"While we have largely fixed the product output from our Japan factory, we are seeing a market share shift that, together with the ZTE Denial Order, may result in lighter demand for our legacy 28Gbaud EML [electro-absorptively modulated laser] products during 2018 [causing the Japan fab to remain underloaded, until 53Gbaud EML demand arises in 2019]," says Eby. At March's OFC 2018 event, NeoPhotonics introduced its 53GBaud Linear Optical Component family, which includes PAM4-capable optical components for 100G and 400G hyperscale data-center applications, as well as drivers and EML lasers in transmitters plus photodetectors and transimpedance amplifiers in receivers. The product family provides all of the optical content necessary for single-wavelength 100G PAM4 transmission (demonstrated at OFC) and four-wavelength 400G PAM4 transceivers, such as DD-QSFP. "Our focus has moved to using these [EMLs] for

400G-per-wavelength PAM4 applications," adds Jenks.

The inventory target of 90 days in hand was due to be achieved in Q2/2018, but it now looks like its going to be Q3, notes Eby. "We are

focused on cash, cash flow and a return to profitability," she stresses. "We have reduced OpEx and CapEx commitments for the year, and continue to focus on reducing inventory and improving gross margin to lower

our breakeven point," Eby adds. "We still expect to return to profitability in the second half of 2018, as revenue exceeds the breakeven point in the mid-eighties."

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

## Juniper Supplier of the Year award for Source Photonics

On 3 May, Source Photonics Inc of West Hills, CA, USA (which provides optical connectivity products for hyper-scale data-center and IP network applications) was honoured by Juniper Networks Inc of Sunnyvale, CA, USA (during its Supplier Summit on 3 May) as 'Supplier of the Year', along with being awarded 'Component Supplier of the Year'.

Source Photonics is the first optical component vendor to receive Juniper's Supplier of the Year award.

Source Photonics says it has been partnering with customers to bring leading-edge technology and innovative products to market for data-center and IP applications during the rapid migration to the cloud over the last several years. Coupled with aggressive expansion of capacity, it is positioning itself to continue serving key partners like Juniper.



**Source Photonics' executives receives Supplier of the Year and Components Vendor of the Year awards from Juniper's leadership team.**

"We would like to thank Juniper for recognizing the value of our partnership and the technology and investments we have made in support of our most recent generation of network upgrades," says CEO Doug Wright. "We will continue to invest in leading products and our support of partners like Juniper to deliver the next generation of dis-

ruptive network upgrades enabling a wide range of new applications in 5G, AI, IoT and many others."

Source Photonics was also the most nominated supplier, with nominations in four out of the seven categories awarded by Juniper.

Source Photonics was nominated for the following categories and won two awards:

- Component Supplier of the Year (winner);
- Quality Supplier of the Year;
- Technology and Innovation Award;
- Supplier of the Year (winner).

The ceremony was attended by CEO Doug Wright, VP of global sales Jimmy Tate, and Juniper's regional sales director Robin Crandell, who received the honor on behalf of Source Photonics.

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

[www.juniper.net](http://www.juniper.net)

## Targeting multi-chip integration, OIF initiates CEI-112G-XSR project for D2D/D2OE common electrical interface

At its Q218 Technical and MA&E Committees meeting in Nuremberg, Germany (24–26 April), the OIF (Optical Internetworking Forum) launched the CEI-112G-XSR project for die-to-die (D2D) and die-to-optical engine (D2OE) Common Electrical Interface. The project aims to enable intra-package interconnects to optical engines or between dies with high throughput density and low normalized power operating in the data-rate range of 72–116Gbps with up to 50mm reach.

In addition to the existing CEI-112G-MCM OIF project, which is dedicated to wide, high-bandwidth CMOS-to-CMOS interconnects, the CEI-112G-XSR project proposes to

support technology mix, in particular CMOS-to-SiGe (silicon germanium), which is frequently used to build optical engines. System-in-package (SIP) leads to the requirement to support up to 50mm trace length between the multiple chips on a common (organic) package substrate.

"We jointly designed this project to address the problem of integrating multiple dies, including driver devices for optical engines on non-CMOS technologies, onto a common substrate within a large multi-chip-package design," says the OIF's Technical Committee chair Klaus-Holger Otto of Nokia. Supporting this mix of technology

allows combining the high logic density of CMOS devices with the high drive strength of analog components."

The working group for the CEI-112G-XSR project has identified the following benefits for OIF members:

- Allow lower normalized power, double shoreline throughput density and provide a multi-source 72–116Gbps D2D and D2OE electrical I/O interface. This will enhance the integration, normalized power reduction, and cost reduction for integrated OE, multiple-die SIPs.
- Enable 1 to N lanes of 72–116Gbps electrical I/Os (e.g. on ASIC/FPGA/OE).

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

# Oclaro quarterly revenue falls 21.5% year-on-year

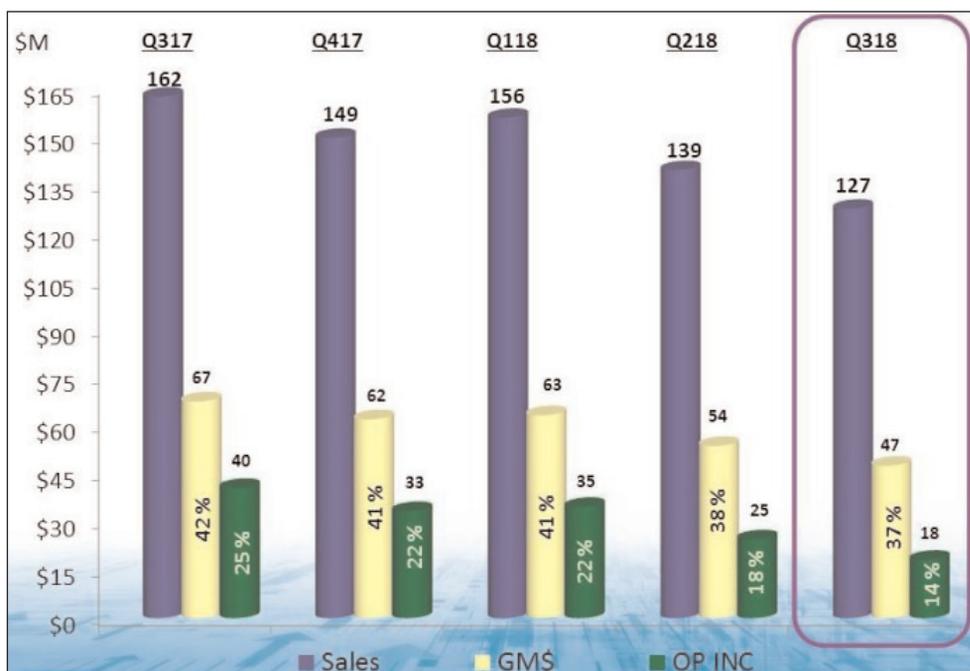
## Strong sales mix drives smaller-than-expected drops in margins

For its fiscal third-quarter 2018 (to end-March), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has reported revenue of \$127.3m (split about 41%:59% between client-side/datacoms and line-side/telecoms). This is down 8.6% on \$139.3m last quarter and 21.5% on \$162.2m a year ago, but at the high end of the \$120–128m guidance, driven by record revenue for the 100G CFP2-ACO (analog coherent optics) product family and the laser chip business.

Despite this, sales of 100G-and-above products still fell by 9.2% from \$105.4m last quarter to \$95.7m (75% of total revenue).

Sales of 40G-and-below products fell by 7% from \$34m to \$31.6m (25% of total revenue).

“As a result of the US Department of Commerce recently re-imposing export sanctions on [China-based]



Fiscal Q3/18 revenue, gross profit (& margin) and operating income (& margin).

ZTE, we have temporarily suspended all shipments to, and activities with, ZTE [a greater-than-10% customer],” notes CEO Greg Dougherty.

China has fallen back from 37% of total revenue last quarter (\$51.4m) to 32% (\$40.3m) and the Americas from 32% (\$44.4m) to 27%



\* Sales in Japan account for remainder

(\$33.9m), while Europe, the Middle East & Africa (EMEA) has risen from 17% (\$23.1m) to 23% (\$29.7m) and Southeast Asia from 14% (\$18.9m) to 17% (\$21.6m).

Due to the strong sales mix, non-GAAP gross margin was 37.2%, above the forecasted 34–37%. However, this is still down from 38.4% last quarter and 41.6% a year ago.

Operating expenses have risen further, from \$27m a year ago and \$29.1m last quarter to \$32.5m.

Operating income has fallen further, from \$40.5m a year ago

(operating margin of 24.9%) and \$24.5m last quarter (17.6% margin) to \$18.1m (14.2% margin, the eighth consecutive quarter of double-digit operating margin), exceeding the guidance of \$13–17m (12% margin).

Likewise, net income has fallen further, from \$39.9m a year ago (\$0.23 per diluted share) and \$23.1m (\$0.14 per diluted share) last quarter to \$19m (\$0.11 per diluted share).

Adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) was \$25.9m, down

from \$31.8m last quarter and \$45.5m a year ago.

During the quarter, cash, cash equivalents and short-term investments rose from \$290.1m to \$304.4m.

“Despite the loss of ZTE as a greater-than-10% customer for an indefinite period, we continue to believe our solid financial model and tight expense controls, when coupled with our highly differentiated products, will allow us to continue to demonstrate strong financial performance,” says Dougherty.

## Oclaro and Acacia Communications partner on 100/200G CFP2-DCO products

### Collaboration enables interoperable and multi-vendor 200G pluggable coherent modules

Acacia Communications Inc of Maynard, MA, USA (which manufactures high-speed coherent optical interconnect products) and Oclaro Inc of San Jose, CA, USA (which provides components and modules for optical communications) say they are enabling a multi-vendor environment of fully interoperable CFP2-DCO modules based on Acacia’s Meru digital signal processor (DSP). Oclaro plans to launch a new CFP2-DCO module that will feature plug-and-play compatibility with the Acacia CFP2-DCO, providing two proven coherent optics suppliers for the 100/200G CFP2-DCO form factor.

CFP2-DCOs are becoming increasingly important for higher-speed optical networks because they integrate the coherent DSP into the pluggable module. The digital host interface enables simpler integration between module and system, resulting in faster service activation and a pay-as-you-grow deployment model for telecom providers whereby the cost of additional ports can be deferred until additional services are needed.

The CFP2-DCO pluggable coherent modules from Oclaro and Acacia

support transmission speeds of 100G and 200G for use in access, metro and data-center interconnect markets. This form factor is being introduced by multiple network equipment manufacturers (NEMs) in switch, router and transport platforms. The CFP2-DCO modules support four times higher density than current-generation 100G CFP-DCO solutions by doubling the data rate in a smaller, lower-power, pluggable module enabling customers to quickly and cost-effectively roll-out 200G networks.

In addition to proprietary operating modes, both firms intend to support the requirements of the Open ROADM MSA (multi-source agreement) for interoperability at 100G.

“Network operators and our system partners are excited about the ramp of our CFP2-DCO module,”

**CFP2-DCOs are becoming increasingly important for higher-speed optical networks because they integrate the coherent DSP into the pluggable module**

says Acacia’s chief technology officer Benny Mikkelsen. “By partnering with Oclaro to ensure interoperability with their Meru-based CFP2-DCO module, we believe we will be better positioned to address the DCO market as industry trends shift favorably toward the CFP2 form factor... Broader adoption of 200G CFP2-DCO modules will be mutually beneficial to our two companies and the customers we serve,” he believes.

“Our 43Gbaud coherent transmitter receiver optical sub-assembly (TROSA) is at the heart of our CFP2-DCO,” says Beck Mason, president of Oclaro’s Integrated Photonics business. “The TROSA leverages proven indium phosphide PIC [photonic integrated circuit] technology from Oclaro’s highly successful CFP2-ACO to achieve industry-leading optical performance in a small form factor,” he claims.

“By establishing a fully interoperable solution with Acacia, our customers will have two sources of supply for these critical components, enabling them to efficiently upgrade their networks to higher speeds,” concludes Mason.

[www.acacia-inc.com](http://www.acacia-inc.com)

# Lumentum's seasonal decline in 3D sensing revenue offset by growth in Telecom, Datacom and Commercial Laser products

## Expansion of pump laser and ROADM capacity to ease constraints

For fiscal third-quarter 2018 (to 31 March), optical and photonic optical component and subsystem maker Lumentum Holdings Inc of Milpitas, CA, USA has reported revenue of \$298.8m, down 26.1% on \$404.6m last quarter (driven by an expected reduction in 3D sensing product revenue, offset partially by growth in Telecom, Datacom and Commercial Laser products) but up 16.8% on \$255.8m a year ago.

"Our strategy of investing in differentiated products and technologies, focusing on close relationships with market leading customers, and leveraging our technologies across multiple growing end markets, is working," says president & CEO Alan Lowe. "Driven by strong customer demand and execution on capacity expansion, in the third quarter we achieved new record Lasers revenues, which increased 18% sequentially, and grew Telecom revenues by more than 11% sequentially, with notable strength in ROADMs [reconfigurable optical add/drop multiplexers], which were up 27% sequentially."

Commercial Laser revenue was a record \$52.5m (17.6% of total revenue), up 18% on \$44.5m (11% of total revenue) last quarter and 32.2% on \$39.7m (15.5% of total revenue) a year ago. Growth was driven by both micro-machining and kilowatt laser products (for both micro and macro material processing markets).

Optical communications revenue was \$246.3m (82.4% of total revenue), up 14% on \$216.1m a year ago but down 31.6% on \$360.1m (89% of total revenue) last quarter. This is due mainly to Consumer & Industrial revenue of \$87.4m, which rose by more than 600% year-on-year due to 3D sensing volumes but fell 59% from \$215.5m last quarter due to customer

seasonality. "Though seasonally down, we made good progress on new 3D sensing customer programs and are well positioned for new customer product introductions during fiscal year 2019," reckons Lowe. "The seasonality is continuing into the fourth quarter, but we expect volume will ramp up again in the first half of fiscal 2019." Telecom revenue was \$122.6m, down 25% on a year ago but up 11% on \$110.2m last quarter due to 27% growth in ROADMs, for which shipments were limited by production capacity). Sales of telecom pump lasers (both 980nm and Raman) continue to be strong, but quarter-on-quarter growth was also limited by production capacity. Telecom transmission and Datacom revenues also grew sequentially after having had a few slow quarters. Datacom revenue was \$36.3m, down 7% on a year ago but up 6% on \$34.4m last quarter.

On a non-GAAP basis, gross margin was 36.3%, down from 44.9% last quarter (due mainly to product mix and lower volumes) but up from 34.4% a year ago.

Optical Communications gross margin has fallen from 45% last quarter to 33.7% (despite 3D sensing margins being better than the corporate average), due to product mix and lower volumes (diluted by lower-margin datacom products plus start-up expenses from the firm's Thailand manufacturing operation, which will remain diluted for the next 5-6 quarters or so).

Commercial Lasers gross margin has risen further, from 44.7% last quarter to 48.4%, due to higher volumes (execution on ramping capacity) and product mix.

Operating expenses have fallen from \$67.2m last quarter to \$59.1m (19.8% of revenue).

Operating income was \$49.4m

(operating margin of 16.5% of revenue), down from 28.3% last quarter but up from \$32.2m (12.6% margin) a year ago. Likewise, net income was \$50.6m (\$0.78 per diluted share), down on \$107.8m (\$1.67 per diluted share) last quarter but up from \$30.8m (\$0.49 per diluted share) a year ago.

Capital expenditure (CapEx) has been cut from \$26m last quarter to about \$17m. During the quarter, cash and short-term investments hence rose by \$68m, from \$624.5m to \$692.8m.

During fiscal Q3, Lumentum agreed to acquire Oclaro Inc of San Jose, CA, USA (which provides optical components and modules for the long-haul, metro and data-center markets), and the firm continues to work with Oclaro on the pending transaction.

For fiscal fourth-quarter 2018, Lumentum forecasts revenue of \$275–300m, with 3D sensing down again seasonally (counteracting growth in other sectors, most notably Telecom transport). Operating margin is hence expected to fall to 14–16%. With OpEx roughly level with the March quarter, diluted earnings per share should fall to \$0.55–0.75.

"Our industrial diode laser product line, which is primarily driven by customers building their own fiber lasers, also delivered continued strong results [in fiscal Q3]," says Lowe. "Growth in this business was limited by production capacity. The combination of external customer demand and internal demand for use in our own fiber laser outstripped our ability to supply," he adds. "We are expanding capacity in these product lines to enable higher external sales as well as increased supply into our own fiber lasers. All these capacity additions are in our own factory in Thailand, which

started shipping qualified industrial diode laser products in April.”

“We are extending pump laser and ROADM capacity to meet customer demand, which we expect to remain strong,” says Lowe.

“We are very close to releasing a very low-cost hyperscale-focused Datacom transceiver later this year and continuing those engagements with hyperscale data centers... it is our strategy to keep that door open as we introduce the new lower-cost product,” continues Lowe. “Through this quarter and next we’re going to continue to have some challenges with respect to the margins on

hyperscale, but we expect to rectify that later this year.”

“We expect continued strength in our Commercial Lasers business as we ramp our newest fiber-laser products to meet strong customer demand,” says Lowe. “Later this calendar year, we will be introducing a full turnkey fiber-laser system to broaden our fiber-laser customer base and further accelerate growth,” he adds.

Regarding 3D sensing, fiscal Q3 revenue contained modest contributions from Android customers including those purchasing Lumentum’s latest high-performance

edge-emitting lasers. “These customers are expected to drive far more business in the future, as we look to our fiscal 2019 and beyond,” says Lowe. “Between these customers, and numerous additional customer engagements under way, we expect we will broaden our customer and product mix overtime. With our proven manufacturing scalability, proven fuel reliability and new product pipeline, we believe we are well positioned to be the partner of choice for 3D sensing customers around the world in fiscal 2019 and over the long run.”

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

## Lumentum orders Veeco’s K475i As/P MOCVD system to produce components for 3D sensing, high-speed fiber-optic communications and laser-based materials processing

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says optical and photonic product maker Lumentum Holdings Inc of Milpitas, CA, USA has ordered its K475i arsenide/phosphide (As/P) metal-organic chemical vapor deposition (MOCVD) system for the production of components addressing the 3D sensing, high-speed fiber-optic communications and laser-based materials processing end-markets.

“The global communications, industrial and consumer electronics markets that our proprietary semiconductor lasers address are growing rapidly,” says Lumentum’s VP of manufacturing Susan Wang. “We chose Veeco’s K475i system with its high capacity/throughput, uniformity of quality, repeatability

and exceptional performance to help expand our capacity and better address these growth opportunities,” he comments. “We have a long-standing relationship with Veeco and look forward to future collaboration together.”

The K475i system incorporates proprietary TurboDisc and Uniform FlowFlange MOCVD technologies, allowing users to improve compositional uniformity and dopant control while reducing cost-per-wafer by up to 20% compared with alternative systems through higher productivity, best-in-class yields and lower operating expenses, Veeco reckons. Applications include lighting, solar, laser diodes, vertical-cavity surface-emitting lasers (VCSELs), pseudomorphic high-electron-mobility transistors (PHEMTs) and heterojunction bipo-

lar transistors (HBTs).

“A leading player in the optical communications and commercial laser markets, Lumentum is well positioned to capitalize on the growing demand for next-generation laser and optical devices using Veeco MOCVD technology,” comments Peo Hansson Ph.D., senior VP & general manager of MOCVD operations at Veeco. “As customers look for technologies that enable demanding new applications in increasingly competitive markets, many leading photonics, power electronics and LED device manufacturers continue to choose our proven MOCVD systems that deliver strong wafer uniformity and the lowest cost of ownership,” he adds.

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# Emcore's revenue falls 22% after inventory correction from broadband CATV customer

For its fiscal second-quarter 2018 (to end-March), Emcore Corp of Alhambra, CA, USA — which makes indium phosphide (InP)-based chips, components, subsystems and systems for broadband and specialty fiber-optics markets — has reported revenue of \$18.6m, down 22.5% on \$24m last quarter and 43% on a \$32.6m a year ago, and below the initial guidance of \$21–23m.

“Revenues from our cable TV products were impacted by an inventory correction with our largest cable TV customer when they consolidated their contract manufacturing [EMS] capabilities into their own captive facility,” says chief financial officer Jikun Kim.

“This inventory correction was more acute than anticipated,” he adds.

“Although general cable TV MSO [multi-service operator] capital expenditures showed consistent demand in the quarter, the portion of the MSO capital expenditures resulting in orders from our direct customers were received too late to ship before the end of Q2,” he adds. “The product mix in these orders was substantially different than the forecast and outside of our normal lead times for purchased assemblies,” notes president & CEO Jeff Rittichier.

“Other major customers met or exceeded their forecasts, confirming that the inventory situation was not the result of a downturn in MSO spending but a straightforward yet painful inventory bubble,” he adds.

“We saw good design-win traction with our LEML [linear externally modulated laser] products, an uptick in demand from our other CATV customers and good performance in line with our expectations in our Chip and Navigation businesses.”

Of total revenue (compared with last quarter), Broadband comprised 74% (down from 87%) including a less-than-expected 65% from cable TV (down from 72%). So, total non-CATV sales comprised 35% of overall revenue (up from 28% last

quarter). Specifically, Navigation comprised 11% (up from just 4%) and Chips a more-than-expected 16% (up from 9%). “We continue to see strong demand for 2.5G PON [passive optical network] products within China,” notes Rittichier. “In China, price drives an awful lot of decisions... 10G is not going to really take over from 2.5G for quite some time, just because its a fair bit more expensive - it’s probably more than four times as expensive,” he adds.

On a non-GAAP basis, gross margin has fallen from 34.4% a year ago and 33.6% last quarter to 27.3%, driven by lower volumes that negatively impacted manufacturing overhead absorption.

Operating expenses were \$8.9m, up slightly from last quarter’s \$8.7m but cut from \$9.3m a year ago, as Emcore continues to hold down expenses while it works through the cable TV inventory headwind.

Operating loss was \$2.2m (margin of –12% of revenue), compared with an operating profit of \$0.6m (+2.5% margin) last quarter and \$3.7m (+11.4% margin) a year ago.

Likewise, pre-tax net loss was \$2.1m (\$0.08 per diluted share), compared with a profit of \$0.7m (\$0.03 per diluted share) last quarter and \$3.7m (\$0.14 per diluted share) a year ago. Capital expenditure (CapEx) was just \$850,000 (cut further, from \$2m last quarter). Depreciation was \$1.4m. During the quarter, cash and cash equivalents nevertheless rose by \$1.3m, from \$64.2m to \$65.5m.

For fiscal third-quarter 2018 (ending 30 June) Emcore expects revenue of \$17–19m, as the continued inventory overhang in broadband cable TV will be largely offset by growth in Navigation and Chips.

“We expect additional growth in the PON market in the third quarter,” says Rittichier. “Outlook for this market is limited more by third-party testing capacity than our internal fab capacity. However, we expect to

have this bottleneck resolved in the beginning of the fourth quarter,” he adds. “Although we don’t sell chips directly to [China-based] ZTE, our supply chain checks have shown us a few places where we could see some headwinds with our customer’s customers. We have factored this into our forecast for Q3.”

“In our February call, we estimated that it would take our [CATV] customer approximately two quarters to work through this overhang.

However, predicting the exact slope of the recovery down to the month remains outside of our normal forecast window,” says Rittichier.

“Offsetting the inventory headwinds however is the potential for new product introductions with the same customer which would use a different part from Emcore versus the ones that are currently in inventory,” he adds. “We believe the third quarter represents a trough in demand from this customer and that the slope and sustainability of any ramp will be predicated on our customer’s product mix for the next several quarters. We have a terrific relationship with this customer and we’re working together in a positive, productive process to meet both of our operational goals.”

“Beyond these customer-specific issues, we continue to see solid demand in the cable TV transmission market as a whole. As we look to the third quarter, we expect the demand strength to continue and we placed additional inventory in assembly to better take advantage of any upside,” notes Rittichier.

“Demand for linear optics space, DOCSIS 3.1 remains on a solid footing, while the number of linear EML design wins increases. There are now five LEML transmitter designs in the market, up from two in 2017, and the total volume of LEML sales through Q2 is a 130% of what we saw in all fiscal 2017. In addition, we are expecting at least two more design wins in fiscal year 2018.”

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

# Emcore launches mini-Tx 1.2GHz, 1550nm L-EML CATV transmitter subassembly

Emcore Corp of Alhambra, CA, USA — which provides indium phosphide (InP)-based optical chips, components, subsystems and systems for the broadband and specialty fiber-optics markets — has launched the Model 3644 mini-Tx 1.2GHz, 1550nm linear externally modulated laser (L-EML) CATV transmitter subassembly, which is claimed to be the most compact L-EML-based transmitter released to-date. The Model 3644 will support links up to 100km with all the core elements required for designers to quickly integrate L-EML device technology into a variety of CATV transmitter platforms.

Invented, developed and manufactured exclusively at Emcore, the L-EML technology consists of a high-power, low-noise, narrow-linewidth laser combined with a proprietary highly linearized modulator in a monolithic assembly. It enables long-distance optical link

performance approaching traditional lithium niobate-based externally modulated transmitters, but is much more cost-effective and far exceeds the performance of distributed feedback (DFB) laser-based systems.

The new 3644 mini-Tx is designed to support traditional hybrid fiber coax (HFC) multi-wavelength node-splitting radio frequency over glass (RFoG) and RF overlay for fiber-to-the-premise (FTTP) applications. The platform supports RF loads of analog, quadrature amplitude modulation (QAM) and orthogonal frequency division multiplexing (OFDM) to 1218MHz and is fully DOCSIS 3.1 compatible. The 3644 mini-Tx achieves a modulation error ratio (MER) of 44dB across the entire operating band under full QAM load conditions. MER at the receiver is the key parameter for link performance in modern QAM-based HFC networks.

Additionally, there is an RF test port on-board with monitor and control via an RS-232 interface.

“Since their introduction, the acceptance of L-EML-based CATV transmitters has been tremendous,” says senior product line director Grant Olecko. “Our customers asked us to expand on the form-factor options to allow them greater flexibility on how they integrate the technology into their platforms,” he adds. “With the new 3644 mini-Tx we now have a wider range of form-factor options to satisfy broader customer and market requirements.”

Emcore showcased its new Model 3644 mini-Tx 1.2GHz, 1550nm L-EML CATV transmitter subassembly, along with its complete line of cable network solutions, at ANGACOM 2018 Exhibition & Congress for Broadband, Cable and Satellite at the Cologne Congress Center, Germany (12–14 June).

## Emcore announces test results of OBI-mitigated L-EML RF-over-glass optical networking unit transceiver

Emcore has announced successful performance test results of its linear externally modulated laser (L-EML), radio frequency over glass (RFoG) optical networking unit (ONU) transceiver by Kyrio, a subsidiary of CableLabs. Emcore says Kyrio’s results showed that its L-EML-based ONUs are significantly better at reducing the occurrence of optical beat interference (OBI) in a passive optical network than traditional ONUs.

Kyrio’s results are based on a test of up to 32 distributed feedback (DFB) ONUs and 32 L-EML-based ONUs in a network with Kyrio-provided passive optical splitters and cable. Testing compared the OBI performance of the set of traditional DFB RFoG ONUs to Emcore’s new L-EML solution for RFoG upstream communication. OBI

results in poor data performance of all ONUs, cable modems and consumer devices connected to the same optical splitter. The results examined the ability of Emcore L-EML-based ONUs to reduce the occurrence of OBI.

“Emcore’s L-EML RFoG ONU achieves OBI mitigation due to the inherent narrow spectral width of our laser technology, as well as through proprietary upstream laser wavelength management designed to significantly improve RFoG network performance in high-density customer environments,” says Gyo Shinozaki, Emcore’s VP of marketing. “Test results by Kyrio proved that our L-EML-based RFoG ONU reduced the effects of OBI compared to traditional ONUs.”

The L-EML RFoG ONU transceiver

is designed to support standard CATV downstream and upstream transmission bands. Downstream it receives a 1550nm forward-path optical signal carrying an RF cable television spectrum up to 1.2GHz. For return path the L-EML transmitter operates at 1610nm and supports 5-42/65/85 or 204MHz spectrum options. The unit is compliant with the SCTE (Society of Cable Telecommunications Engineers) RF over Glass specification.

Emcore showcased its OBI-mitigated L-EML RFoG ONU transceiver, as well as its complete line of cable network solutions, at ANGACOM 2018 Exhibition & Congress for Broadband, Cable and Satellite at the Cologne Congress Center, Germany (12–14 June).

[www.angacom.de](http://www.angacom.de)  
[www.emcore.com](http://www.emcore.com)

# Alta Devices launches Gen4 solar cell

Hanergy's US-based subsidiary Alta Devices of Sunnyvale, CA, USA, which holds the record for single-junction solar cell efficiency, has launched its Gen4 fourth-generation solar cell technology, which weighs significantly less than the Gen3 previous-generation technology and results in an improved power-to-weight ratio of 160%. Able generate substantial power over small surfaces with minimal impact to vehicle design criteria, the single-junction gallium arsenide (GaAs) technology in the lightweight, flexible solar cells is said to be critical for unmanned aerial vehicles (UAVs), solar cars and other electric vehicles.

"Autonomy in the air and on the ground is becoming a reality," says CEO Jian Ding. "While there has been much discussion, thought and progress on the 'eyes, ears, and brains' for these vehicles, there has been little focus on autonomous power. Autonomy diminishes in value when range is compromised," he adds. "Because Alta's new generation solar cells have such a high power-to-weight ratio, we are moving closer to realizing a vision of vehicles that never have to stop to refuel."

Autonomous power is critical because each sensor, processor or communication device added to increase system capabilities simultaneously increases power demand. For example, to be of practical use for applications like remote internet connectivity, a high-altitude, long-endurance unmanned aerial vehicle (HALE UAV) needs to add sensor-based avionics and navigation, in addition to reserving power and weight budget for communications payloads. Adding additional batteries or energy sources adds weight and bulk and, due to aircraft weight limitations, they are still limited to only a few days of energy supply. Alta's solar technology integrates into the surface of the aircraft or vehicle without upsetting aerodynamics.

For example, if Alta's Gen4 technology had been available and used on the large solar-powered aircraft Solar Impulse 2 instead of crystalline silicon, the result in weight savings would have been up to 100kg. In addition, the technology would have provided up to 15% more solar power. Benefits for operations would include a larger service ceiling, faster rate of climb and the ability

to operate at higher latitudes in winter while carrying more sophisticated and capable payloads.

At the solar cell level, Alta's new Gen4 technology provides a weight reduction of 40% or a power-to-weight improvement of 160% over the earlier Gen3 version. Gen4 solar cells can be used to power UAVs, automobiles, sensors, etc.

Alta has now transitioned its production to Gen4, utilizing cells that are much thinner than the previous generation while continuing to improve electrical performance. This translates to going from a ratio of 240g/m<sup>2</sup> to 170g/m<sup>2</sup> at the matrix level, including cell-to-cell interconnects, ribbons and protective diodes. The reduced cell thickness also results in a smoother, conformal and more aerodynamic surface when integrated into solar vehicles and UAV platforms.

Alta Devices has a history of breaking efficiency records for both single-junction solar cells and solar modules. The firm has broken the single-junction solar cell efficiency record more than four times since 2010 and has held the record since 2012 at 28.8%.

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

## NRL chooses Alta Devices' flexible solar cells for Hybrid Tiger UAV

The US Naval Research Laboratory (NRL) will use Alta's flexible, lightweight GaAs solar technology to help power the Hybrid Tiger UAV (unmanned aerial vehicle) project, which is designed to create a Group-2 UAV that will stay aloft for at least 3.5 days. Technologies that are developed will be applicable to other unmanned vehicles.

Sponsored by the Office of the Deputy Assistant Secretary of Defense for Operational Energy and the US Marine Corps Expeditionary Energy Office, the Hybrid Tiger program integrates multiple technologies into a single UAV for long-range endurance. It will use high-efficiency flexible solar cells,

a hydrogen fuel cell and energy-aware guidance algorithms.

The Hybrid Tiger UAV demonstration includes flights over multiple days, during the winter solstice and as far North as 50° latitude to highlight how extreme endurance UAV flight can be achieved using hybridization of solar photovoltaics, a hydrogen fuel cell, and autonomous soaring algorithms, regardless of latitude or time of year. The aircraft will fly for multiple days without using traditional fuels.

The multi-day endurance technology will enable applications such as low-altitude communications enablement, atmospheric

research, and search & rescue missions, according to a fact sheet provided by NRL.

"Widespread use of small UAVs in both the military and industry has been limited to-date by endurance," says Alta Devices' CEO Jian Ding. "The Hybrid Tiger will demonstrate that very long-endurance flights, with sophisticated telemetry and capabilities, can be achieved with the inclusion of solar arrays," he adds. "This project will open the door for many new solar powered UAV applications, and we look forward to achieving next-generation breakthroughs via this cooperative effort."

[www.nrl.navy.mil/vrs](http://www.nrl.navy.mil/vrs)  
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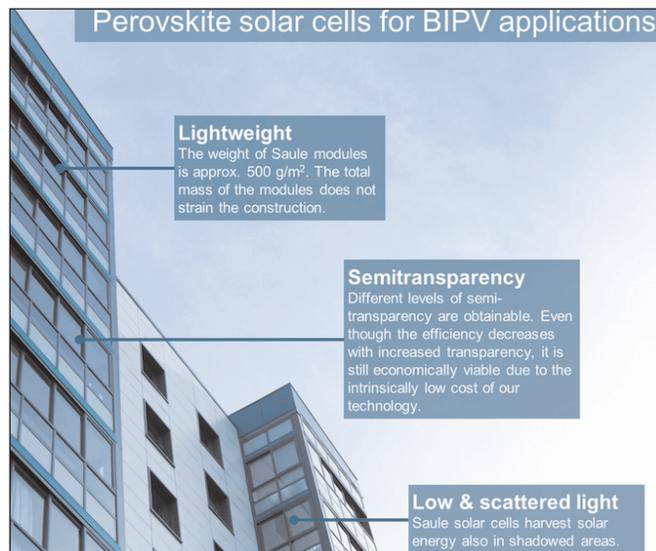
# Saule licencing perovskite solar window technology

After in January announcing what was said to be the first commercial contract in perovskite-based building-integrated photovoltaics (BIPV) — in which Sweden-based Skanska (one of Europe's biggest construction companies) will implement semi-transparent perovskite solar cells into office buildings — Saule Technologies of Warsaw, Poland has issued an open call for companies interested in licence agreements for Middle Eastern countries.

Saule is now offering flexible licence-based cooperation opportunities for companies active in the Middle East, available for entities interested in the development, distribution and integration of Saule's solar cells in BIPV applications.

The subject of the licence is an opaque PV product with high energy conversion efficiency that can be integrated with building facades, and an efficient, translucent perovskite cell ('solar window') in any color. A conditional licence (exclusive licence and non-exclusive licence) for the use of any future product can be granted for a chosen country or group of countries not covered by the licence agreement with another entity.

"Our technology has advanced to a perfect stage now for our customers to take part in the product development process to make sure we meet all their needs and expect-



tations," says co-founder & CEO Piotr Krych. "The goal is to cooperate with companies with a long-term renewable energy strategy, including solar energy harvesting technologies."

Saule has been working since 2014 on the application of ink-jet printing for the fabrication of free-form perovskite solar modules, allowing the shapes and areas covered by each layer to be customized according to requirements. The stability and water resistance of the modules makes them suitable for the construction industry, the firm says. Saule is cooperating with universities in the UK, Israel, Germany, Italy and Spain on researching perovskite applications in solar energy harvesting and optoelectronics. To

meet conditions concerning the encapsulation of perovskites, Saule is leading a project for the ultra-high barrier film with Ergis Group, which produces rigid plastic films. With a Japanese investor on board, along with support from the Polish National Centre for Research and Development and several research grants worth more than €20m,

Saule is now working on a large-scale, prototype production line.

"We find Middle East as one of the most promising regions for BIPV applications of our product," says Krych. "The latitude works obviously in favor of solar technology development and makes it one of the most desirable renewable energy sources there," he adds. "We also noticed activities of local governments investing in solar energy development as a part of a long-term strategy of shifting from fossil fuels."

Companies interested in licence-based cooperation opportunities are invited to contact Saule for specific details for a chosen country and terms and conditions of future cooperation.

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

## Singulus' latest €10m order prepayment takes 2018 total to over €40m, boosting order backlog above €130m

Singulus Technologies AG of Kahl am Main, Germany (which makes production equipment for the optical disc and solar sectors) has received the agreed prepayment from its customer China National Building Materials (CNBM) regarding the contract signed on 21 December 2017 for delivery of five additional CISARIS selenization machines for copper indium gallium diselenide (CIGS) solar module production,

expanding capacity of the factory in Bengbu, Anhui province, from 150MW to 300MW (out of a total planned capacity of 1500MW).

Singulus recently entered into another agreement with a subsidiary of a large, stock-listed energy firm and producer of solar modules in China for the delivery of TENUIS II systems for wet-chemical coating processes in CIGS production. The volume exceeds €10m, and pre-

payment for this project has already been received.

So far in 2018 Singulus has already received over €40m in prepayments for CIGS production equipment orders. "We are thus able to further expand our leading position for the delivery of production machines for CIGS solar modules," says CEO Dr Stefan Rinck. The firm's order backlog now exceeds €130m.

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

# First Solar building new 1.2GW Series 6 module manufacturing plant, tripling US capacity

## \$400m capital investment to create 500 new jobs in Ohio

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA plans to build a new 1 million square foot facility in Lake Township, Ohio (near its existing flagship plant in Perrysburg) to manufacture its Series 6 modules.

Contingent on confirmation of state and local incentive packages currently in negotiation, construction should begin in mid-2018, and the plant should enter full production mode in late 2019 with an annualized capacity of 1.2GW.

The factory is expected to create 500 new jobs in northwestern Ohio.

Already the USA's largest PV module maker, the existing plant's Series 6 manufacturing capacity of 600MW plus the new plant's 1.2GW will raise First Solar's annualized US module manufacturing capacity to 1.8GW.

"Strong demand in the US for advanced solar technology, along with recent changes in US corpo-

rate tax policies, have encouraged our decision to grow First Solar's US production operations," says senior VP of global manufacturing Mike Koralewski. "State and local officials and Jobs Ohio have also worked with us to create a business-friendly environment that supported our objectives," he adds. "These factors, combined with our own economies of scale in high-tech manufacturing, make expanding US operations an attractive, win-win opportunity."

The capital investment for the expansion will be about \$400m, with a workforce of about 500 associates and an annual payroll of \$30m. Koralewski says that First Solar also has options for potential further manufacturing expansion in the future, depending on sustained US demand for solar technology.

"We originated in Ohio, and we're proud to build on that history as we grow into the future," says chief

operating officer Tymen de Jong. In 2017, First Solar invested \$175m in re-tooling the original Perrysburg plant for production of its new Series 6 product. This April, the facility re-started an idled Series 4 production line to meet continued demand for that product.

First Solar was formed in 1999, and established its first manufacturing facility in Perrysburg. Full-scale commercial production began in 2002. The firm has so far invested about \$3bn in Ohio, including wages paid, manufacturing purchases, research & development costs and taxes. The flagship Perrysburg plant is the largest solar manufacturing facility in the USA, working with more than 250 US suppliers and indirectly supporting more than 4000 jobs across Ohio. With production facilities in the USA, Malaysia and Vietnam, First Solar has so far sold more than 17GW of modules.

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

# 5N Plus secures multi-year supply contracts to supply materials and services to First Solar

Specialty metal and chemical products firm 5N Plus Inc of Montreal, Québec, Canada has secured a series of multi-year contracts for the supply of semiconductor materials and ancillary services associated with the manufacturing of cadmium telluride (CdTe) thin-film photovoltaic (PV) modules by First Solar Inc of Tempe, AZ, USA.

5N Plus provides purified metals such as bismuth, gallium, germanium, indium, 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.

Since 2007, 5N Plus has been a key supplier of semiconductor compounds and related services to First Solar, and over this period several long-term contracts have been signed and executed between the two companies. Given 5N Plus' current position in this sector, the new contracts are not expected to require additional investments by 5N Plus. The terms of the contracts will be in effect until early 2021 and will rely on the global asset-base and capabilities of 5N Plus across Asia, Europe and North America.

"We are very pleased to continue to foster what is undoubtedly a time-tested mutually rewarding partnership between 5N Plus and

First Solar," says Nicholas Audet, executive VP – Electronic Materials. "In 2016, our management unveiled its strategic plan 5N21, which included continued leadership in the renewable energy sector among the list of targeted achievements. The conclusion of these agreements is clearly an enabling step toward that ambition," he adds. "The specialty semiconductor market is a natural growth space for the future development of 5N Plus, with the segment Electronic Materials' range of advanced semiconductor products ideally positioned to enable our customers across a spectrum of applications to competitively serve their end markets."

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

## 5N Plus secures new US\$79m syndicated credit facility

Specialty metal and chemical products firm 5N Plus Inc of Montreal, Québec, Canada has secured a US\$79m senior secured multi-currency revolving syndicated credit facility to replace its existing US\$50m revolving facility.

5N Plus provides purified metals such as bismuth, gallium, germanium, indium, 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.

Addressing current financing and other corporate purposes, the new credit facility is also expected to be used to finance growth initiatives related to the second and third pillars of the firm's strategic plan '5N21' to improve profitability while

reducing earnings volatility. Unveiled last September, its three main pillars are: (a) optimizing the balance of contribution between upstream and downstream activities; (b) extracting more value from core businesses, existing assets and capabilities; and (c) delivering quality growth from existing growth initiatives including future M&A activities.

The new credit facility has a four-year term, bearing interest and a margin based on 5N Plus' senior consolidated debt to EBITDA ratio. Subject to lenders' approval, 5N Plus can exercise its option to request an expansion of the credit facility through a US\$30m accordion feature that would increase the total size of the facility to US\$109m. The syndicate consists of six banks and financial institutions, with HSBC Bank assuming the role of lead arranger and book runner.

5N21 fosters "a new business model which is transforming 5N Plus, as evident by the significant improvement in profitability, substantial enhancement in return on capital employed, reduction in earnings volatility, recurrent cash flows and a solid balance sheet," says chief financial officer Richard Perron. "Over the past two years we have utilized selectivity as the tenet of our approach to address market opportunities, consolidate assets across the globe, optimize global supply chain and address investment requirements of our business," he adds. "We are now shifting our focus toward growth initiatives and find a combination of a solid balance sheet along with the conclusion of this new expanded and flexible credit facility timely, to efficiently support and deliver growth in-line with our ambitions."

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

## Midsummer lists on Nasdaq First North Stockholm after IPO 5x oversubscribed

### Funds to boost production capacity for DUO thin-film PV manufacturing system and launch 'Clix by Midsummer' PV-integrated metal roof

Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines as well as flexible, lightweight copper indium gallium diselenide (CIGS) thin-film solar panels for building-integrated photovoltaics (BIPV) — has completed its initial public offering (IPO), issuing new shares worth about SEK100m (\$11.5m; €9.8m), listed as 'MIDS' on Nasdaq First North Stockholm (Nasdaq's European growth market designed for small and growing companies). The share offer was oversubscribed by 400%.

As well as being financial adviser in connection with the IPO, G&W Fondkommission is Midsummer's certified adviser at Nasdaq First North Stockholm.

"The listing opens an opportunity for global small and large investors



to own shares in a highly innovative, fast-growing and profitable solar energy technology leader," says CEO & co-founder Sven Lindström. "The IPO also gives us financial muscles for our planned rapid expansion, including increased production capacity of the company's flagship DUO thin-film solar cell manufacturing system, as well as the launch of 'Clix by Midsummer' — a PV integrated metal roof."

Last year, Midsummer established a strategic production partnership with Swedish roof manufacturer Clix for the launch of 'Clix by Midsummer', a plug & play roofing system with integrated solar panels, which has added a second business area to Midsummer.

The IPO follows the announcement of another record financial year (in 2017) during which revenue and profits doubled (as they did in 2016), due mainly to several new orders for the compact DUO thin-film solar cell manufacturing system.

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

# Improving magnesium doping of aluminium gallium nitride

Researchers seek better hole injection from molecular beam epitaxy material for deep ultraviolet light-emitting diodes.

**Y**. H. Liang and E. Towe of Carnegie Mellon University in the USA have increased the effectiveness of magnesium (Mg) doping in high-aluminium-content aluminium gallium nitride (AlGaN) material for deep ultraviolet light-emitting diodes (LEDs) produced by molecular beam epitaxy (MBE) [J. Appl. Phys., vol123, p095303, 2018]. Magnesium produces acceptor levels in AlGaN for p-type conductivity through hole transport. Such devices need to bring electrons and holes together so that they can recombine into high-energy photons.

There are a number of factors that restrict the efficiency of most DUV LEDs to a few percent (or less) — among them the poor efficiency of Mg doping in AlGaN. In fact, the efficiency of MBE DUV LEDs is even further restricted to about 0.4%. Last year, metal-organic chemical vapor deposition (MOCVD) was used to give DUVs 275nm LEDs with 20% efficiency [Takano et al, Appl. Phys. Express, vol10, p31002, 2017]. Most DUV LEDs use more established Mg doping of GaN for hole injection, but then many DUV photons are lost through absorption in the narrower bandgap GaN.

The epitaxial material was grown on sapphire at  $\sim 770^\circ\text{C}$  under liquid-metal-rich conditions — i.e. a monolayer of liquid metal uniformly covered the growth surface. The aim was to produce  $\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$ . In-situ reflection high-energy electron diffraction (RHEED) was used to monitor the process and determine layer thicknesses. The material was fabricated into  $500\mu\text{m}\times 500\mu\text{m}$  mesa diodes.

Liang and Towe achieved hole carrier concentrations in  $\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$  up to  $6\times 10^{17}/\text{cm}^3$  with  $9.4\text{cm}^2/\text{V}\cdot\text{s}$  mobility. The same techniques used on GaN films achieved up to  $5\times 10^{18}/\text{cm}^2$  hole density and  $5.6\text{cm}^2/\text{V}\cdot\text{s}$  mobility. The activation efficiency of the magnesium (Mg) dopant was 1.2% for  $\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$ . Liang and Towe comment: "This result is intriguing because, in a typical AlN film, only a small fraction ( $\sim 10^{-9}$ ) of Mg dopants can be activated at room temperature due to the extremely high activation energy, which has been reported to be up to 630meV."

Temperature-dependent photoluminescence was used to estimate the activation energy of the Mg acceptor levels as 220meV for  $\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$  and 128meV for GaN. Other groups have reported activation energies in the

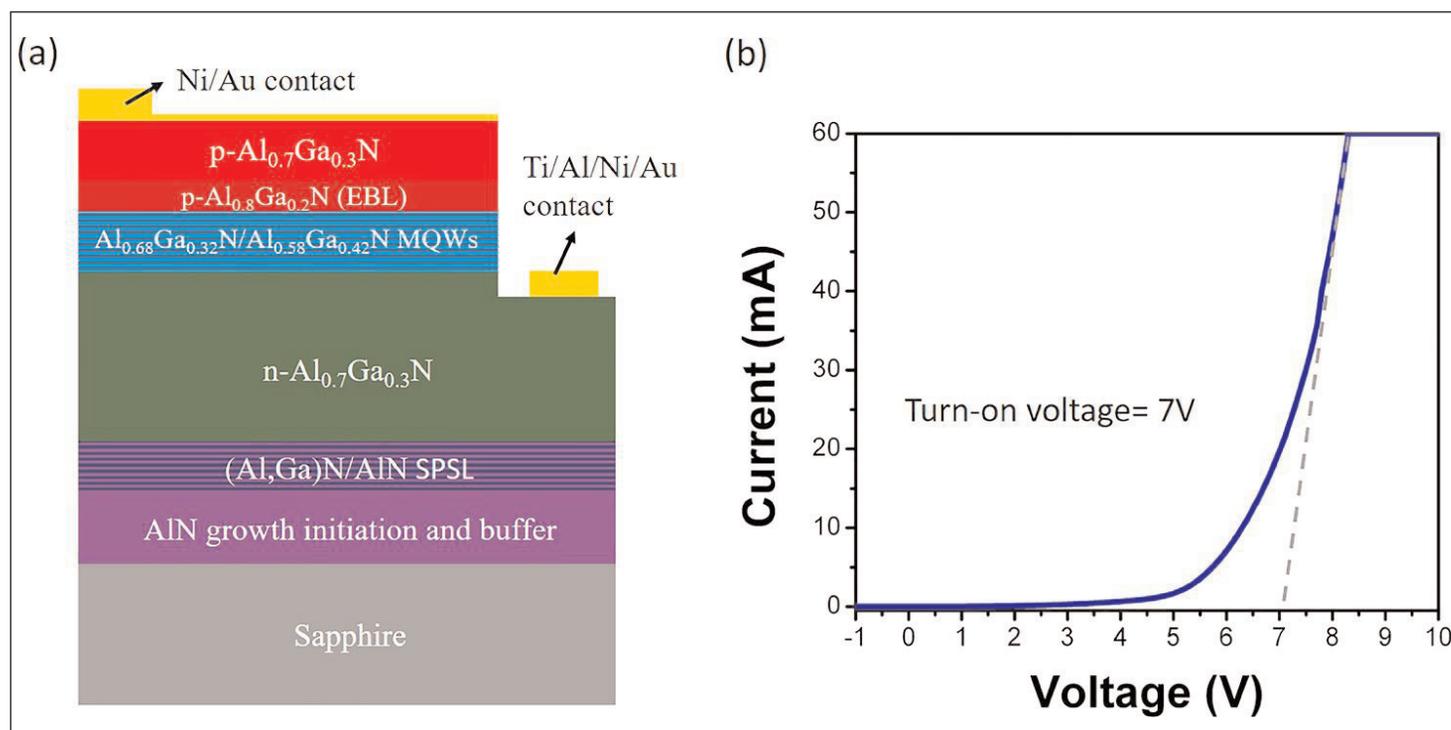
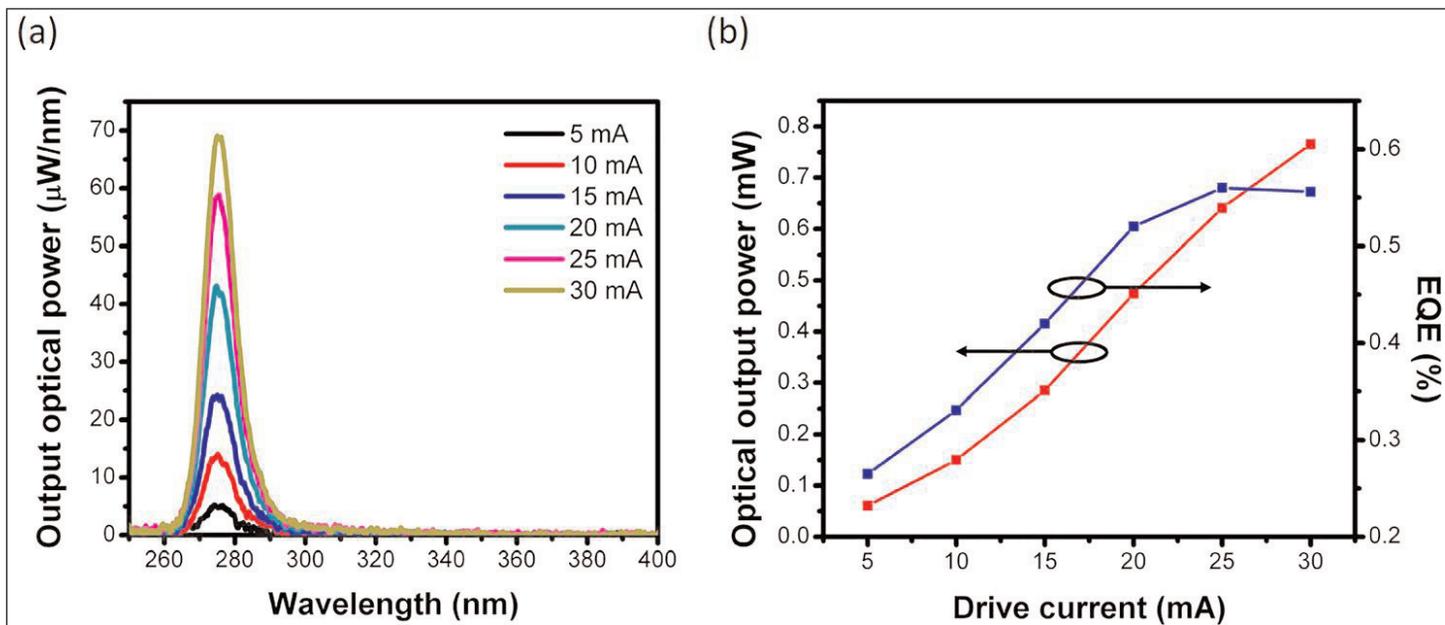


Figure 1. (a) Schematic of deep UV-C LED structure. (b) Current-voltage characteristic.



**Figure 2. (a) Electroluminescence spectra of output power/nanometer versus wavelength, for deep UV-C LED device with peak emission intensity at 274nm for various drive currents. (b) Optical output power and external quantum efficiency for various drive currents.**

range 408–507meV for  $\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$ , which severely constrains hole carrier concentration.

The metallic monolayer is thought to prevent re-evaporation of dopants at the relatively high substrate growth temperature of 770°C. Also, the high density of Mg atoms may allow ‘banding’ of the acceptor levels, with some levels being closer to the valence band, reducing activation energies.

For n-type doping with silicon, the electron carrier density reached  $\sim 10^{20}/\text{cm}^3$  with  $130\text{cm}^2/\text{V}\cdot\text{s}$  mobility for GaN and  $17.4\text{cm}^2/\text{V}\cdot\text{s}$  for  $\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$ .

The LED material consisted of 30nm AlN nucleation, a 0.2 $\mu\text{m}$  AlN buffer, 3nm/3nm (Al,Ga)N/AlN 10-period superlattice strain relief, n-AlGa<sub>0.3</sub>N cladding, an  $\text{Al}_{0.58}\text{Ga}_{0.42}\text{N}/\text{Al}_{0.68}\text{Ga}_{0.32}\text{N}$  5-period quantum well active region, a 10nm p- $\text{Al}_{0.8}\text{Ga}_{0.2}\text{N}$  electron-blocking layer, and a 150nm  $\text{Al}_{0.7}\text{Ga}_{0.3}\text{N}$  contact. The quantum wells were 2nm thick. The barriers were asymmetric — 10nm close to the n-type region and 7nm towards the p-type region. Liang and Towe comment: “The asymmetric design of the quantum-well structure is intended to balance the electron and hole injection levels since these carrier types have different diffusion lengths.”

The turn-on voltage of the device was  $\sim 7\text{V}$ . The near-band-edge emission peak was 274nm with 11nm

full-width at half maximum. Output power saturated around 30mA injection to give a value of 0.76mW. This was attributed to the unoptimized structure and thermal effects. The external quantum efficiency and wall-plug efficiency were 0.56% and 0.35%, respectively.

The researchers comment: “Compared to state-of-the-art ultraviolet diodes in the same spectral range, whose film structures are grown by MBE, this generation of devices is an improvement. Even though these device structures were not optimized, we attribute the improvement to the successful achievement of heavy n-type and particularly p-type doping in aluminum-rich (Al,Ga)N films.” They add: “What remains is the design task to optimize the various parameters of the films in the structure now that the fundamental issue for MBE-grown films has been resolved.”

Liang and Towe point out that issues around the directionality of the photon transmission and polarization make light extraction difficult. Also, the impact of defects on radiative recombination needs to be minimized. Liang and Towe see the defects primarily as a substrate problem, which can be solved with the use of (expensive) AlN or AlGa<sub>0.3</sub>N free-standing substrates. ■

<https://doi.org/10.1063/1.5009937>

Author: Mike Cooke

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# Near-UV optoelectronic transmitter/receiver system

III-nitride on silicon technology has been used to create an integrated platform for power monitoring, free-space light communication and wearable applications.

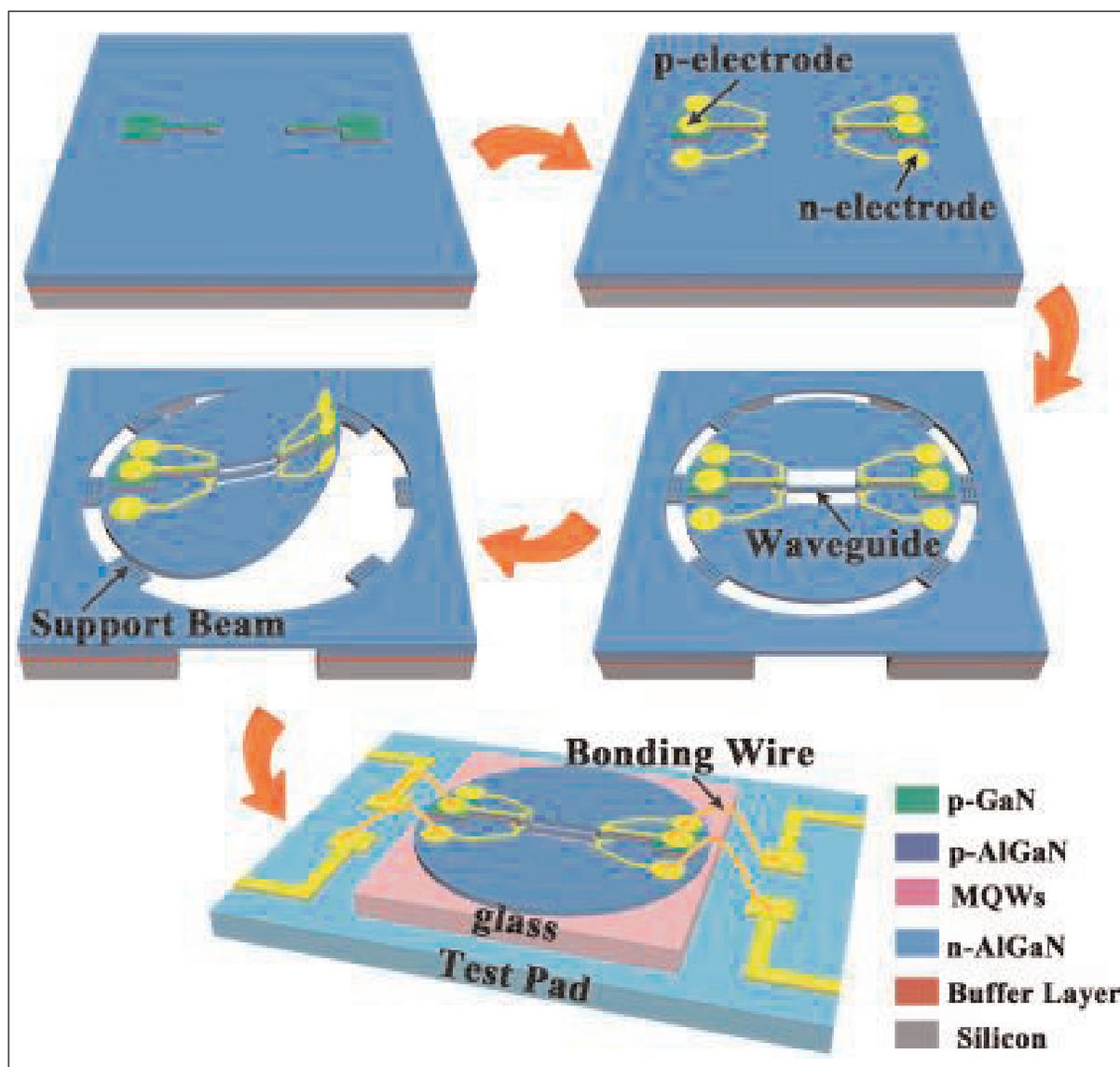
Researchers in China and Japan have used III-nitride on silicon (Si) technology to create integrated near-ultraviolet (NUV) optoelectronic transmitter/receiver systems [Chuan Qin et al, Appl. Phys. Express, vol11, p051201, 2018]. The monolithic devices were released from the silicon growth substrate and transferred to glass on a test pad. The NUV light was emitted and detected by indium gallium nitride (InGaN) multiple quantum wells (MQWs) in aluminium gallium nitride (AlGaN) barriers. The light transfer was enabled by an integrated waveguide.

The team from Nanjing University of Posts and Telecommunications and Zhengzhou University in China and Nagoya University in Japan suggests that the platform could be used for

**Figure 2. Schematic of fabrication, release, transfer and wire-bonding process flow for monolithic NUV multi-component system.**

Contact	p-GaN	10nm
Cladding	p-Al <sub>0.05</sub> Ga <sub>0.95</sub> N	80nm
Multiple quantum wells	InGaN/Al <sub>0.10</sub> Ga <sub>0.90</sub> N (3nm/10nm)	105nm
Superlattice	In <sub>0.02</sub> Ga <sub>0.98</sub> N/Al <sub>0.10</sub> Ga <sub>0.90</sub> N	108nm
Cladding	n-Al <sub>0.05</sub> Ga <sub>0.95</sub> N	2.5µm
Step-graded buffer	AlN/AlGaN	
Substrate	(111) Si	

**Figure 1. Epitaxial structure.**

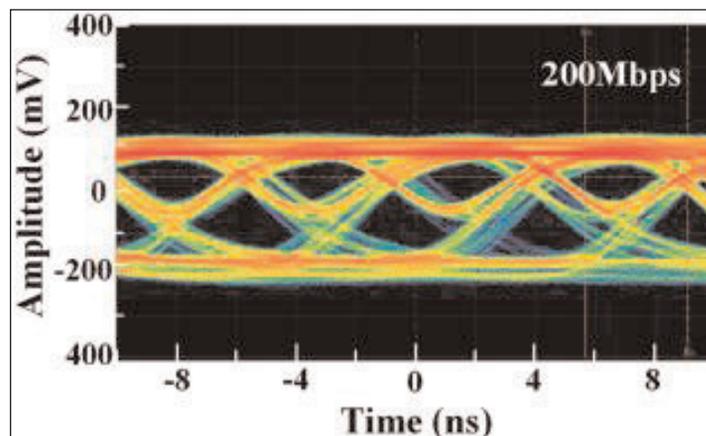


on-chip power monitoring of light-emitting systems, free-space light communication, and wearable optoelectronics in the NUV region. The advantages of using silicon substrates include low material cost and potential for mass production from larger-diameter wafers.

The researchers grew III–N films on (111)Si (Figure 1). This material was used to fabricate the multi-component optoelectronic system (Figure 2). Inductively coupled plasma reactive ion etching created two isolation mesas for the transmitter and receiver sections, and exposed the n-AlGaIn contact layer. The p- and n-contact electrodes consisted of nickel/silver, which can also function as mirrors directing light out of the bottom of the structure. Further etching created the 6 $\mu\text{m}$ -wide, 100 $\mu\text{m}$ -long optical waveguide connection between the devices, and the support beams for the membrane formation.

The release of the silicon substrate was prepared by applying a photoresist to the wafer top side as protection. Deep reactive ion etching removed the silicon to give suspended membranes. The III–nitride layer was then thinned with further etching from the back side. The 0.8mm-diameter device structure was released and transferred to a foreign substrate. The system was then connected to the test pad by wire bonding.

The turn-on voltages of the MQW diodes were 2.8V. The peak wavelengths of the devices shifted after the transfer due to changes in internal stresses that affect the electric fields in the devices due to the charge



**Figure 3. Eye diagrams for free-space light communication at transmission rate of 200Mbps.**

polarization of the various III–nitride atomic bonds. The dominant electroluminescence peak was at 386nm after transfer to glass. The response function peak of the MQW diode (operated as a photodiode receiver) is blue-shifted toward  $\sim 372\text{nm}$ , but there was some overlap for detection.

Non-return-to-zero on–off keying modulation, with 3.5V peak-to-peak signals and 2.2V offset, produced open eye diagrams at 200 megabits per second (Mbps) pseudorandom binary sequence (PRBS) data streams (Figure 3). ■

<https://doi.org/10.7567/APEX.11.051201>

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# Electro-absorption modulators for VCSELs

Modulation depth up to 68% achieved in integrated structure.

Researchers at Université de Toulouse in France and Vrije Universiteit Brussel in Belgium have developed vertical electro-absorption modulators (EAMs) for use with vertical-cavity surface-emitting lasers (VCSELs) [L Marigo-Lombart et al, J. Phys. D: Appl. Phys., vol51, p145101, 2018]. Such devices are desired for optical communications, signal processing and 3D imaging.

VCSELs can be modulated by modulating the current injection, but there are speed limits related to how fast the carriers can recombine, leading to delays in output response. The team targets faster

signaling by using separate modulator structures.

The EAM structures comprised quarter-wavelength pairs of aluminium gallium arsenide ( $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}/\text{Al}_{0.15}\text{Ga}_{0.85}\text{As}$ ) forming distributed Bragg reflectors (DBRs) around GaAs multiple quantum wells (MQWs) in  $\text{Al}_{0.3}\text{Ga}_{0.7}\text{As}$  digital alloy barriers (Figure 1). The DBRs create a Fabry-Perot (FP) cavity. The EAM is effected through an electric field that changes the overlap between the FP resonance and exciton absorption of photons in the MQW.

After testing and analyzing separate EAM structures, the team built an EAM-VCSEL combination. The epitaxial material was grown by molecular beam epitaxy (MBE) on n-GaAs substrate: 35-pairs of quarter-wavelength  $\text{Al}_{0.9}\text{Ga}_{0.1}\text{As}/\text{Al}_{0.15}\text{Ga}_{0.85}\text{As}$  VCSEL DBRs, a wavelength cavity with three GaAs QWs, 30nm  $\text{Al}_{0.98}\text{Ga}_{0.02}\text{As}$  for lateral oxidation confinement, a p-doped 22-period

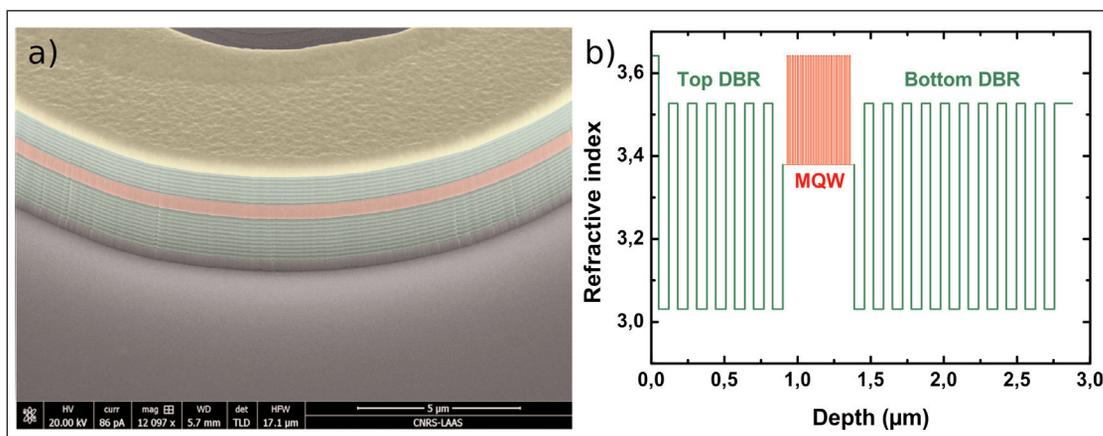


Figure 1. (a) SEM of EAM with 10-period bottom DBR, 25 quantum wells and 6-period top DBR. (b) Refractive index of EAM structure as a function of depth.

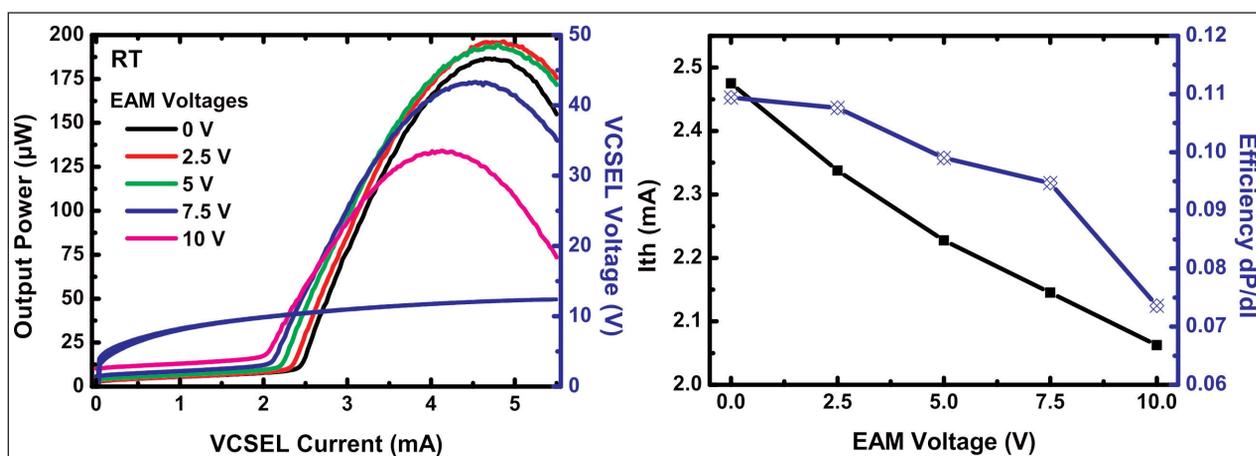


Figure 2. (a) Output power–current–voltage curves of EAM-VCSEL for different EAM voltages. (b) Evolution of VCSEL threshold and efficiency.

shared DBR, a 25-period EAM MQW, and a doped 6-period top EAM DBR. The middle DBR also included a  $\frac{3}{4}$ -wavelength layer for a ground contact.

The operating voltage was rather high, and the output power low, due to the less than 1 μm-diameter oxide aperture (Figure 2). Also, there was temperature degradation of performance. With 5.5 mA VCSEL injection and a 5 V EAM bias, the output power was 172 μW. The power fell by 57% to 73.5 μW for a 10 V EAM bias.

A higher modulation depth of 68% was achieved with 2.5 mA injection (near threshold) with the output power increasing from 17.2 μW at 0 V bias to 54.5 μW at 7.5 V. The 5.5 mA injection therefore gave 11.4%/V modulation and 2.5 mA gave 9%/V. ■

<https://doi.org/10.1088/1361-6463/aab1dc>

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# Indium arsenide quantum dot laser on silicon from molecular beam epitaxy

Researchers claim first electrically pumped device using on-axis substrate.

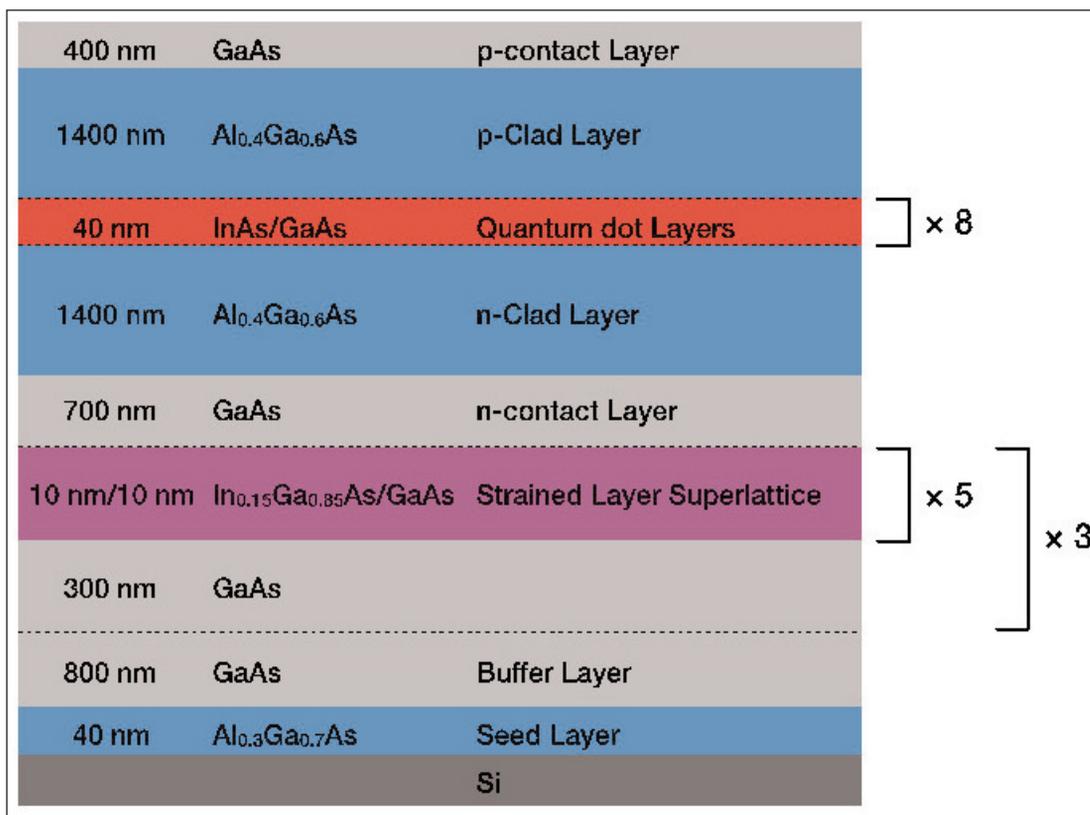
Japan's University of Tokyo claims the first electrically pumped 1.3 $\mu\text{m}$  indium arsenide (InAs) in gallium arsenide (GaAs) quantum dot (QD) lasers directly grown on on-axis (001) silicon (Si) substrates using molecular beam epitaxy (MBE) exclusively as the material growth process [Jinkwan Kwoen et al, Optics Express, vol26, p11568, 2018].

On-axis growth on (001) Si is usually initiated by metal-organic chemical deposition (MOCVD) before MBE QD layers. Alternative techniques that allow MBE seeding involve offcut substrates to avoid crystal defects such as threading dislocations (TDs), antiphase boundaries (APBs) and cracks.

Unfortunately, off-axis Si is not compatible with mainstream CMOS-based electronics. MOCVD is not able to filter dislocations effectively or produce QDs with efficient luminescence.

The team sees the development of the 1.3 $\mu\text{m}$  laser as contributing to the push for silicon photonics "to solve the problems of metal wiring such as low bandwidth density and high-power consumption" for next-generation computing.

The researchers used n-type substrates for the solid-source MBE (Figure 1). The chamber was first heated to 950°C for 5 minutes of substrate annealing. Threading dislocations were inhibited from reaching the QD layers by growing a series of three 300nm GaAs layers followed by InGaAs/GaAs strained superlattices. The threading dislocation density in the QD region was estimated at 5x10<sup>7</sup>/cm<sup>2</sup>. The team points to thermal cyclic annealing during deposition as



**Figure 1. Schematic of InAs/GaAs QD laser material grown on on-axis Si (001) substrate.**

a possible route to even lower density.

Anti-phase boundaries were avoided by a relatively high 500° growth temperature and high growth rate (1.1 $\mu\text{m}/\text{hour}$ ) for the AlGaAs seed layer, enabling APB annihilation within 400nm of the GaAs buffer deposition.

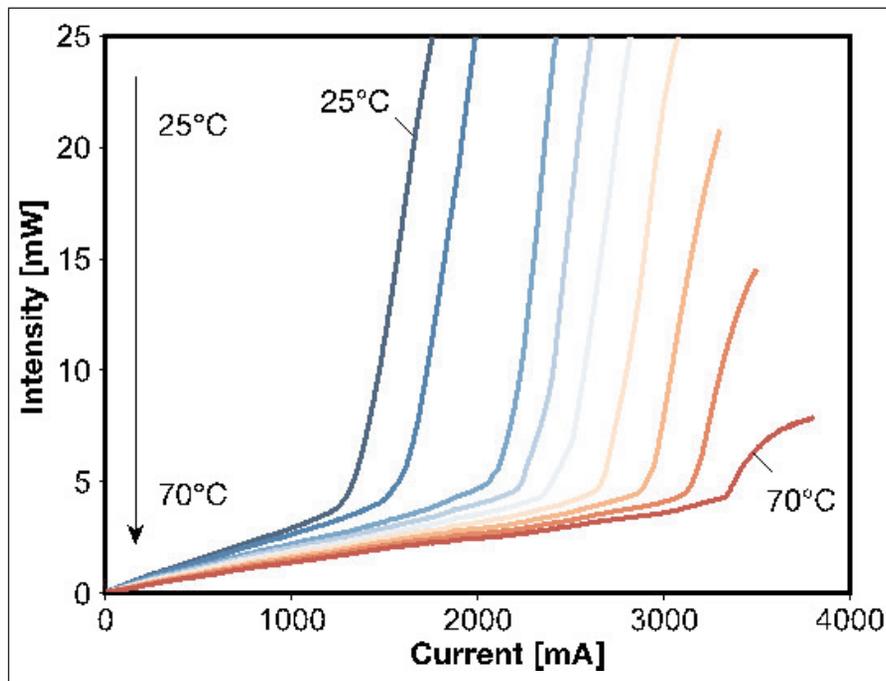
The QDs measured about 30nm laterally with a density of 5x10<sup>10</sup>/cm<sup>2</sup>. The photoluminescence from the structure had 80% of the intensity from a structure grown on GaAs substrate. The peak wavelength was at 1250nm with 31meV full-width at half maximum. An excited level at 1150nm (+86meV) was also visible in the spectrum.

The material was fabricated into 80 $\mu\text{m}$ -wide broad-area Fabry-Perot lasers. The contacts were gold-germanium-nickel/gold. The back-side of the substrate was thinned to 100 $\mu\text{m}$ . The structures were

then cleaved into 2mm-long lasers. The mirror facets were formed as-cleaved without applying high reflectivity coatings.

Under pulsed injection, the lowest lasing threshold current density was  $320\text{A}/\text{cm}^2$ . The maximum output power from a single facet was more than 30mW. The characteristic temperature for the laser threshold was 51K in measurements made in the range 25–70°C. At 25°C, the slope efficiency was  $0.052\text{W}/\text{A}$ . The devices did not lase under continuous-wave current injection up to 1000mA.

The researchers admit that the laser grown on silicon demonstrated “degradation of several characteristics such as the output and thermal characteristics”, compared with devices on GaAs substrate. The lower quality of the GaAs buffer layer and the broad mesa width were blamed. The team hopes that optimization of the growth process, particularly of the seed layer, will improve laser performance. Narrower mesas should also improve current constriction and thermal management. ■



**Figure 2. Temperature-dependent light output power versus current curves for laser under pulsed injection.**

<https://doi.org/10.1364/OE.26.011568>

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# Platform for fully vertical GaN-on-silicon power devices

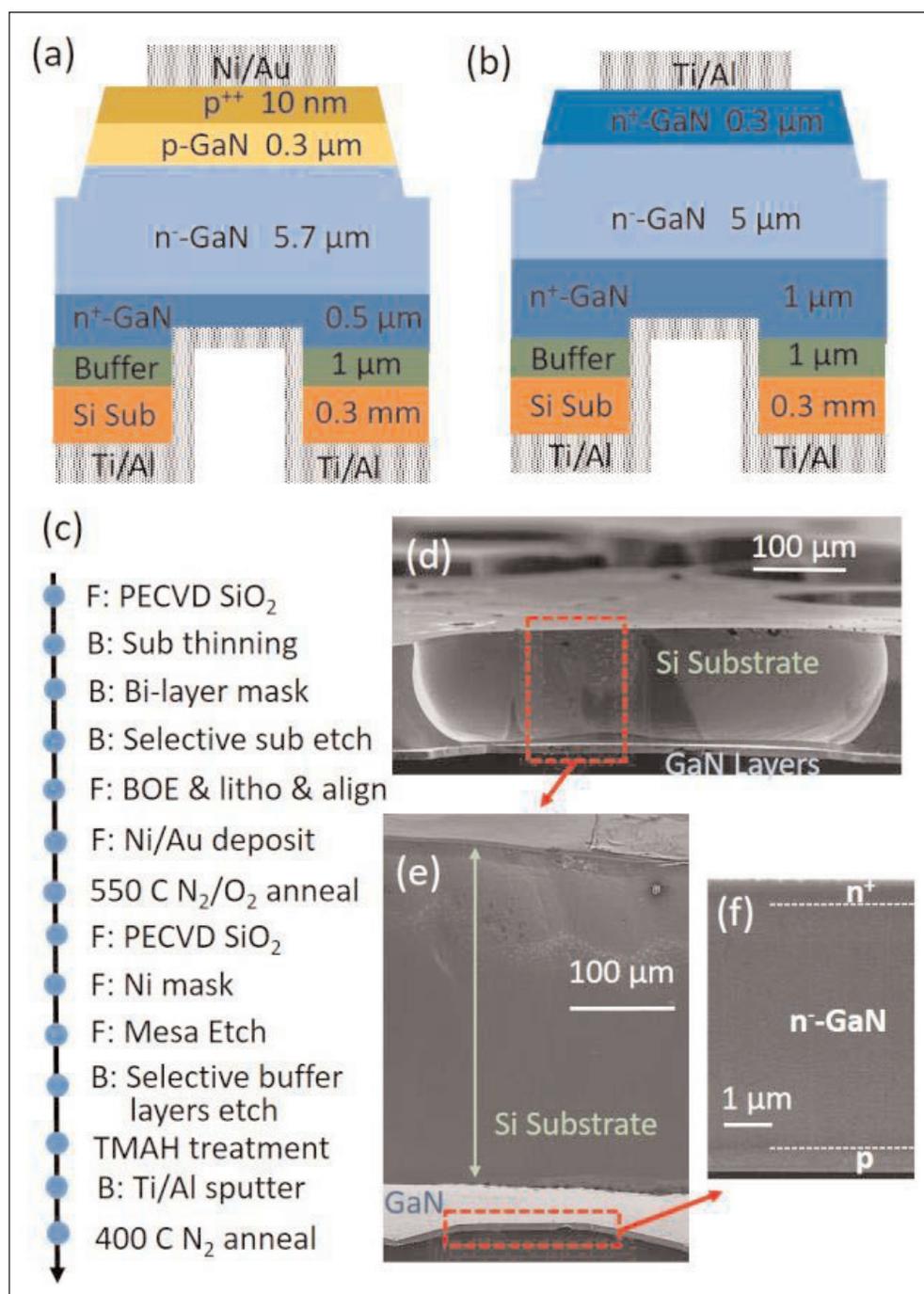
Record power performance claimed for GaN pn diodes on a foreign substrate.

**M**assachusetts Institute of Technology (MIT) in the USA and Enkris Semiconductor Inc in China claim record performance for vertical gallium nitride (GaN) power diodes on foreign substrate [Yuhao Zhang et al, IEEE Electron Device Letters, published online 26 March 2018]. The researchers have developed a new platform for vertical GaN on silicon that creates a back-side trench, allowing a back contact to be made to the n-GaN layers.

The trench etching removes resistive buffer layers that have up to now mainly restricted GaN/Si power electronics to lateral or quasi-vertical structures with all contacts on the top side of epitaxial structures. The buffer layers are needed to bridge the lattice and thermal expansion mismatch between the foreign substrate and the GaN crystal structure. Fully vertical GaN power devices have generally been demonstrated on very expensive bulk or free-standing GaN substrates.

Vertical power devices are attractive because they push peak electric fields away from the surfaces and associated electron states that can cause premature breakdown. Vertical structures hence allow higher currents and voltages in more compact footprints. Also, lateral/quasi-vertical devices suffer from current crowding, which increases Joule heating.

The advantages of using silicon substrates are large diameter (8") and low cost (less than \$1/cm<sup>2</sup>). The researchers estimate the cost of 4" silicon carbide substrates at ~\$5/cm<sup>2</sup>, while 2" GaN-on-GaN wafers cost ~\$50/cm<sup>2</sup>.



**Figure 1. Schematic structure of (a) fully vertical GaN-on-Si pn diodes and (b) test device for backside trench etch and contact formation. (c) Main fabrication steps for fully vertical pn diodes. 'F' and 'B' represent front-side and back-side processes, respectively. Cross-sectional scanning electron microscopy (SEM) images of (d) circular back-side trenches, (e) silicon and GaN layers inside trenches and (f) GaN layers at trench bottom.**

The team believes that the trench process constitutes a potential platform for fully vertical power transistors and advanced diodes.

Enkris grew the epitaxial structure (Figure 1) on 6-inch-diameter (111) 1mm-thick silicon by metal-organic chemical vapor deposition (MOCVD). An optimized carbon doping was used in the  $n^-$ -GaN drift layer to compensate for background doping with a view to maintaining electron mobility and dynamic performance. The dislocation density was estimated through x-ray diffraction studies to be  $2 \times 10^8/\text{cm}^2$  — “very low for GaN-on-Si wafers”, the researchers comment.

Device fabrication began with silicon dioxide deposition on the front side as protection. The silicon substrate was thinned to  $300\mu\text{m}$  ( $0.3\text{mm}$ ) with sulfur hexafluoride plasma etch. Further selective etching was used to remove all the silicon in the desired trench region.

The top-side silicon dioxide was removed before depositing an annealed nickel/gold (Ni/Au) ohmic contact. Selective etching of the top and bottom sides of the wafer created mesa isolation and removed the buffer layer so the back contact trench could be made, respectively.

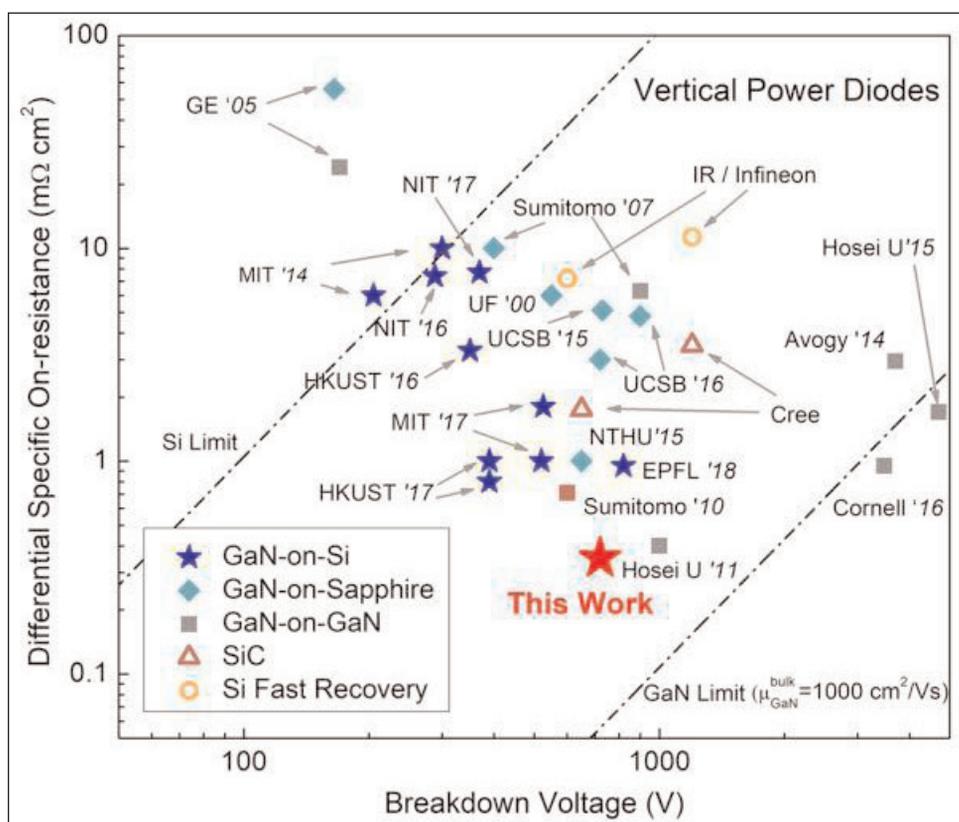
Hot tetramethylammonium hydroxide (TMAH) treatment was used to remove surface damage and roughness from the plasma etch processing. After cleaning the etch mask materials, titanium/aluminium (Ti/Al) was sputtered and annealed to make the back ohmic contact.

The team fabricated pn diode devices with a  $300\mu\text{m}$ -diameter circular backside trench and  $350\mu\text{m}$ -diameter front-side anode. The larger anode was designed to compensate for the lower conductivity of p-GaN.

The on/off current ratio was  $10^9$  with a turn-on voltage ( $V_{\text{on}}$ ) of 3.1V for  $10\text{A}/\text{cm}^2$  current density. The ideality factor was around 2 for low currents, indicating space-charge recombination. At higher current the ideality increased due to deep-level-assisted tunneling and p-GaN contact resistance ( $R_{\text{on}}$ ), according to the researchers. At 3.7V, the specific differential on-resistance was less than  $0.4\text{m}\Omega\text{-cm}^2$ .

The team comments: “These characteristics are significantly better than previous reports of GaN-on-Si vertical diodes, where the  $V_{\text{on}}$  was around 3.5–4V and the  $R_{\text{on}}$  was extracted at a high bias of 5.5–9V.”

Increasing the temperature to  $150^\circ\text{C}$  increased the



**Figure 2. Specific on-resistance versus breakdown of vertical GaN power diodes on silicon, sapphire and GaN substrates and commercial 600V/1200V SiC power diodes (Cree CPW5-0650-Z050B/CPW5-1200-Z050B) and silicon fast recovery power diodes (IR IRD4CC17HB5/IRD3CH42DB6).**

on-resistance to  $0.85\text{--}0.95\text{m}\Omega\text{-cm}^2$ . The turn-on voltage was slightly reduced due to increased dopant activation in the p-GaN.

Room-temperature reverse breakdown (BV) occurred at 720V — at 500V the leakage was  $10^{-2}\text{A}/\text{cm}^2$  ( $10^{-1}\text{A}/\text{cm}^2$  at 700V). The researchers claim these values are “at least 10-to-100-fold lower than the lowest leakage reported in quasi-vertical GaN-on-Si diodes so far”. They add: “The off-state leakage mechanism is dominated by the trap-assisted space-charge-limited current (SCLC), similar to previous reports of GaN-on-Si vertical diodes.” These previous vertical diodes managed reverse breakdown voltages of more than 350V.

The breakdown came a little earlier (680V) for  $150^\circ\text{C}$  conditions. The breakdown occurred at the mesa edges, so edge-termination field-plate/ring structures should be effective in increasing breakdown voltages.

The researchers compared their devices with a wide range of alternative research and commercial devices (Figure 2). They write: “Our device shows a record performance for GaN-on-Si vertical power diodes with a power figure of merit ( $\text{BV}^2/R_{\text{on}}$ ) of  $1.5\text{GW}/\text{cm}^2$ . Our diodes also showed lower  $R_{\text{on}}$  than commercial SiC and Si power diodes at similar voltage classes.” ■

<https://doi.org/10.1109/LED.2018.2819642>  
Author: Mike Cooke

# Normally-on gallium nitride nanowire transistors with inverted p-channel

Researchers create devices with +2.5V threshold voltage.

Researchers based in Germany claim the first vertical gallium nitride (GaN) nanowire (NW) metal-oxide-semiconductor field-effect transistors (MOSFETs) with an inverted channel, allowing a positive 2.5V threshold voltage and giving enhancement-mode normally-off behavior [Feng Yu et al, IEEE Transactions On Electron Devices, published online 19 April 2018].

The high threshold was achieved by using p-GaN as the channel material. With 0V on the gate, the channel blocks current flow. Increasing the gate potential inverts the channel, increasing the electron density and allowing transport.

The team from Technische Universität Braunschweig, Universität Kassel and Physikalisch-Technische Bundesanstalt sees advantages from GaN electronics over silicon as including "switching speed, operation temperature, output power, as well as radiation immunity". Logic and switching applications prefer circuit designs based on normally-off enhancement-mode transistors.

Metal-organic vapor phase epitaxy created a GaN structure with different doping levels on c-plane sapphire (Figure 1). The vertical nanowires were created through patterning with a chromium (Cr) mask and etching with sulfur hexafluoride inductively coupled plasma.

The nanowires were ~1µm diameter and 2.8µm high. The pitch between the wires was 4µm. Further wet etching with AZ400K developer was performed to smooth the wire surfaces and remove other damage from the dry etch.

In fact, the wires had non-uniform diameter of 1.3µm at the bottom and 0.85µm at the top after dry etching. The wet etch also resulted in vertical wires of 0.47µm diameter and 'mushroom' top just

Drain	n <sup>+</sup> -GaN	1x10 <sup>19</sup> /cm <sup>3</sup> Si	0.5µm
Drift	n-GaN	3x10 <sup>17</sup> /cm <sup>3</sup> Si	1.6µm
Channel	p-GaN	1x10 <sup>18</sup> /cm <sup>3</sup> Mg	0.5µm
Source	n-GaN	3x10 <sup>18</sup> /cm <sup>3</sup> Si	1µm
Buffer	n-GaN	2x10 <sup>18</sup> /cm <sup>3</sup> Si	2.5µm
Substrate	c-plane sapphire		

Figure 1. Epitaxial structure.

under the Cr mask.

The magnesium (Mg) doping of the buried p-GaN layer was activated with rapid thermal annealing (RTA) – 30 seconds at 950°C and 5 minutes at 600°C. The larger surface area of the nanowire structure allowed passivating species such as hydrogen to escape. In normal epitaxial structures, the p-GaN layers are deposited last, since buried p-GaN layers are not able to expel passivating atoms.

The MOSFET (Figure 2) was produced with 25nm plasma-enhanced atomic layer deposition silicon dioxide (SiO<sub>2</sub>) on the wire sidewalls, and 200nm silicon oxide

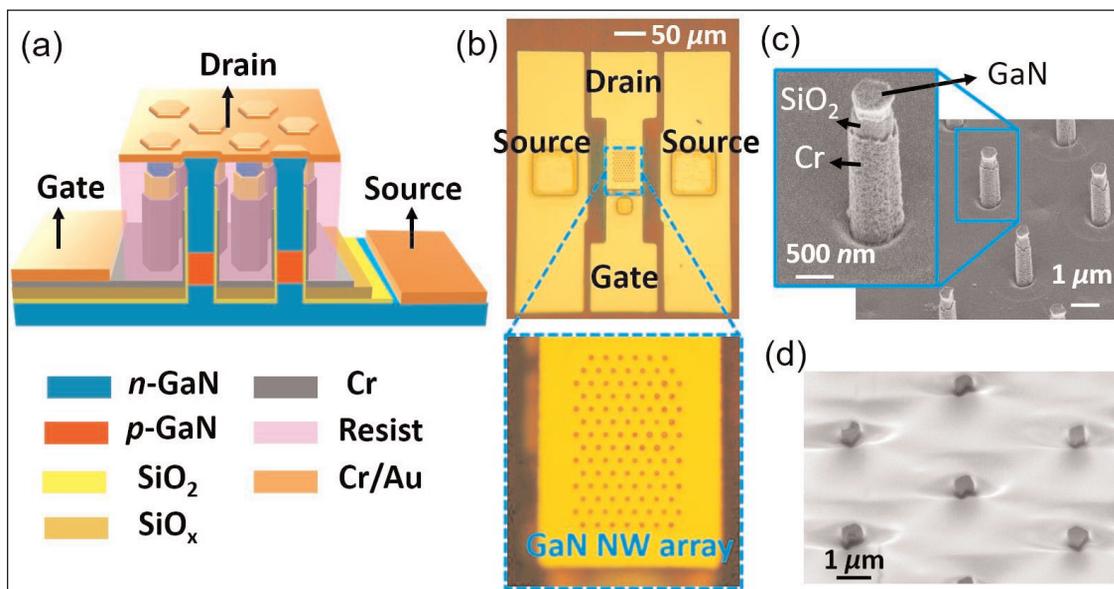


Figure 2. (a) Schematic and (b) microphotograph of fabricated vertical GaN nanowire-based MOSFET with inverted p-GaN channel. 45°-tilted scanning electron microscope images (c) before and (d) after filling with resist.

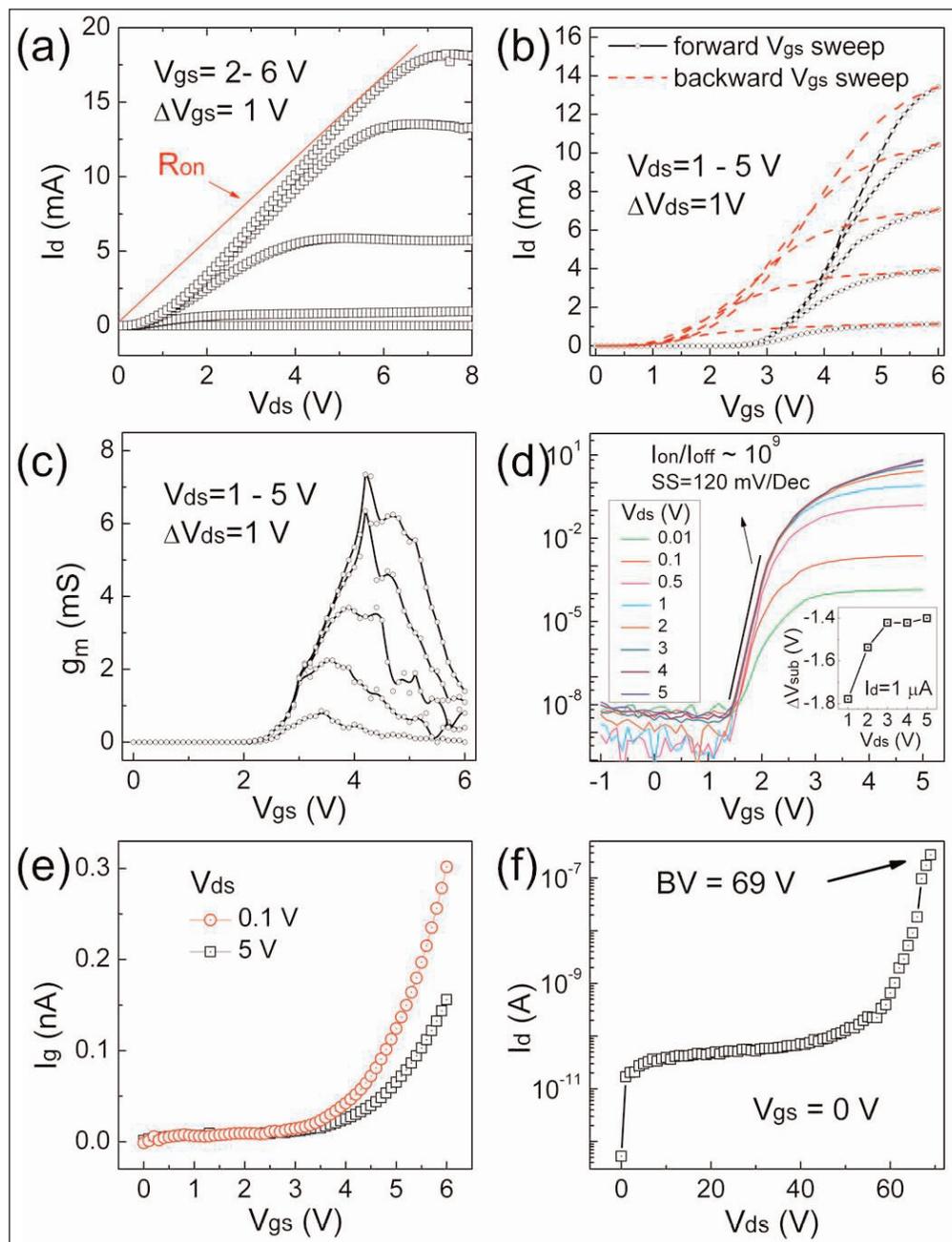
(SiO<sub>x</sub>). The gate metal was 300nm electron-beam-evaporated chromium. The space between the wires was filled with photo-resist. The resist was etched back and refilled a number of times to enable selective removals of chromium and silicon oxide. The resist was finally cured and chromium/gold electrodes formed.

The MOSFET consisted of 103 nanowires. The gate length of 0.5μm was defined by the thickness of the p-GaN layer. The width was given by the combined circumferences of the nanowires. The device area was 1.4x10<sup>-5</sup>cm<sup>2</sup>. The ohmic source-drain contacts were not ideal.

The maximum drive current ( $I_d$ ) at 6V gate potential was 18mA. The current density in the wires was 101kA/cm<sup>2</sup>. The specific on-resistance was small at 5.3mΩ-cm<sup>2</sup>, including the space between the wires. The threshold voltage ( $V_{th}$ ) was +2.5V and the normalized peak transconductance was 41mS/mm. The on/off current ratio was of the order of 10<sup>9</sup>. The subthreshold swing was 120mV/decade, rather high compared with previous devices. The large swing was tentatively attributed to a high trap density at the p-GaN/SiO<sub>2</sub> interface in the gate region. Breakdown with 0V gate came at 69V drain bias.

Some gate-bias-dependent hysteresis was found which the researchers suggest was due to "positive charging close to or at the channel region, especially at high gate bias". They comment: "The hysteresis brings instability in both  $V_{th}$  and  $I_d$ , which would limit the device application in high-frequency switching."

The team considers mobile ions as the most likely cause of the hysteresis. They comment: "The mobile ions in SiO<sub>2</sub> could be primarily alkaline impurities introduced unintentionally during the device processing, e.g. alkaline involved wet etching and photoresist curing". The researchers suggest that aluminium oxide or silicon nitride would be preferable dielectrics, compared with silicon dioxide, allowing alkaline-free processing.



**Figure 3. Electrical characteristics of vertical GaN MOSFET consisting of 103 nanowires. (a) Output characteristic. (b) Transfer characteristic under bidirectional gate sweep with rate of 0.8V/s. (c) Transconductance ( $g_m$ ) characteristic of forward gate transfer in (b). (d) Subthreshold characteristic under the forward-gate sweep. Inset: corresponding voltage shift ( $\Delta V_{sub}$ ) at  $I_d$  of 1μA during bidirectional gate sweep. (e) Gate leakage at drain bias  $V_{ds}$  of 0.1V and 5V. (f) Breakdown voltage (BV) test at 0V gate potential ( $V_{gs}$ ).**

The researchers compared their inverted p-GaN channel device with n-GaN channel NW MOSFETs — the p-GaN allowed a higher threshold than the competitors, some of which had negative values, indicating depletion-mode normally-on behavior. The p-GaN device also demonstrated high values for the normalized maximum current and on/off ratio. ■

<https://doi.org/10.1109/TED.2018.2824985>

Author:

Mike Cooke

# Silicon carbide superjunction Schottky junction diodes

Researchers detail processing and analysis of the first functional devices.

China's Zhejiang University claims the first functional silicon carbide (SiC) superjunction (SJ) device, in the form of a Schottky diode [Xueqian Zhong et al, IEEE Transactions On Electron Devices, vol65, p1458, 2018]. However, the device seems similar to a device presented by three members of the Zhejiang team at the 28th International Symposium on Power Semiconductor Devices and ICs (ISPSD) in 2016.

Superjunctions consist of vertical p- and n-type regions that, with perfect charge balancing, allows the drift regions of power devices to be depleted, increasing blocking voltages. In principle, this should allow SJ devices to beat the theoretical limits for unipolar power devices in terms of the trade-off between high breakdown voltage and low on-resistance.

The researchers comment: "It is expected that higher-voltage SJ devices based on SiC will offer more advantages over the conventional devices. Also, three-terminal devices are more favorable but their developments are even more challenging."

The material used for the devices was an n-type 4°-offcut 4H-SiC substrate with a 12µm n-SiC epitaxial layer. Trenches 3µm wide (TW) and mesas 2µm wide (MW) were etched with inductively coupled plasma with a complex recipe to round corners and avoid sub-trenches that can create the conditions for field crowding and premature breakdown (Figure 1).

The trench wall angle was 86° to enable tilted implantation of aluminium p-type dopants and silicon dioxide refill. The implantation was carried out in a number of vertical and tilted steps to give a box profile. The depth of the doping was 0.5µm at the bottom of the trench and 0.3µm for the sidewalls. Nickel was used for a Schottky anode contact.

The optimum annealing temperature to activate the p-type doping was found to be 1350°C, which gave the highest breakdown voltage of 1350V. This breakdown figure was 95% of the simulated 1420V for a perfectly charge-balanced device.

The researchers suggest, based on simulations of the implant process, that lower-dose implants combined with higher annealing temperatures would be more effective in repairing implant damage to the crystal structure, giving better device performance in future work.

The devices underwent reversible avalanche breakdown. The forward current-voltage curve has a knee at about 1.3V, reflecting nickel's work function. The specific on-resistance was 0.92mΩ-cm<sup>2</sup> — about 0.6mΩ-cm<sup>2</sup>

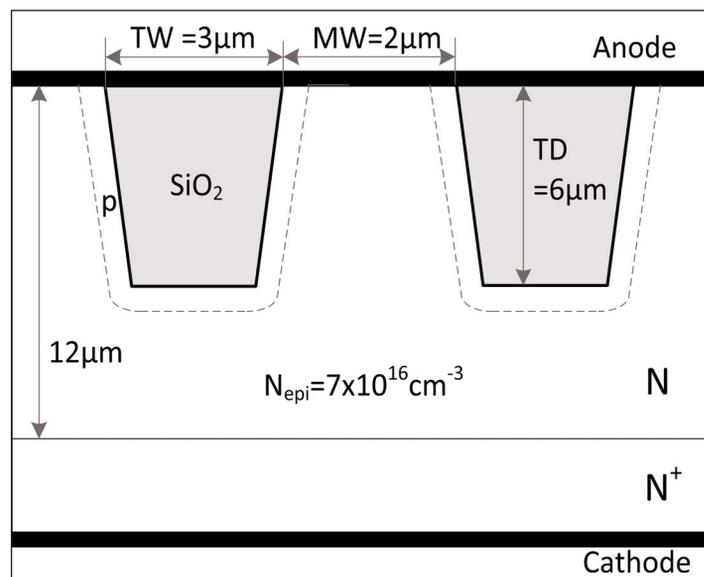


Figure 1. SiC-SJ Schottky diode cell structure with basic dimensions.

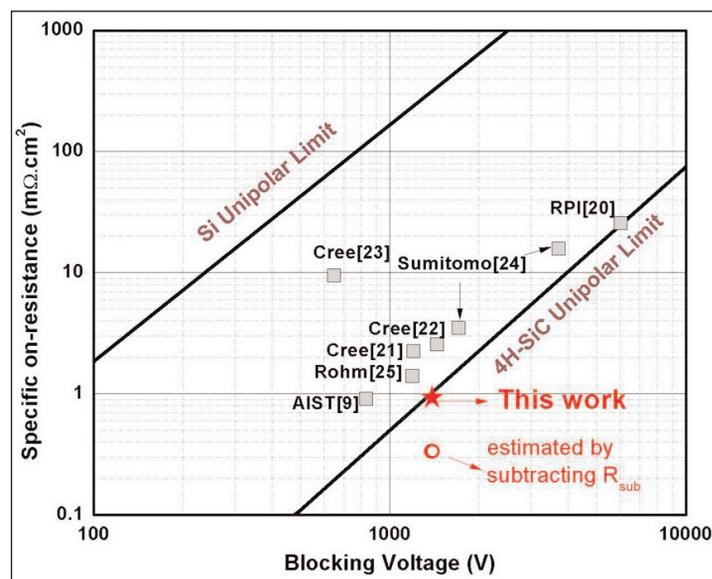


Figure 2. Trade-off between breakdown voltage and specific on-resistance in recent 4H-SiC-commercial products and research devices.

of this is attributed to the substrate. By subtracting the substrate resistance, the researchers point out that the residue of 0.32mΩ-cm<sup>2</sup> for the drift region breaks the theoretical limit for one-dimensional unipolar Schottky-junction SiC devices (Figure 2). ■

<https://doi.org/10.1109/TED.2018.2809475>

<https://doi.org/10.1109/ISPSD.2016.7520820>

Author: Mike Cooke

# Ohio State uses modulation doping to demonstrate high electron mobility in gallium oxide

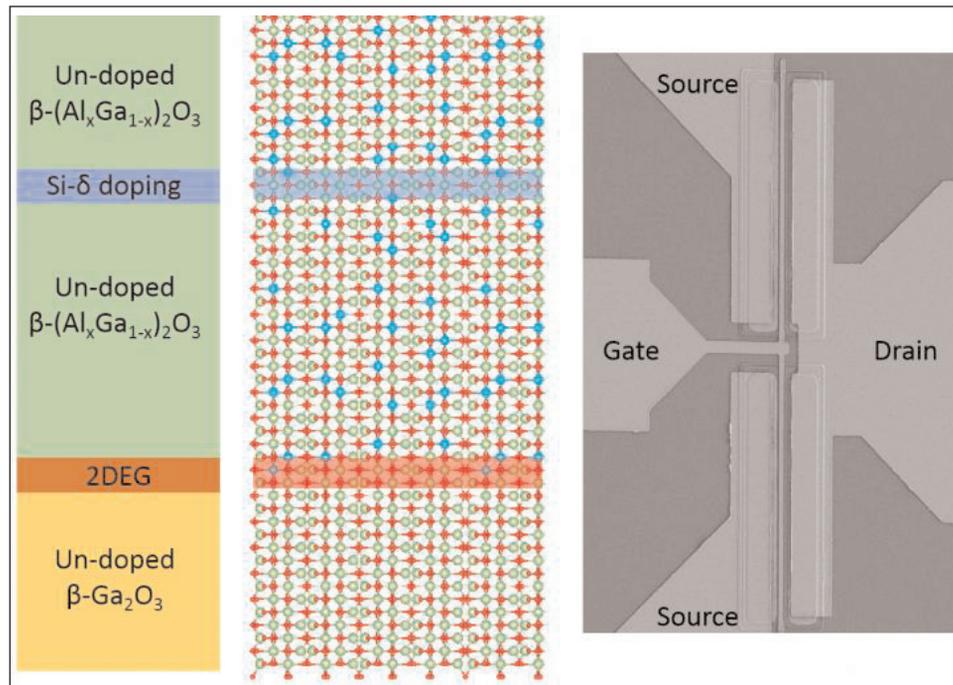
New  $\beta\text{-(Al}_x\text{Ga}_{1-x})_2\text{O}_3/\text{Ga}_2\text{O}_3$  quantum structures and electronics could yield high-frequency communication systems and energy-efficient power electronics

Ohio State University has shown that the wide-bandgap semiconductor gallium oxide ( $\text{Ga}_2\text{O}_3$ ) can be engineered into nanometer-scale structures that allow increased mobility of electrons within the crystal structure (Yuewei Zhang et al, 'Demonstration of high mobility and quantum transport in modulation-doped  $\beta\text{-(Al}_x\text{Ga}_{1-x})_2\text{O}_3/\text{Ga}_2\text{O}_3$  heterostructures', *Applied Physics Letters*, vol112 (2018) 173502).  $\text{Ga}_2\text{O}_3$  could hence be a promising material for applications such as high-frequency communication systems and energy-efficient power electronics, it is reckoned. "Gallium oxide has the potential to enable transistors that would surpass current technology," says Siddharth Rajan, who led the research.

Because  $\text{Ga}_2\text{O}_3$  has one of the largest bandgaps of the wide-bandgap materials being developed as alternatives to silicon, it is especially useful for high-power and high-frequency devices. It is also unique among wide-bandgap semiconductors in that it can be produced directly from its molten form, which enables large-scale manufacturing of high-quality crystals.

For use in electronic devices, it is desirable a material to enable for high electron mobility under an electric field. Normally, to populate a semiconductor with electrons, the material is doped with other elements. However, the problem is that the dopants also scatter electrons, limiting electron mobility in the material.

To solve this problem, the researchers used modulation doping. The approach was first developed in 1979 by Takashi Mimura to create a gallium arsenide



**Schematic stack and scanning electron microscopic image of  $\beta\text{-(Al}_x\text{Ga}_{1-x})_2\text{O}_3/\text{Ga}_2\text{O}_3$  modulation-doped field-effect transistor. Credit: Choong Hee Lee and Yuewei Zhang.**

high-electron-mobility transistor (HEMT), which won the Kyoto Prize in 2017. While it is now a commonly used technique to achieve high mobility, its application to  $\text{Ga}_2\text{O}_3$  is new.

In their work, the researchers created a heterostructure interface between gallium oxide and its alloy aluminum gallium oxide, which has the same crystal structure but a different energy gap. A few nanometers away from the interface, embedded inside the aluminum gallium oxide is a sheet of electron-donating impurities only a few atoms thick. The donated electrons transfer into the  $\text{Ga}_2\text{O}_3$ , forming a two-dimensional electron gas (2DEG). However, because the electrons are now also separated from the dopants (hence the term modulation doping) in the aluminum gallium oxide by a

few nanometers, the electrons scatter much less and remain highly mobile.

Using this technique, the researchers reached record mobilities. They were also able to observe Shubnikov-de Haas oscillations, a quantum phenomenon in which increasing the strength of an external magnetic field causes the resistance of the material to oscillate. These oscillations confirm the formation of the high-mobility 2D electron gas and allow the researchers to measure critical material properties.

Rajan says that such modulation-doped structures could lead to a new class of quantum structures and electronics that harnesses the potential of  $\text{Ga}_2\text{O}_3$ .

<http://aip.scitation.org/doi/full/10.1063/1.5025704>  
<https://nano.osu.edu>

# High-voltage gallium oxide transistors with more than 1kV breakdown

Enhancement-mode, normally-on operation achieved for first time.

Researchers based in the USA and Japan claim the first enhancement-mode high-voltage vertical gallium oxide ( $\text{Ga}_2\text{O}_3$ ) metal-insulator-semiconductor field-effect transistors (MISFETs) [Zongyang Hu et al, IEEE Electron Device Letters, published online 25 April 2018]. Enhancement-mode operation (normally-off at 0V gate) is highly desired for power electronics, reducing power consumption and allowing for fail-safe designs.

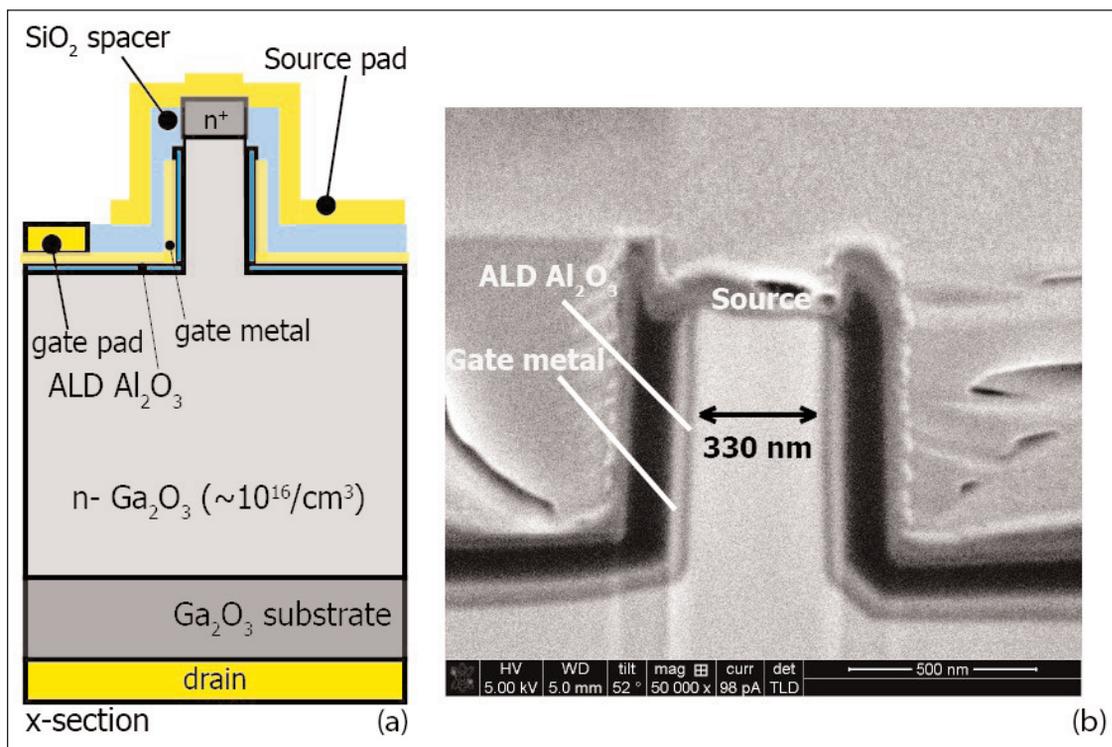
$\text{Ga}_2\text{O}_3$  has a wide 4.9eV bandgap and expected 8MV/cm breakdown field. The electron mobility has a decent limit of  $250\text{cm}^2/\text{V}\cdot\text{s}$ , allowing

realistic power device proposals. Large single-crystal substrates are commercially available.

Cornell University in the USA and Hosei University and Novel Crystal Technology Inc in Japan used hydride vapor phase epitaxy (HVPE) to deposit  $10\mu\text{m}$  n- $\text{Ga}_2\text{O}_3$  on n- $\text{Ga}_2\text{O}_3$  (001) substrate. The substrate carrier density was  $2 \times 10^{18}/\text{cm}^3$ . The epitaxial drift layer doping concentration was less than  $2 \times 10^{16}/\text{cm}^3$ . A silicon box-implant added a  $50\text{nm}$   $\text{n}^+$ - $\text{Ga}_2\text{O}_3$  layer with  $5 \times 10^{19}/\text{cm}^2$  doping to allow low contact resistance for the source contact after activation annealing.

Vertical fin-channels were inductively coupled etched using platinum masking. The target fin height and width were  $1.0\mu\text{m}$  and  $0.3\mu\text{m}$ , respectively. The gate stack consisted of atomic layer deposition (ALD) aluminium oxide ( $\text{Al}_2\text{O}_3$ ) dielectric and sputtered chromium (Cr) metal.

Photoresist fill and planarization steps were used to



**Figure 1. (a) Schematic cross section of  $\text{Ga}_2\text{O}_3$  vertical power MISFET. (b) 52° scanning electron microscope SEM cross-section image showing 330nm wide and 795nm long fin-channel.**

remove metal from the  $50\text{nm}$   $\text{n}^+$ - $\text{Ga}_2\text{O}_3$  source contact material. Plasma-enhanced chemical vapor deposition (PECVD) of  $200\text{nm}$  silicon dioxide ( $\text{SiO}_2$ ) spacer was followed by resist fill and planarization to clear the source contact region again. The ohmic source titanium/aluminium/platinum (Ti/Al/Pt) metals were then deposited. Devices (Figure 1) were isolated by removing  $\text{SiO}_2$  and Cr from between them.

Devices with  $0.33\mu\text{m} \times 80\mu\text{m}$  source area had a drain current density of  $\sim 350\text{A}/\text{cm}^2$  with 10V drain bias and the gate set at 3V under pulsed operation, avoiding thermal effects. The differential on-resistance was  $\sim 18\text{m}\Omega\cdot\text{cm}^2$ , normalized to the source contact area. Process non-uniformity led to a wide range of drain currents ( $300\text{--}500\text{A}/\text{cm}^2$ ) and on-resistances ( $13\text{--}18\text{m}\Omega\cdot\text{cm}^2$ ). Threshold voltages were all positive, in the range  $+1.2\text{V--}+2.2\text{V}$ , giving enhancement-mode, normally-on operation. The on/off current ratio was of

the order  $10^8$ . The leakage was at the limit of the measurement system. The sub-threshold swing was  $\sim 85\text{mV/decade}$ .

Hard breakdown occurred at 1057V drain voltage (BV) with leakage current low at close to the detection limit up to that point (Figure 2). The breakdown field is estimated at  $1.44\text{MV/cm}$ , far below the value expected for  $\text{Ga}_2\text{O}_3$ .

The researchers comment: "Examination of the devices after breakdown shows visible damage near the outer edges of the gate pads. For the same reason, the three-terminal BV demonstrated in this work is slightly lower compared to the two-terminal BVs in heterojunction  $\text{p-Cu}_2\text{O/n-Ga}_2\text{O}_3$  diode fabricated on similar HVPE- $\text{Ga}_2\text{O}_3$  epitaxial layers and substrates." The team expects higher breakdown voltages from implementing field plates or ion implantation edge termination. ■

<https://doi.org/10.1109/LED.2018.2830184>

Author: Mike Cooke

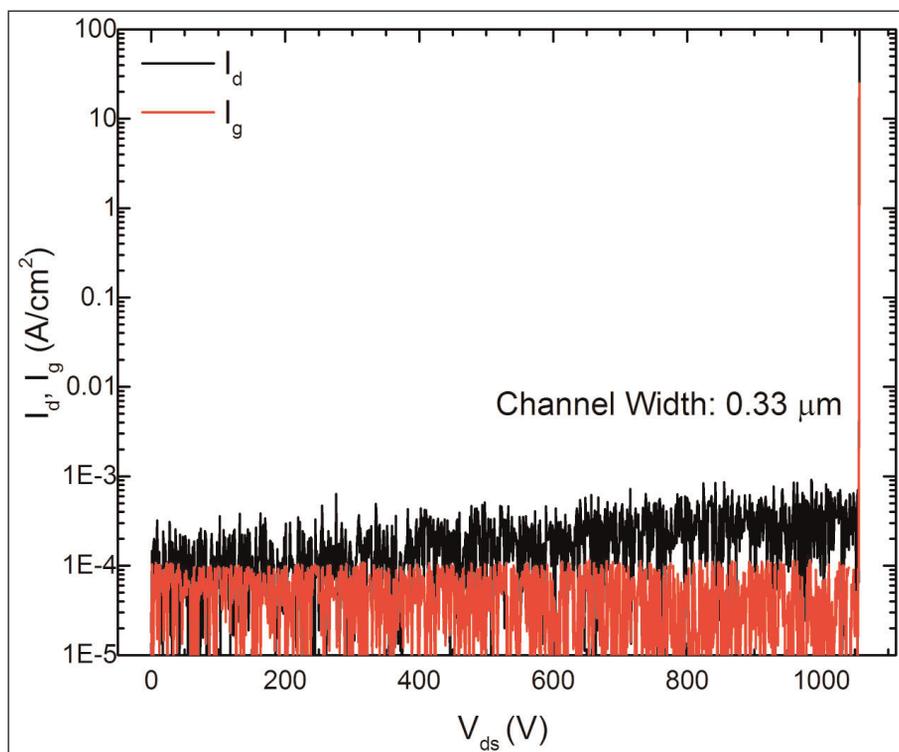


Figure 2. Representative three-terminal off-state (at 0V gate) drain and gate current versus drain bias ( $I_d/I_g - V_{ds}$ ) characteristics and breakdown voltage.

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# ZTE denial and the semiconductor supply chain

**Mike Cooke** tries (and fails) to understand the complexities of the impact of US trade and security policy on the new world order.

**I**t is rather unsettling and unexpected to be writing this article. As a species, we are faced with (at least) two existential crises: fast nuclear war or slow degeneration of our lived environment as a result of uneven climate changes. The effects of the latter problem are mainly being felt as yet by our poorer fellow world inhabitants, helped on by agricultural failures and war.

Occasionally this magazine touches on the hopes of contributing to avoiding climate change through solar energy conversion or more efficient electronics. Less obvious, perhaps, is the impact of semiconductor electronics on the politics of averting nuclear conflict.

Enter Zhongxing Telecommunications Equipment Corp (ZTE). This Chinese company has agreed to pay a penalty after allegedly "engaging in a multi-year conspiracy to violate the US trade embargo against Iran to obtain contracts to supply, build, operate and maintain telecommunications networks in Iran using US-origin equipment, and also illegally shipping telecommunications equipment to North Korea in violation of the Export Administration Regulations (15 C.F.R. Parts 730-774 (2017)) ('EAR', or the 'Regulations')" [US Department of Commerce, "ZTE Corporation and ZTE Kangxun Order Activating Denial Order", 15 April 2018].

This came before US President Donald Trump's announcement withdrawing from the 'Iran nuclear deal', officially known as the Joint Comprehensive Plan of Action (JCPOA). Meanwhile, the US President was gearing up for direct talks with North Korea's Supreme Leader Kim Jong-Un on 12 June in Singapore. Previously, on 15 May, North Korea had canceled talks with South Korea in response to joint military drills with the USA.

## Access denied

The Denial Order on ZTE was initiated on 23 March, but some aspects were suspended subject to several probationary conditions. The activation of the suspended parts of the agreement follow a "pattern of deception, false statements and repeated violations of US law" by

ZTE, according to the US Commerce Department's Bureau of Industry and Security. The effect is that ZTE "may not, directly or indirectly, participate in any way in any transaction involving any commodity, software or technology... exported or to be exported from the United States that is subject to the Regulations, or in any other activity subject to the Regulations."

In an 'Inside Information Announcement' (9 May) to the Hong Kong stock exchanges, ZTE reported that, as a result of the Denial Order, major operation activities had ceased. Shenzhen Stock Exchange suspended trading in A shares from 17 April, at the application of ZTE. This was continuing as of 16 May.

Conversely, President Trump added this via Twitter: "ZTE, the large Chinese phone company, buys a big percentage of individual parts from US companies. This is also reflective of the larger trade deal we are negotiating with China and my personal relationship with President Xi." (14 May). This was in clarification of "President Xi of China, and I, are working together to give massive Chinese phone company, ZTE, a way to get back into business, fast. Too many jobs in China lost. Commerce Department has been instructed to get it done!" (13 May).

In the background of this may also be the pending merger/acquisition of NXP Semiconductors by Qualcomm, which is being held up by China's commerce ministry. It is also thought that about half of ZTE's phones contain Qualcomm CPUs. The withdrawal of access to wide-ranging US-based intellectual property and devices is surely a major part of the ZTE shutdown decision.

## Commercial interlude

Who are the US suppliers that President Trump is worried about?

Qorvo reports that about \$10m of its quarterly revenue involves ZTE. The forecast for its Infrastructure & Defense Products (IDP) revenue is \$645-665m in the quarter to end-June (fiscal first-quarter 2019). The IDP division is the source of most of the ZTE sales, according to Qorvo.



**ZTE's headquarters in Shenzhen, China.**

The company produces chips based on both III-V — gallium arsenide (GaAs) and gallium nitride (GaN) — and silicon technologies.

NeoPhotonics is also worried, since it had estimated that up to 5% of its annualized revenue was to come from ZTE and its suppliers. Senior vice-president & chief financial officer Beth Eby also reported to an analyst briefing that the company was holding products in inventory for ZTE valued at approximately \$1.2m that has now been written down. The company's below-forecast performance was blamed mainly on this write-down. NeoPhotonics supplies photonic ICs and modules based on silicon photonics, hybrid photonic integration, indium phosphide, GaAs, silicon germanium, and indium gallium arsenide phosphide (InGaAsP) and indium gallium aluminium arsenide (InGaAlAs) lasers.

Lumentum commented in its 10-Q Security and Exchanges Commission filing (2 May): "Although we do not derive significant revenue from ZTE, there is increased attention from the government, the media and stockholders in this area and our stock price may be adversely affected as a result of this or further action. Further, we are aware that certain of our other customers have been investigated by the US government in the past and may be in the future. Any further sanctions or limitation on our ability to sell our products to certain customers could have an adverse effect on our business."

However, the company is also in the process of

acquiring fellow Silicon Valley-based firm Oclaro. Lumentum laments that "we face indirect reputational and business risks with respect to events that affect Oclaro's business during the pendency of the transaction and following the closing. For example, Oclaro has publicly disclosed that ZTE has been among its customers."

Lumentum produces photonics devices including edge-emitting and vertical-cavity surface-emitting laser diodes. Oclaro produces photonics products based on indium phosphide and lithium niobate.

Skyworks is another company that supplies ZTE and it expects the ban to hit its annual sales by \$25–30m. Second-quarter revenue was \$913m, and the next quarter (to June) is expected to be in the range \$875–900m. The company uses a range of silicon and III-V (GaAs and GaN) technologies for its RF components.

### Push back

Getting back to the politics, tweets do not yet constitute legal documents of the US state, and they don't allow one to interpret and plan on the basis of a coherent policy position.

There was much push back on the US President's tweeted position (during the 'pro-China' phase) by US Commerce Secretary Wilbur Ross and from Republican US Senators such as Marco Rubio. Also, within a few days the tweets were more negative towards a general China trade deal and more particularly ZTE. ▶

On 17 May the US House of Representatives 'Appropriations Committee' unanimously approved an amendment to the Fiscal Year 2019 Commerce, Justice and Science Appropriations Bill before congress aimed at blocking any attempt at a ZTE bailout by Trump. The text from Democratic Representatives C.A. Dutch Ruppertsberger and Rosa DeLauro reads: "None of the funds made available by this Act may be used in contravention of the 'Order Activating Suspended Denial Order Relating to Zhongxing Telecommunications Equipment Corporation and ZTE Kangxun Telecommunications Ltd' (83 Fed. Reg. 17644) published on 23 April by the Bureau of Industry and Security."

A statement from Ruppertsberger's office adds that the congressman "has long suspected ZTE is used by the Chinese government to spy on Americans through the cell-phone components they manufacture."

In line with these security concerns, in early May the Defense Department (the Pentagon) ordered stores on military bases to stop selling ZTE and Huawei devices. Further, independent of the executive led by President Trump, the US Congress Defence Authorisation Bill (presently under construction) plans to ban government agencies from using ZTE technology, also on "national security" grounds.

Of course, given the close relationship between the Chinese state and Chinese companies, it is not difficult to believe that there could be backdoors and such in Chinese technology that could be accessed by China's Ministry of State Security for the purposes of state and industrial espionage. However, evidence of such activity is generally not offered, presumably due to the supposed need to protect national security sources and techniques.

## Trade war

Also in the background is a looming and more generalized trade war between China and the USA. Trump's administration claimed (~17 May) that China had promised to buy more than \$200bn of US-made goods to avoid sanctions. In response, China's foreign ministry denied the claim. Talks are ongoing, but Trump himself is not hopeful.

Of course, ZTE is not the only Chinese technology company in the US Department of Commerce's sights. In fact, the leading Chinese smartphone producer Huawei could face a very similar ban to ZTE, and it has many of the same suppliers who could be hit much worse (for example, comprising 48% of NeoPhotonics' second-quarter revenue). On the other hand, Huawei owns more intellectual property and might be less liable to shutdown in the event of a US ban.

The ban(s) might be a blessing in disguise for Chinese technology development, making China's industry less dependent on external suppliers. The Chinese government has invested heavily in research in recent years, against the austerity trend in the West that has hit government and private R&D since the 1980s. A more self-sufficient Chinese supply chain would put up an increasing barrier to a very lucrative and expanding market for the rest of the world.

Other potential targets for bans on Chinese smartphone suppliers include OnePlus and Xiaomi.

Here's hoping this article is not obsolete by the time of publication.

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*The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.*

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 Fax: +49 (0)911 650 78 650 93  
 E-mail: [info@crystal-n.com](mailto:info@crystal-n.com)

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## 17 Assembly/packaging foundry

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San Diego, CA 92127,  
USA

Tel: +1 858 674 4676  
Fax: +1 8586 74 4681

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

## 18 Chip foundry

### Compound Semiconductor Technologies Ltd

Block 7, Kelvin Campus,  
West of Scotland, Glasgow,  
Scotland G20 0TH, UK

Tel: +44 141 579 3000  
Fax: +44 141 579 3040

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

## United Monolithic Semiconductors

Route departementale 128,  
BP46, Orsay, 91401,  
France

Tel: +33 1 69 33 04 72  
Fax: +33 169 33 02 92

[www.ums-gaas.com](http://www.ums-gaas.com)

## 19 Facility equipment

### MEI, LLC

3474 18th Avenue SE,  
Albany, OR 97322-7014,  
USA

Tel: +1 541 917 3626  
Fax: +1 541 917 3623

[www.marlerenterprises.net](http://www.marlerenterprises.net)

## 20 Facility consumables

### W.L. Gore & Associates

401 Airport Rd, Elkton,  
MD 21921-4236,  
USA

Tel: +1 410 392 4440  
Fax: +1 410 506 8749

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

## 21 Computer hardware & software

### Ansoft Corp

4 Station Square,  
Suite 200,  
Pittsburgh, PA 15219,  
USA

Tel: +1 412 261 3200  
Fax: +1 412 471 9427

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

### Crosslight Software Inc

121-3989 Henning Dr.,  
Burnaby, BC, V5C 6P8,  
Canada

Tel: +1 604 320 1704  
Fax: +1 604 320 1734

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

### Semiconductor Technology Research Inc

10404 Patterson Ave.,  
Suite 108, Richmond, VA 23238,  
USA

Tel: +1 804 740 8314  
Fax: +1 804 740 3814

[www.semitech.us](http://www.semitech.us)

## 22 Used equipment

### Class One Equipment Inc

5302 Snapfinger Woods Drive,  
Decatur, GA 30035,  
USA

Tel: +1 770 808 8708  
Fax: +1 770 808 8308

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

## 23 Services

### Henry Butcher International

Brownlow House, 50-51  
High Holborn, London WC1V 6EG,  
UK

Tel: +44 (0)20 7405 8411  
Fax: +44 (0)20 7405 9772

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

### M+W Zander Holding AG

Lotterbergstrasse 30,  
Stuttgart, Germany  
Tel: +49 711 8804 1141  
Fax: +49 711 8804 1950  
[www.mw-zander.com](http://www.mw-zander.com)

## 24 Consulting

### Fishbone Consulting SARL

8 Rue de la Grange aux Moines,  
78460 Choisel, France  
Tel: + 33 (0)1 30 47 29 03  
E-mail: [jean-luc.ledys@neuf.fr](mailto:jean-luc.ledys@neuf.fr)

## 25 Resources

**Al Shultz Advertising  
Marketing for Advanced  
Technology Companies**

1346 The Alameda,  
7140 San Jose, CA 95126,  
USA  
Tel: +1 408 289 9555  
[www.alshultz.com](http://www.alshultz.com)

### SEMI Global Headquarters

3081 Zanker Road,  
San Jose, CA 95134,  
USA  
Tel: +1 408 943 6900  
Fax: +1 408 428 9600  
[www.semi.org](http://www.semi.org)

### Yole Développement

45 rue Sainte Geneviève,  
69006 Lyon,  
France  
Tel: +33 472 83 01 86  
[www.yole.fr](http://www.yole.fr)

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**9–11 July 2018**

## IEEE Photonics Society's 2018 Summer Topicals Meeting Series

Waikoloa, Hawaii, USA

**E-mail:** [i.donnely@ieee.org](mailto:i.donnely@ieee.org)

[www.sum-ieee.org](http://www.sum-ieee.org)

**10–12 July 2018**

## Intersolar North America

San Francisco, CA, USA

**E-mail:** [info@intersolar.de](mailto:info@intersolar.de)

[www.intersolar.us](http://www.intersolar.us)

**10–12 July 2018**

## SEMICON West 2018

Moscone Center,

San Francisco, CA, USA

**E-mail:** [semiconwest@xpressreg.net](mailto:semiconwest@xpressreg.net)

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

**19–23 August 2018**

## SPIE Optics + Photonics 2018

San Diego Convention Center,

San Diego, CA, USA

**E-mail:** [customerservice@spie.org](mailto:customerservice@spie.org)

[http://spie.org/Optics\\_Photonics](http://spie.org/Optics_Photonics)

**5–7 September 2018**

## SEMICON Taiwan 2018

Taipei Nangang Exhibition Center 1F&4F, Taipei, Taiwan

**E-mail:** [semicontaiwan@semi.org](mailto:semicontaiwan@semi.org)

[www.semicontaiwan.org/en](http://www.semicontaiwan.org/en)

**5–8 September 2018**

## CIOE 2018: 20th China International Optoelectronic Exposition

Shenzhen Convention and Exhibition Center, China

**E-mail:** [derek.deng@cioe.cn](mailto:derek.deng@cioe.cn)

[www.cioe.cn/en](http://www.cioe.cn/en)

**17–21 September 2018**

## EPE'18 ECCE Europe (20th European Conference on Power Electronics and Applications)

Riga, Latvia

**E-mail:** [info@epe2018.com](mailto:info@epe2018.com)

[www.epe2018.com](http://www.epe2018.com)

**23–27 September 2018**

## ECOC 2018: 44th European Conference on Optical Communications

Nuova Fiera di Roma, Rome, Italy

**E-mail:** [registration@ecoc2018.org](mailto:registration@ecoc2018.org)

[www.ecoc2018.org](http://www.ecoc2018.org)

**23–28 September 2018**

## 13th European Microwave Integrated Circuits Conference (EuMIC 2018), part of 21st European Microwave Week (EuMW 2018)

IFEMA, Madrid, Spain

**E-mail:** [eumwreg@itnint.com](mailto:eumwreg@itnint.com)

[www.eumweek.com/conferences/eumic.html](http://www.eumweek.com/conferences/eumic.html)

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**24–28 September 2018**

**35th European Photovoltaic Solar Energy Conference (EU PVSEC 2018)**

SQUARE - Brussels Meeting Centre, Belgium

**E-mail:** pv.conference@wip-munich.de

[www.photovoltaic-conference.com](http://www.photovoltaic-conference.com)

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**24–26 October 2018**

**BIT's 8th Annual Congress of Nano Science and Technology-(Nano S&T-2018)**

Kongresshotel Potsdam am Templiner See, Germany

**E-mail:** stella@bitconferences.com

[www.bitcongress.com/nano2018](http://www.bitcongress.com/nano2018)

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**31 October – 2 November 2018**

**6th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA 2018)**

Georgia Tech Hotel and Conference Center,  
Georgia Institute of Technology, Atlanta, GA, USA

**E-mail:** ieee-mce@ieee.org

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

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**4–7 November 2018**

**2nd IEEE International Power Electronics and Application Conference and Exhibition (PEAC 2018)**

Shenzhen, China

**E-mail:** peac@cpss.org.cn

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

(China Power Supply Society)

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**3–5 December 2018**

**IEEE International Electron Devices Meeting (IEDM 2018)**

Hilton San Francisco and Towers, San Francisco, CA, USA

**E-mail:** iedm@his.com

[www.ieee.org/conference/iedm](http://www.ieee.org/conference/iedm)

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**5–8 December 2018**

**49th IEEE Semiconductor Interface Specialists Conference (SISC 2018)**

San Diego, CA, USA

**E-mail:** meetings@ucsd.edu

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

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**2–6 February 2019**

**IEEE International Solid- State Circuits Conference (ISSCC 2019)**

San Francisco, CA, USA

**E-mail:** Issccinfo@yesevents.com

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

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**2–7 February 2019**

**SPIE Photonics West 2019, including OPTO 2019 – Optoelectronic Materials, Devices, and Applications**

Moscone Centre, San Francisco, CA, USA

Abstract deadline: 23 July 2018

**E-mail:** customerservice@spie.org

[www.spie.org/SPIE\\_PHOTONICS\\_WEST\\_Conference](http://www.spie.org/SPIE_PHOTONICS_WEST_Conference)

[www.spie.org/SPIE\\_OPTO\\_conference](http://www.spie.org/SPIE_OPTO_conference)

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**17–21 March 2019**

**APEC 2019: IEEE Applied Power Electronics Conference and Exposition**

Anaheim Convention Center, CA, USA

**E-mail:** apec@apec-conf.org

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

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**7–9 May 2019**

**PCIM Europe (Power conversion and Intelligent Motion) 2019**

Nuremberg Messe, Germany

**E-mail:** daniela.kaeser@mesago.com

[www.mesago.de/en/PCIM/main.htm](http://www.mesago.de/en/PCIM/main.htm)

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**27–31 May 2019**

**10th International Conference on Power Electronics (ICPE 2019 – ECCE Asia)**

BEXCO, Busan, South Korea

**E-mail:** icpe2019@icpe2019.org

[www.icpe2019.org](http://www.icpe2019.org)

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**24–28 June 2019**

**PVSC 2019: IEEE 46th Photovoltaic Specialists Conference**

Chicago, IL, USA

**E-mail:** info@ieee-pvsc.org

[www.ieee-pvsc.org](http://www.ieee-pvsc.org)

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**8–10 July 2019**

**2019 Summer Topicals Meeting Series**

Fort Lauderdale, FL, USA

**E-mail:** i.donnelly@ieee.org

[www.sum-ieee.org](http://www.sum-ieee.org)

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**2–5 September 2019**

**21st Conference on Power Electronics and Applications (and Exhibition), EPE'19 ECCE (Energy Conversion Congress and Expo) Europe**

Genova, Italy

**E-mail:** info@epe2019.com

[www.epe2019.com](http://www.epe2019.com)

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**6–11 October 2019**

**22nd European Microwave Week (EuMW 2019)**

Paris Expo Porte de Versailles, Paris, France

**E-mail:** eumwreg@itnint.com

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



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