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COMPOUNDS & ADVANCED SILICON

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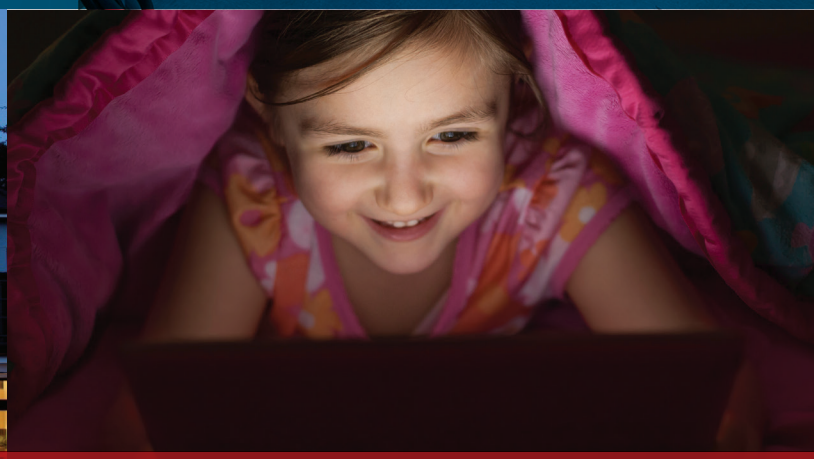
Nitrides for visible light communications

Microchip buying Microsemi • Cree buys Infineon RF Power unit
Lumentum to acquire Oclaro • News from APEC 2018

Lower Cost LEDs



Faster LED Adoption

Another breakthrough from Veeco. This time it's EPIK.

Introducing Veeco's new TurboDisc® EPIK700™ GaN MOCVD system

As global consumption for LED general lighting accelerates, manufacturers need bigger, better MOCVD technology solutions that increase productivity and lower manufacturing costs.

The EPIK700 MOCVD system combines Veeco's award-winning TurboDisc reactor design with improved wafer uniformity, increased productivity and reduced operations expenses to enable a cost per wafer savings of up to 20 percent compared to previous systems.

It also features a reactor with more than twice the capacity of previous generation reactors. This increased volume coupled with productivity advancements within the EPIK700 reactor, results in an unmatched 2.5x throughput advantage over previous reactors.

Learn how Veeco's TurboDisc EPIK700 GaN MOCVD system can improve your LED manufacturing process today.

The advantage is not just big. It's EPIK.

Contact us at *www.veeco.com/EPIK700* to learn more.

Veeco's New TurboDisc EPIK700 GaN MOCVD System

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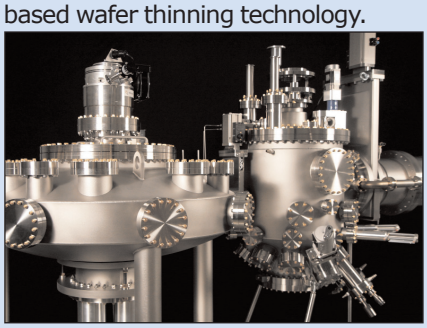
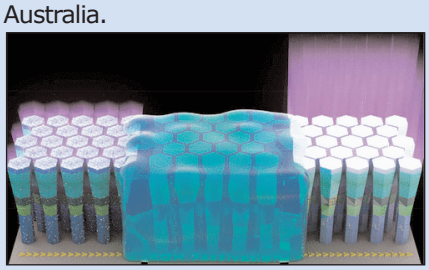
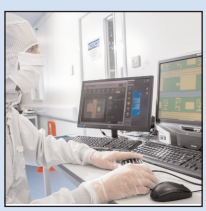


p36 Veeco has completed installation of its 100th automated MBE system — a GEN10 for Silanna Semiconductor in Australia.



p46 KAUST has demonstrated a technique using diluted potassium hydroxide solution for reducing the loss of UV light at the surface of nanostructures.



Cover: III-V opto-electronic foundry CST Global says that its 1490nm, 2.5Gb/s DFB lasers for Gigabit passive optical network applications have been beta sampled and are now available to order from its standard product portfolio. **p56**

editorial

Acquisitions and growth trends

Mid-March's annual Optical Networking and Communication Conference & Exhibition (OFC) in San Diego saw the usual plethora of developments targeting higher data rates (400Gbps) and greater integration of components — see pages 58–71 for a selection of news (with more to follow next issue). But this year's event coincided with the much anticipated integration (of the business variety) among Silicon Valley-based optical component makers, as Lumentum announced a deal to acquire Oclaro for $1.8bn (see page 70).

Lumentum will gain Oclaro's capabilities in indium phosphide lasers and photonic integrated circuits as well as coherent components and modules, as it aims to strengthen its position for high-speed communications.

This supplements Lumentum's strong position in having not only 4"- but also 6"-wafer gallium arsenide manufacturing lines for volume production of vertical-cavity surface-emitting laser (VCSEL) arrays for 3D sensing applications in consumer electronics (for Apple). This recently helped to drive 66.4% quarter-on-quarter growth in Lumentum's revenue.

Meanwhile, dominant optical component supplier Finisar has reported quarterly revenue down 12.7% year-on-year, albeit flat quarter to quarter (see page 68). However, after starting to ship VCSEL arrays for 3D sensing from its 4" fab in Allen, Texas, only late the prior quarter, the firm is aiming to start production at a new 6"-wafer VCSEL fab in Sherman, Texas, in second-half 2018.

Due largely to VCSEL manufacturing ramping up in second-half 2017 for mass-market consumer applications, epiwafer maker IQE more than doubled its Photonics revenue in 2017, and is planning a large capacity expansion, particularly targeting growing demand for VCSELs (see page 34). Likewise, metal-organic chemical vapor deposition (MOCVD) system maker Aixtron is banking on demand for 3D sensing VCSEL manufacturing helping to drive its return to sustainable annual profit in 2018 (see page 39).

As well as VCSELs, Lumentum is also manufacturing edge-emitting lasers for 3D sensing (enabling it to broaden its customer base). Likewise, II–VI Inc has also just launched an edge-emitting laser for 3D sensing, made on 6" GaAs wafers (see page 54).

Meanwhile, in the microelectronics sector, Microchip Technology Inc of Chandler, AZ, has agreed to acquire California-based Microsemi, which makes chips using silicon, GaAs, silicon carbide and gallium nitride technology, for $8.35bn (page 14).

Also, North Carolina-based Cree has acquired the largely US-based RF Power business of Germany's Infineon for €345m, aiming to strengthen its Wolfspeed business' position in RF GaN-on-SiC technologies (targeting faster 4G networks and the transition to 5G) — page 18. This follows Cree in February 2017 terminating a deal to sell its Wolfspeed Power & RF division to Infineon for $850m, after failing to meet national security concerns of the Committee on Foreign Investment in the United States (CFIUS). Ironically, Wolfspeed has since been Cree's best performing sector, with quarterly revenue growing 30% year-on-year (compared with 11% for LED Products and helping to counteract a 31% drop in Lighting Product revenue), rising to 19% of total revenue, with gross margin of over 48% (versus 25.3% for LED Products and just 15.9% for Lighting Products). Cree has also agreed a $100m deal to supply Wolfspeed 150mm SiC wafers to Infineon, exemplifying the other big growth trend at the moment (apart from 3D sensors) — power electronics.

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

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HVM: High Volume Manufacturing

Increase in MOCVD system installations to lead to 28.3% GaN LED surplus in 2019

China capacity expansions for mid-power lighting LEDs driving others to focus on high-power, automotive, UV and light engine sectors

In the last two years, the surplus in gallium nitride (GaN)-based LED wafers and die has been quite small, says market research firm IHS Markit. Metal-organic chemical vapor deposition (MOCVD) system capacity utilizations have been high but, in an environment of uncertain demand and falling prices, manufacturers were reluctant to make further investments, notes Jamie Fox (principal analyst, LEDs & Lighting).

However, in response to growing demand, Chinese manufacturers are once again taking advantage of government subsidies. China's Focus Lighting and Shenzhen MTC have announced MOCVD expansion plans in recent months. Meanwhile Sanan, Osram Opto, HC Semitek and others are also expanding in 2018.

After assessing planned purchases by LED makers, IHS Markit projects that, in 2018, 330 MOCVD reactor chambers will be installed worldwide for producing gallium nitride (GaN)-based LEDs. At the peak in MOCVD shipment in 2010, 754 reactor chambers were shipped but, allowing for the greater production capacity of today's more modern reactors, the actual wafer and die area capacity added in 2018 will be similar to that peak year. So, after MOCVD reactor chamber installations led to a GaN LED surplus of 7.4% in 2017, this surplus will grow to 15.8% in 2018 and 28.3% in 2019 (with an average capacity utilization of 78% in 2019).

IHS Markit's forecast takes account of the available GaN LED supply — MOCVD system makers AMEC in China and Veeco in the USA will likely be working at full capacity to meet the expected higher demand in the coming years. MOCVD shipments in 2018 may even be limited by the available supply of systems, rather than demand.

China gaining market share

China's production capacity for LED wafers and die increased dramatically between 2010 and 2018. The country has transformed itself from a small player in the LED market to become the country with more production capacity than the rest of the world combined.

This planned growth by Chinese companies was more than an attempt to meet demand; instead the goal was to increase the country's market share, says IHS Markit. In fact, China's San'an is now clearly ahead of Taiwan's Epistar as the global leader in wafer and die production capacity.

Mid-power LEDs in lighting, automotive headlights and signage are among the areas that did well in 2017, and they will continue to grow in 2018 — even allowing for the fact that some portion of the announced orders might be canceled or deferred into the following year, says IHS Markit. The expected over-capacity will have a bigger effect on some markets, including lighting, and less on automotive and other markets, where the newer entrants are not qualified and the barrier to entry is much higher.

The expected over-capacity will have a bigger effect on some markets, including lighting, and less on automotive and other markets, where the newer entrants are not qualified and the barrier to entry is much higher

In a world of $0.01 2835-packaged mid-power LEDs for general lighting in Asia, LED vendors from other countries are realizing that they cannot compete with China's subsidies and low costs. Vendors outside China are therefore now typically focusing on other LED categories for growth and profitability, including high power instead of low power, automotive instead of lighting, ultraviolet instead of visible, and light engines instead of packaged LEDs.

For example, South Korean LED maker LG Innotek's revenue fell in fourth-quarter 2017, and the firm announced that it will instead focus on higher-end products and ultraviolet LEDs. This is a direct response to the growth of Chinese capacity. Other companies have followed a similar strategy, but they have been able to avoid revenue declines by focusing more on the high-end market, along with automotive and signage, in addition to lighting.

Another dynamic is that most non-Chinese companies have not expanded their capacity in recent years. In fact, many of them have not invested in MOCVD at all, which means that capacity may even decline over time, as older systems go offline. These companies instead buy die from China and sell them as packaged LEDs or light engines. In some cases, they outsource to China their entire production of packaged LEDs. The current trend of expanding production capacity — along with further expansions in China — likely means that this trend will continue, says IHS Markit.

www.ihsmarkit.com

Micro-LED & mini-LED applications to account for 11.4% of LED wafer volume by 2022

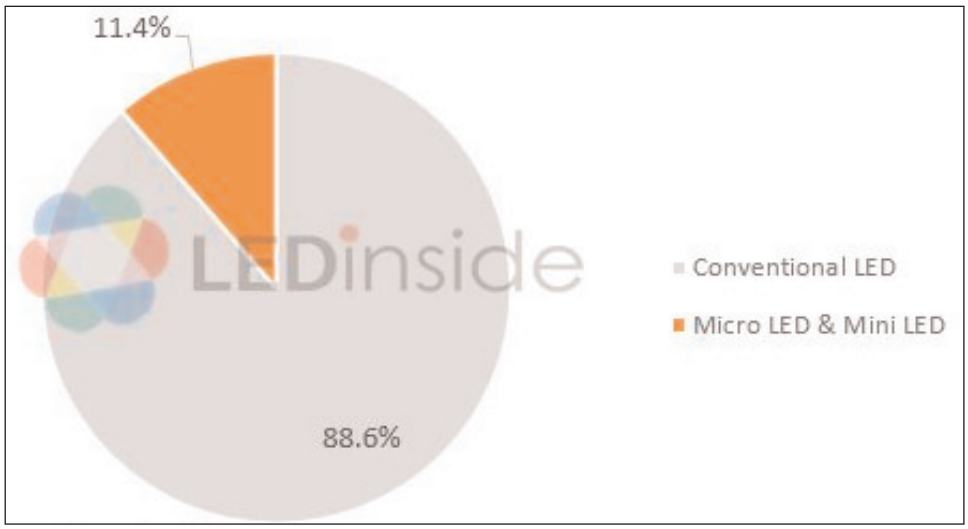
LED makers need new applications as China's LED capacity expansion accelerates price declines

While conventional LEDs are used for backlighting, micro-LED and mini-LED technology has been used for self-emitting in displays of consumer electronics. Since each LED represents a pixel (increasing the number of LED wafers used), wafers for applications using micro-LEDs and mini-LEDs will account for 11.4% of the total LED wafers used worldwide by 2022, forecasts market research firm LEDinside (a division of TrendForce). These applications will become a key driver of market demand, it adds.

The volume of 4-inch equivalent LED wafers was about 37 million in 2017, up 30% year-on-year, according to research director Roger Chu. Although the rise of organic light-emitting diodes (OLEDs) will affect the number of LEDs used in backlighting of mobile phones and large-size panels, the number of LED wafers used for general lighting and automotive lighting continues to grow. Coupled with the rapid growth of fine-pitch display applications, the number of LED wafers used has increased dramatically.

However, as Chinese LED makers continue to expand their capacities significantly, overall industry capacity may grow much faster than demand in the future. Vendors therefore need to rely on new applications to boost demand, so technical progress in micro-LEDs and mini-LEDs will play a key role, believes LEDinside.

In terms of LED market revenue, LED prices will decline further due to the substantial capacity expansion of Chinese manufacturers, notes the market research firm. However, LED penetration continues to increase, driven by general lighting and automotive lighting applications. Coupled with the new applications of micro-LEDs and mini-LEDs, it is forecasted that LED market revenue will grow at a compound annual growth rate (CAGR) of 7% from $17.16bn in 2017 to $25.5bn in 2022.



LED wafer volume forecast for applications using micro-LED and mini-LEDs by 2022.

The volume of 4-inch equivalent LED wafers was about 37 million in 2017, up 30% year-on-year

Deployment of micro-LED & mini-LED technology worldwide

Micro-LEDs are considered to represent a new-generation display technology due to its properties of high resolution, high brightness, power saving, and rapid response time etc. Companies worldwide have been actively involved in developing micro-LED products, and key players include Apple, Samsung, LG, Sony, Facebook and Google, as well as Chinese firms like San'an Optoelectronics, HC Semi-Tek, Changelight, Leyard and MTC etc.

LED market revenue will grow at a compound annual growth rate of 7% from $17.16bn in 2017 to $25.5bn in 2022

Taiwanese companies are also active in micro-LED development. The Industrial Technology Research Institute (ITRI) is establishing a micro-LED demo product line, which is expected to deliver products to virtual reality (VR) product makers from third-quarter 2018. Other major companies such as Epistar, AU Optronics, Innolux, PlayNitride and Macroblock etc have all actively joined in the development of related technologies.

As micro-LED technology still faces technical bottlenecks, transitional mini-LED products are being favored by manufacturers, including chip makers like Epistar, Lextar, San'an Optoelectronics and HC SemiTek, packaging companies like Everlight, Advanced Optoelectronic Technology, Harvatek and Seoul Semiconductor, IC designers like Macroblock, Raydium and Jasper Display, panel makers like AU Optronics and Innolux, and digital display makers like Leyard, notes LEDinside.

www.ledinside.com

Skyworks launches SkyOne LiTE front-end for LTE mobile devices

At the Mobile World Congress (MWC2018) in Barcelona, Spain (26 February – 1 March), Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) launched SkyOne LiTE, a highly integrated front-end solution for LTE mobile devices.

Building on the firm's proven SkyLiTE architecture, the new platform incorporates power amplifiers, proprietary duplexers and innovative switching technology to support complex carrier aggregation combinations in a much reduced form factor. The systems also include a diversity receive front-end module and high linearity antenna switches to further improve functionality. The SkyOne LiTE family is said to decrease development time for smartphone manufacturers.

With the increasing demand for feature-rich mobile phones utilizing full-screen displays, dual cameras and seamless multi-tasking capabilities, handset OEMs across the mobile ecosystem are faced with balancing the constraints of RF operation and industrial design, says Skyworks. To address this need, SkyOne LiTE delivers what is claimed to be best-in-class transmit and receive performance while reducing the footprint by more than 20%. With two variants, the pin-to-pin solution supports 10 bands for North America and 12 bands for Europe and Asia Pacific.

The SkyOne LiTE family supports carrier aggregation with switch hexaplexer functionality while delivering higher power, lower insertion loss and reduced current consumption. The platform includes the following options:

- SKY78185-11/21 — low-band front-end modules with 2G/3G/4G power amplifiers (PAs) for LTE applications that include four duplexers and are designed for use in all regions;
- SKY78187-11 — a mid- and high-band front-end module with 3G/4G PAs for LTE applications that integrates five duplexers and one TDD filter and is designed for North America;
- SKY78188-11 — a mid- and high-band front-end module with 3G/4G PAs for LTE applications that uses four duplexers and four TDD filters and is designed for Europe and China;
- SKY96500-11 — LTE diversity receive module with a MIPI RF front-end interface; and
- SKY13698-694LF — double-pole, double-throw antenna swap switch.

"Skyworks' newest connectivity solutions are enabling next-generation, value-oriented smartphones with the most advanced wireless architectures," says Reza Kasnavi, VP & general manager, Open Market Platforms for Skyworks. "SkyOne LiTE embodies our close collaboration with partners and customers to significantly push the technology envelope and simplify the design process with fully integrated modules."

According to a 2017 report from Accenture, developing markets are expected to account for 75% of all smartphone sales in 2018 and will be the engine for overall market growth. This reflects consumers' growing demand for upgraded handsets that include enhanced entertainment and media features, productivity and gaming experiences.

www.mobileworldcongress.com
www.skyworksinc.com/Products_SkyOne_LiTE.aspx

Fairview launches E- & W-band PIN diode waveguide switches

Fairview Microwave Inc of Lewisville, TX, USA, which provides on-demand RF and microwave components, has released a new line of E-band and W-band millimeter-wave single-pole single-throw (SPST) and single pole double-throw (SPDT) PIN diode waveguide switches offering an ultra-broadband frequency range with fast switching performance.

Suitable for telecoms, test instrumentation, R&D programs and radar front ends in applications that involve general switching, receiver protection, pulse modulation and antenna beam switching, the four new PIN diode waveguide switches feature fully integrated WR10 and WR12 waveguide ports that support a UG387/U flange and cover E-band (60–90GHz) and W-band (75–110GHz) frequencies.

The designs use gallium arsenide (GaAs) beam-lead diodes and low-loss Fin-line technology, yielding 4dB typical insertion loss, 25dB of isolation and fast switching speed of <300ns. Fully integrated TTL driver circuitry with an SMA connector control port provides ease of use. All models require a dual voltage bias of +5/–5V_{dc} and have a maximum rated CW input power level of 0.5dBm. Rugged MIL-grade compact package configurations integrate both switch and control packaging and offer maximum performance and reliability over a full temperature range of –55°C to +85°C.

"These waveguide switches usually command long lead-times, but Fairview has four different models available off-the-shelf and ready for delivery," says product manager Tim Galla. Fairview's new E- and W-band PIN diode waveguide switches are in stock and ready for immediate shipment with no minimum order quantity.

www.fairviewmicrowave.com/rf-products/e-and-w-band-waveguide-pin-diode-switches.html

Skyworks unveils suite of Sky5 solutions for 5G wireless communications

At the GSMA's Mobile World Congress (MWC2018) in Barcelona, Spain (26 February – 1 March), Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) launched its first family of products from its Sky5 platform enabling 5G connectivity.

The wireless engines, which include highly integrated, high-performance transmit/receive front-end solutions as well as diversity receive (DRx) modules, are designed specifically for new spectrum in the sub-6GHz range, are baseband agnostic and compliant with 3GPP standards. Future products will include modules that address eLAA and C-V2X applications in the same frequency ranges.

To meet early demand for sub-6GHz 5G new radio (NR) usage cases, Skyworks is leveraging its technology portfolio to meet requirements for low, mid, high and ultra-high cellular frequency bands. Through its SkyBlue enabling technology, these modules also provide what is claimed to be industry-leading power efficiency. All Sky5 solutions will support new 5G waveforms and spectrum in addition to enhanced carrier aggregation and dual connectivity (4G/5G) while delivering high levels of integration and performance.

"Skyworks' innovative Sky5 architectures are accelerating the deployment of 5G wireless communications," says Joel King, VP & general manager of Advanced Mobile Solutions. "We recognize that 5G requires significantly more powerful and complex connectivity solutions and are excited to employ our systems expertise, operational scale and solid customer partnerships to resolve these challenges."

According to Ericsson's June 2017 Mobility Report, 15% of the world's population is expected to be covered by 5G in 2022. North America is projected to be first in adoption rates for 5G, with a quarter of all mobile subscriptions in the region to be on 5G by 2022.

The GSMA reports that 60% of the world's population is already covered by 4G networks and more than 2.5 billion individuals are connected to 3G or 4G networks and services. LTE-Advanced networks will form the foundation for rapid rollout of 5G, providing both networks and platforms to further digitize economies and societies.

All Sky5 solutions offer MIPI interface and are highly flexible, with customizable architectures to optimize performance, footprint and power efficiency. Initial products include:

- SKY78250 — a 5G NR power amplifier module with integrated filtering and dual-path low-noise amplifiers (LNA) supporting N77, N78, N79 and B42, B43, B48 bands. This device also uses SkyBlue technology and integrates a dual antenna output.
- SKY97005 — a 5G NR diversity receive module with integrated filtering and dual-path LNAs supporting N77, N78, N79 and B42, B43, B48 bands. This device also incorporates a dual antenna interface.
- SKY85762 — an eLAA front-end module with a dual-mode power amplifier and simultaneous LAA/Wi-Fi receive functionality (for release in late 2018).
- SKY85761 — a cellular Vehicular-to-Everything (C-V2X) front-end module with Class 2 power and integrated gain control (for release in late 2018).

www.mobileworldcongress.com
www.skyworksinc.com/Sky5
www.skyworksinc.com/Products_5G.aspx

Anokiwave launches second IC in new family supporting 3GPP-compliant millimeter-wave 5G equipment

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 launched the 28GHz AWMF-0157 as the second product in a new family of second-generation 5G silicon quad core ICs enabling 3GPP-compliant base stations (part of Anokiwave's on-going strategy to enable the commercialization of 5G mmW systems with silicon ICs).

Like the 37.1–40.0GHz AWMF-0156, the new AWMF-0157 (which operates at 26.5–29.5GHz) supports four radiating elements, and includes gain and phase controls for analog RF beam steering. Anokiwave's patent-pending IP blocks implemented in silicon technology enable low-cost hybrid beam forming with high energy efficiency and low-latency beam steering.

"As the push to roll out 5G networks by the end of the year is proceeding at full speed, Anokiwave is executing on an aggressive strategy to deliver mmW 5G solutions with industry-first ICs at 26GHz, 28GHz and 39GHz," says chief architect David Corman. "The new family of ICs that enable 3GPP compliance is an essential step that allows network operators to roll out 5G coverage in earnest," he adds.

The AWMF-0157 is a highly integrated silicon IC packaged in a wafer-level chip-scale package (WLCSP), fitting within the typical 5.3mm lattice spacing at 28GHz.

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 in May.

www.anokiwave.com

Anokiwave highlights strategy to enable roll-out of millimeter-wave 5G systems at Mobile World Congress

Anokiwave says that, at the GSMA's Mobile World Congress (MWC 2018) in Barcelona Spain (26 February – 1 March), its 5G ICs powered more than 10 customer 5G arrays at all three mmW 5G bands. In addition, more than 10 Anokiwave Active Antenna Innovator Kits, driven by the firm's 5G ICs, were featured at several partner booths.

As part of its strategy to enable mmW 5G systems by industrializing planar active antennas with silicon core ICs, Anokiwave has introduced silicon ICs at each of the major mmW bands — 26GHz, 28GHz and 39GHz. The AWMF-0108 IC (launched in 2016) operates at 26.5–29.5GHz, the AWMF-0123/5 ICs (launched in 2017) operate at 37.1–40GHz, and the AWMF-0135 (launched in 2017) operates at 24.25–27.5GHz. Each of the quad core ICs features embedded functions for remote telemetry and low-latency steering.

To demonstrate the performance achievable using low-power silicon integration and efficient antenna layout and design, Anokiwave and its partner Ball Aerospace have introduced a family of Active Antenna Innovator Kits at the frequencies 26GHz and 28GHz. The 64-element and 256-element active antennas show how 5G coverage can be rolled out by network operators using the mmW bands, with low power footprint and high energy efficiency, while meeting key operating specifications for data rate, latency, coverage and reliability.

"As 5G wireless network deployments are expected worldwide as early as 2018, Anokiwave stands ready to equip service providers and OEMs with innovative ICs in large volumes for all major 5G mmW bands," says CEO Robert Donahue.

www.mobileworldcongress.com
www.anokiwave.com/mwc2018

GlobalFoundries' new RF ecosystem program to speed time-to-market for wireless connectivity, radar and 5G

RFWave Partner Program targets faster product deployment on RF technology platforms

GlobalFoundries of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with operations in Singapore, Germany and the USA) has announced the new ecosystem partner program RFWave, designed to simplify RF design and help customers reduce time-to-market for a new era of wireless devices and networks.

The last few years has seen increasing demand for connected devices and systems that will require innovations in radio technologies to support the new modes of operation and higher capabilities, notes the firm. The RFWave Partner Program builds on GlobalFoundries' 5G vision and roadmap (announced last October), with a focus on its RF solutions such as fully depleted silicon-on-insulator (FD-SOI), RF CMOS (bulk & advanced CMOS nodes), RF SOI and silicon germanium (SiGe) technologies. The program aims to provide a low-risk, cost-effective path for designers seeking to build highly optimized RF solutions for wireless applications such as Internet of Things (IoT) across various wireless connectivity and cellular standards, standalone or transceiver-integrated 5G front-end modules, millimeter-wave backhaul, automotive radar, small-cell and fixed-wireless and satellite broadband.

RFWave enables customers to build RF solutions as well as packaging and test solutions. Initial partners have committed a set of key offerings to the program, including:

- electronic design automation (EDA) tools that complement industry-leading design flows by adding specific modules to easily leverage features of GlobalFoundries' RF technology platforms;
- a comprehensive library of design elements (IP), including foundation IP, interfaces and complex IP to enable foundry customers to start their designs using pre-validated IP elements;
- resources (design consultation, services), trained and globally distributed, for partners to gain easy access to support in developing solutions using GlobalFoundries' RF technologies

"An explosion of digital information is expected to drive an enormous amount of growth in the coming years, and our customers are already preparing for a future of seamless, reliable ultrahigh-data-rate wireless connectivity everywhere," says Bami Bastani, senior VP of the RF business unit. "GlobalFoundries' RFWave program takes industry collaboration to a new level, enabling our customers to build differentiated, highly integrated RF-tailored solutions that are designed to accelerate the next wave of technology."

The RFWave Partner Program creates an open framework to allow selected partners to integrate their products or services into a validated, plug-and-play catalog of design solutions. This level of integration allows customers to create high-performance designs while minimizing development costs through access to a broad set of offerings, specific to RF technology. The partner ecosystem aims to position members and customers to take advantage of ubiquitous connectivity and the broad adoption of GlobalFoundries' RF technology platforms.

Initial members of the RFWave Partner Program are asicNorth, Cadence, CoreHW, CWS, Keysight Technologies, Spectral Design and WEASIC, which have already initiated work to deliver highly optimized RF solutions.

www.globalfoundries.com

SILTECTRA validates twinned SiC wafer produced using COLD SPLIT laser-based wafer thinning technique

GaN-on-SiC HEMT power device produced on split-off wafer at firm's new facility in Dresden

SILTECTRA GmbH of Dresden, Germany says that it has validated the first high-electron-mobility transistor (HEMT) structure fabricated on a twinned silicon carbide (SiC) wafer processed using its proprietary COLD SPLIT laser-based wafer thinning technology.

As a laser-based wafer-thinning technique for substrate materials like silicon carbide, gallium nitride, silicon and sapphire, COLD SPLIT outperforms traditional grinding methods by thinning wafers to 100μm and below in minutes, with virtually no material loss, claims SILTECTRA. Now, due to a novel 'twinning' adaptation, the firm has 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.

SILTECTRA reckons that the development promises substantial benefits for manufacturers of SiC-based ICs for power electronics and RF applications. The firm reckons that the solution's combined advantages — which include fewer process steps, potentially lower equipment costs, and efficient use of substrate material — could reduce total device production costs by as much as 30%.

SILTECTRA validated the process by producing a GaN-on-SiC HEMT power device on a split-off (twinned) wafer at its new facility in Dresden. The HEMT showed results that were said to be superior to a non-COLD-SPLIT-enabled HEMT when measured for CMP characterization, as well as GaN epitaxy, metal layer and gate layer outcomes.

New substrate materials demand manufacturing cost reductions

Until now, the traditional method to thin wafers to less than 20% of the original thickness was grinding, involving the use of expensive diamond grinding wheels. While valued as a reliable solution for silicon, certain challenges make it difficult for grinding to achieve the extreme level of thinness required for SiC-based devices, says SILTECTRA. Unlike silicon, which is relatively soft, SiC is very hard (second only to diamond), which makes cutting and grinding arduous and expensive. Also, grinding is not a fast process, and the cost of consumables for the grinding wheels can be substantial. Finally, grinding generates material loss, and the process lowers overall yield, further driving up cost.

SILTECTRA hence engineered COLD SPLIT as a faster, higher-yield, lower-cost alternative to grinding for substrates like SiC. The technique employs a chemical-physical process that uses thermal stress to generate a force that splits the material with precision along the desired plane. Thinning is hence accomplished in minutes instead of an hour for traditional grinding tools, and cuts material loss by as much as 90%, it is reckoned.

SILTECTRA's Dresden HQ where COLD SPLIT twinning process was developed.

COLD SPLIT can reclaim substrate material generated during backside grinding, and create a second fully optimizable bonus wafer

The twinning development extends COLD SPLIT's capabilities. The adaptation provides a simple way for integrated device manufacturers (IDMs) to avoid expensive kerf loss when slicing ingots or boules into wafers, says SILTECTRA, effectively replacing backside grinding processes while producing an identical wafer primed for a second device run. "We were confident that we could not only produce a faster and cheaper thinning solution for substrates like SiC, but that we could double the value for customers by extending COLD SPLIT's reach to create a twin wafer from material previously lost during backside grinding," says SILTECTRA's CEO Dr Harald Binder.

Binder notes that the twinning development was achieved ahead of schedule on the company's technology roadmap. IDMs are now evaluating the technology. SILTECTRA is qualifying the process on customers' SiC material at its newly extended facility in Dresden, while preparing to apply the COLD SPLIT technique to additional substrate materials. The firm also provides wafering and thinning services at the same location.

www.SILTECTRA.com

ON Semiconductor extends silicon carbide diode portfolio by adding 650V Schottkys

ON Semiconductor of Phoenix, AZ, USA — which supplies power management, analog, sensors, logic, timing, connectivity, discrete, system-on-chip (SoC) and custom devices — has extended its silicon carbide (SiC) diode portfolio by introducing its newest family of 650V Schottkys. The diodes' SiC technology is said to provide higher switching capabilities with lower power losses and easy paralleling of devices.

The new family of 650V SiC diodes includes surface-mount and through-hole packages ranging from 6A to 50A. All of the diodes provide zero reverse recovery, low forward voltage, temperature-independent current stability, high surge capacity, and positive temperature coefficient.

The new diodes are targeted at engineers designing power factor correction (PFC) and boost converters for applications including solar photovoltaic (PV) inverters, electric vehicle/hybrid electric vehicle (EV/HEV) chargers, telecom power and data-center power supplies while facing challenges to deliver smaller footprints at higher efficiencies.

The 650V devices offer the combined system benefits of higher efficiency, higher power density, smaller footprints and enhanced reliability. They exhibit a reduced power loss due to the inherent low forward voltage (V_F) and no reverse recovery charge of SiC diodes, and hence improved efficiency. The faster recovery of SiC diodes allows for higher switching speeds and therefore reduces the size of magnetics and other passive components, enabling greater power density and smaller overall circuit designs. In addition, they can withstand higher surge currents and deliver stability over their −55°C to +175°C operating temperature range.

ON Semiconductor's SiC Schottky diodes feature a patented termination structure that is said to reinforce reliability and enhance stability and ruggedness. Additionally, they offer what is claimed to be higher avalanche energy, the industry's highest unclamped inductive switching (UIS) capability and lowest leakage currents.

"ON Semiconductor's new 650V family of SiC diodes complement the company's existing 1200V SiC devices, bringing a broader product range to our customers," says Simon Keeton, senior VP & general manager of ON Semiconductor's MOSFET business unit. "Utilizing the unique characteristics of wide-bandgap materials, SiC technology offers tangible benefits over silicon, and their robust construction provides a dependable solution in applications in challenging environments," he adds. "Customers will benefit from simplified, better-performing, smaller-footprint designs as a result of these new devices."

The SiC Schottky diodes feature a patented termination structure that is said to reinforce reliability and enhance stability and ruggedness

The 650V SiC diode devices are offered in DPAK, TO-220 and TO-247 packages, priced at $1.30–14.39 per unit in 1000 unit quantities.

At the Applied Power Electronics Conference (APEC 2018) in San Antonio, Texas (4–8 March), ON Semiconductor gave a live demonstration of its SiC MOSFETs and diodes, showing how the firm's latest simulation modelling techniques can accurately match real-life device operation.

www.onsemi.com/PowerSolutions/parametrics.do

Microchip acquiring Microsemi for $8.35bn

Complementary analog and mixed-signal product lines expand Microchip's solutions for data-center, communications, defense and aerospace markets

Microcontroller, mixed-signal, analog and Flash-IP solution provider Microchip Technology Inc of Chandler, AZ, USA has agreed to acquire Microsemi Corp of Aliso Viejo, CA, USA (which makes chips for aerospace & defense, communications, data-center and industrial markets, using silicon, gallium arsenide, silicon carbide and gallium nitride technology) for $68.78 per share (representing a total equity value of $8.35bn, and an enterprise value of $10.15bn, after accounting for Microsemi's cash and investments, net of debt, on its balance sheet at the end of 2017).

"Even as we execute a very successful Microchip 2.0 strategy that is enabling organic revenue growth in the mid to high single digits, Microchip continues to view accretive acquisitions as a key strategy to deliver incremental growth and stockholder value," says Microchip's chairman & CEO Steve Sanghi.

"The Microsemi acquisition is the latest chapter of this strategy and will add further operational and customer scale to Microchip," he adds.

"Microchip and Microsemi have a strong tradition of delivering innovative solutions to demanding customers and markets, thus creating highly valued and long-lasting revenue streams," says Microchip's president & chief operating officer Ganesh Moorthy. "Joining forces and combining our complementary product portfolios and end-market exposure will offer our customers a richer set of solution options to enable innovative and competitive products for the markets they serve," he believes.

"This transaction represents a compelling opportunity for Microsemi stockholders, employees and customers by combining the leading embedded control market position of Microchip Technology with the world class power, security, reliability and performance solutions from Microsemi," states Microsemi's chairman & CEO James J. Peterson.

The transaction is expected to be immediately accretive to Microchip's non-GAAP earnings per share. Microchip expects $300m in synergies in the third year after the transaction's close. The firm plans to finance the acquisition with $1.6bn of cash from the combined company balance sheets, $3bn from Microchip's existing line of credit, about $5bn in new debt and $0.6bn of a cash bridge loan.

The board of directors of each firm has unanimously approved the acquisition.

Subject to approval by Microsemi stockholders, customary regulatory approvals and other closing conditions, the transaction is expected to close in second-quarter 2018.

www.microchip.com
www.microsemi.com

Analog Devices introduces high-power and high-voltage isolated-gate driver board for Microsemi power modules

In collaboration with Microsemi Corp of Aliso Viejo, CA, USA, Analog Devices Inc of Norwood, MA, USA (which provides mixed-signal ICs for cable access) has introduced a high-power evaluation board for half-bridge silicon carbide (SiC) power modules with up to 1200V and 50A at 200kHz switching frequency. The isolated board is engineered to improve design reliability while also reducing the need to create additional prototypes — saving time, lowering costs and decreasing time to market for power conversion and energy storage customers, it is claimed. Analog Devices and Microsemi are showcasing the board at the Applied Power Electronics Conference & Exposition (APEC 2018) in San Antonio, Texas (4–8 March).

The new board can be used as the building block of more complex topologies, such as full-bridge or multi-level converters, for complete bench debugging of customer solutions. It can also function as a final evaluation platform or in converter-like configuration for full test and evaluation of Analog Devices' ADuM4135 isolated-gate driver with iCoupler digital isolation technology and LT3999 DC–DC driver in a high-power system.

Priced at $495, the EV-MS4135PL1Z-UI high-power evaluation board enables Microsemi's SiC power modules to provide benefits such as a common test bench, higher power density for reduced size and cost, and isolated and conductive substrate and minimum parasitic capacitance for higher efficiency, performance, and thermal management. These attributes make the board suitable for applications including electric vehicle (EV) charging, hybrid EV (HEV)/EV onboard charging, DC–DC converters, switched mode power supply (SMPS), high-power motor control and aviation actuation systems, plasma/semi cap equipment, lasers and welding, MRI and x-rays.

www.microsemi.com/existing-parts/parts/112754

Microsemi samples new 1200V SiC MOSFETs and SiC SBDs for industrial and automotive markets

Microsemi Corp of Aliso Viejo, CA, USA (which makes chips for aerospace & defense, communications, data-center and industrial markets) has announced sampling availability of the 40mΩ MSC040SMA120B, the first product in its next-generation 1200V silicon carbide (SiC) MOSFET range. The firm has also launched its complementary 1200V SiC Schottky barrier diodes (SBDs), further expanding its growing portfolios of SiC discretes and modules.

The new SiC MOSFET family is highly avalanche-rated, demonstrating the devices' ruggedness for industrial, automotive and commercial aviation power applications, and offers a high short-circuit withstand rating for robust operation. Additional members of the product family will be released in the coming months, including commercially and AEC-Q101-qualified 700V and 1200V SiC MOSFETs to address a wide range of power applications that can leverage Microsemi's new SiC SBDs.

The new SiC MOSFET product family provides more efficient switching and high reliability, particularly in comparison to silicon diodes, silicon MOSFETs and insulated-gate bipolar transistor (IGBT) solutions, says Leon Gross, VP & business unit manager for Microsemi's Power Discretes and Modules business unit. "Customers focused on developing cost-effective power electronics solutions for rugged environments can select their ideal solutions from these next-generation offerings, with the ability to scale to their specific SiC MOSFET needs."

The next-generation SiC MOSFETs and new SiC SBDs are designed with high repetitive unclamped inductive switching (UIS) capability at rated current, with no degradation or failures. The new SiC MOSFETs maintain high UIS capability at 10–15J/cm^2 and robust short circuit protection at 3–5μs. The firm's SiC SBDs are designed with balanced surge current, forward voltage, thermal resistance and thermal capacitance ratings at low reverse current for lower switching loss. In addition, its SiC MOSFET and SiC SBD die can be paired together for use in modules.

Microsemi says that its new SiC MOSFETs and SBDs are suitable for a wide range of applications in the industrial and automotive markets, and that its SiC MOSFETs can also be used in switch-mode power supply (SMPS) and motor control applications in the medical, aerospace, defense and data-center markets. Examples include hybrid electric vehicle (HEV)/EV charging, conductive/inductive onboard charging (OBC), DC–DC converters, EV powertrain/tractional control, switch-mode power supply, photovoltaic (PV) inverters, motor control and actuation for aviation.

According to research and consulting firm IndustryARC, wide-bandgap semiconductor technologies, namely SiC-based devices, are likely to shift from the development to commercial phase due to growth in power electronics applications to enhance power conversion efficiency and minimize power losses. The advance in power conversion paves the way for SiC-based devices in EV charging, which helps to reduce battery charging cycles as well the high cost of battery packs. Integration of SiC devices in on-board charging and DC-to-DC power conversion systems enables higher switching frequency and lower losses. IndustryARC expects the SiC market in EV charging to see a growth rate of 33% until 2024.

Microsemi says its SiC MOSFETs offer 10 times lower failure-in-time (FIT) rate than comparable silicon IGBTs at rated voltages with regard to neutron susceptibility. The firm's SiC SBDs complement the robustness of its SiC MOSFETs, with UIS ratings 20% higher than competitor parts tested, it is reckoned. The firm claims that its SiC products offer other advantages including improved system efficiency, with 25–50% power output increases for the same physical dimensions, efficiency at higher switching frequencies over IGBTs, reduced system size and weight, operating stability over temperature (+175°C) and significant cooling cost savings.

The MSC040SMA120B is sampling now, and the complementary SiC SBDs are available in full production.

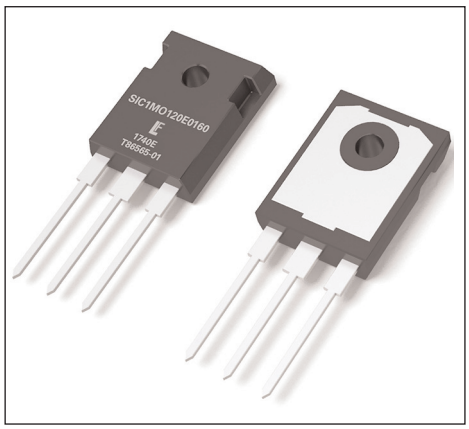
The devices and corresponding SiC gate driver solutions were showcased at the Applied Power Electronics Conference (APEC 2018) in San Antonio, Texas (4–8 March).

www.apec-conf.org
www.microsemi.com/sicmosfets

Littelfuse launches 1200V SiC MOSFETs with 120mΩ and 160mΩ on-resistance at APEC

Littelfuse Inc of Chicago, IL, USA, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), and Monolith Semiconductor Inc of Round Rock, TX, USA, a developer of silicon carbide (SiC) technology in which Littelfuse holds a controlling interest, have added two 1200V SiC n-channel, enhancement-mode MOSFETs to their expanding first-generation portfolio of power semiconductor devices. The new SiC MOSFETs are the latest products of a strategic partnership that Littelfuse formed with Monolith in 2015 to develop power semiconductors for industrial and automotive markets.

Announced in Littelfuse booth at the Applied Power Electronics Conference & Exposition (APEC 2018) in San Antonio, Texas (4–8 March), the LSIC1MO120E0120 and LSIC1MO120E0160 SiC MOSFETs offer ultra-low on-resistance ($R_{DS(ON)}$) levels of just 120mΩ and 160mΩ, respectively. The SiC MOSFETs are designed for use as power semiconductor switches in a wide range of power conversion systems, outperforming their silicon MOSFET counterparts substantially in terms of blocking voltage, specific-on resistance, and junction capacitances. They also offer a combination of high operating voltages and ultra-fast switching that traditional power transistor solutions such as silicon IGBTs with similar current ratings and packages cannot match, says Littelfuse.



Littelfuse's new LSIC1MO120E0120 silicon carbide MOSFET.

Typical applications include: electric vehicles, industrial machinery, renewable energy (e.g. solar inverters), medical equipment, switch-mode power supplies (SMPS), uninterruptible power supplies (UPSs), motor drives, high-voltage DC/DC converters, and induction heating.

"These new SiC MOSFETs provide power converter designers with a state-of-the-art alternative to traditional silicon-based transistors," says Michael Ketterer, product marketing manager for Power Semiconductors at Littelfuse. "Their inherent material characteristics and ultra-fast switching capabilities offer a variety of design optimization opportunities including increased power density, higher efficiency, and the potential for lower bill-of-material costs."

The new 1200V SiC MOSFETs are said to offer the following benefits:

- A reduction in passive filter components at the system level supports increased power density, for a design that's optimized for use in high-frequency, high-efficiency applications.
- Extremely low gate charge and output capacitance, combined with ultra-low on-resistance, allows for minimal power dissipation, higher efficiency and a reduction in the size and sophistication of the cooling techniques required.

The LSIC1MO120E0120 and LSIC1MO120E0160 SiC MOSFETs are available in TO-247-3L packages in tubes in quantities of 450.

www.monolithsemi.com

Littelfuse exhibits expanding power semiconductor portfolio at APEC 2018

Littelfuse Inc of Chicago, IL, USA, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), says that IXYS Corp of Milpitas, CA, USA and Leiden, The Netherlands (which it acquired in January) and Monolith Semiconductor Inc of Round Rock, TX, USA, a developer of silicon carbide (SiC) technology in which Littelfuse holds a controlling interest, exhibited their growing power semiconductor portfolio in the Littelfuse booth at the Applied Power Electronics Conference & Exposition (APEC 2018) in San Antonio, Texas (4–8 March).

The portfolio expansion is the result of the IXYS acquisition and the latest additions to the SiC metal-oxide-semiconductor field-effect transistor (MOSFET) and diode product line from Monolith. This year's APEC conference activities also include a panel discussion, in-booth demonstrations, and industry session presentations.

A broader power semiconductor portfolio

Littelfuse and IXYS made their first joint public appearance at APEC to talk about plans to market what has now become one of the industry's broadest power semiconductor product portfolios, it is reckoned. The IXYS acquisition adds new technologies for the manufacturing of power modules, high-temperature/low-loss discretes, medium- and high-power thyristors, fast recovery diodes and rectifiers, industrial IGBTs, MOSFETs, driver and control ICs, and optical and solid-state relays. These complement existing Littelfuse technologies, which include low-power thyristors, ignition IGBTs, and SiC Schottky diodes and MOSFETs. The IXYS acquisition significantly broadens the Littelfuse power semiconductor portfolio and power electronics applications expertise, and allows serving the full range of power semiconductor needs.

"During the last few years, IXYS and Littelfuse have been expanding their product platforms to pursue many of the same markets," says Corey Deyalsingh, director, Power Semiconductors at Littelfuse. "The IXYS acquisition gives Littelfuse customers a single source for power semiconductors, so no matter what the application is, Littelfuse can support it with the delivery and application support customers need on a global scale," he adds. "The product technology reach means we can offer customers unbiased advice on the best solutions for their applications. Together, we provide power electronics design engineers the advanced application expertise they need to innovate at the very highest levels while complying with changing global standards."

In-booth demonstrations

In-booth demonstrations of Littelfuse technologies included the Dynamic Characterization Platform for characterizing SiC device switching behavior and the Gate Drive Evaluation Platform for studying the optimal device driving conditions for specific applications. In addition, Texas Instruments is exhibiting its 10kW, 1kV, 3-phase, 3-level SiC-based Grid Tie Inverter Reference Design for a transformer-less solar string inverter with 99% peak efficiency, industry-leading power density, and 50kHz switching using SiC from Littelfuse–Monolith.

Expert panel discussion

Littelfuse sponsored an expert panel discussion on 'The Path to Predictable, High-Volume, High-Yield Manufacturing of SiC Devices', describing making the transition from 3-inch and 4-inch SiC wafers to 6-inch SiC wafers and developing design and process techniques that are compatible with processes in a silicon CMOS fab.

Speakers included Monolith's CEO Sujit Banerjee, Andy Wilson, business unit manager at X-FAB SiC Foundry, and Vladimir Blasko, senior fellow at United Technologies Research Center.

Industry session presentations

During the APEC conference, Monolith gave three industry session presentations:

- 'Unleash SiC MOSFETs—Extract the Best Performance';
- 'Are Antiparallel Diodes Needed for SiC MOSFETs?';
- 'Scalable Platform for In-Circuit Reliability Testing of SiC MOSFETs and Diodes Emulating Real-life Voltage and Current Stresses'.

www.apec-conf.org
www.littelfuse.com
www.monolithsemi.com
www.ixys.com

Cree acquires Infineon RF Power business for €345m

LDMOS and GaN-on-SiC transistor and MMIC operation involves 260 staff in USA as well as Finland, Sweden, China and South Korea

Cree Inc of Durham, NC, USA has acquired the Radio Frequency (RF) Power business of Infineon Technologies AG of Munich, Germany for about €345m. The transaction expands the Cree Wolfspeed business unit's wireless market opportunity, while Infineon continues to focus on key growth areas such as electro-mobility, autonomous driving, renewables and technologies for a connected world.

"The acquisition strengthens Wolfspeed's leadership position in RF GaN-on-SiC technologies, as well as provides access to additional markets, customers and packaging expertise," says Cree's CEO Gregg Lowe. "This is a key element of Cree's growth strategy and positions Wolfspeed to enable faster 4G networks and the revolutionary transition to 5G," he adds.

"Cree is a strong new owner for this portion of our RF business," comments Infineon's CEO Reinhard Ploss. "We will be able to focus our resources more effectively on Infineon's strategic growth areas and will retain a strong technology portfolio for the wireless market."

Infineon and Cree have a longstanding history of collaboration and shared business interests. The acquired Infineon RF Power team and capabilities will complement Wolfspeed's existing expertise with additional technology, design, packaging, manufacturing and customer support. The business offers transistors and monolithic microwave integrated circuits (MMICs) for wireless infrastructure RF power amplifiers based on both LDMOS silicon and gallium nitride on silicon carbide (GaN-on-SiC) technologies. The transaction includes:

- the main facility in Morgan Hill, CA, USA, which includes back-end packaging & test operations for LDMOS and GaN-on-SiC, as well as the intellectual property (IP) and technology portfolio;
- established customer relationships with leading manufacturers of wireless infrastructure equipment, including field support personnel on site;
- about 260 staff in the US locations at Morgan Hill and Chandler, AZ, as well as in Finland, Sweden, China and South Korea; and
- a transition service agreement to ensure business continuity and a smooth transition under which Infineon will perform substantially all business operations for about the next 90 days.

The transaction does not include the Infineon Chip Card & Security (CCS) operations in Morgan Hill that will remain at the site and continue to operate as part of Infineon.

Infineon will support the transaction with a long-term supply agreement for LDMOS wafers and related components out of its fab in Regensburg, Germany, and will also supply assembly & test services out of its facility in Melaka, Malaysia.

Cree funded the €345m acquisition from cash and borrowings on its revolving line of credit. The Infineon RF Power business will become part of Cree's Wolfspeed operating segment and is targeted to increase annual revenues by about $115m in the first 12 months post-acquisition. Also, the acquisition is targeted to be accretive to Cree's non-GAAP earnings per share in its first full quarter of operations with Cree (fiscal fourth-quarter 2018, ending 24 June). Targeted non-GAAP earnings per share exclude expenses related to the amortization of acquired intangibles, stock based compensation expense and one-time acquisition related expenses.

www.infineon.com
www.cree.com
www.wolfspeed.com

Cree signs $100m deal to supply 150mm SiC wafers to Infineon

Infineon targets strategic growth areas in automotive and industrial power control

Cree Inc of Durham, NC, USA has signed a strategic long-term agreement (valued at well over $100m) to produce and supply its Wolfspeed 150mm silicon carbide (SiC) wafers to Infineon Technologies AG of Munich, Germany.

The supply of 150mm SiC wafers will enable Infineon to broaden its product offering to address high-growth markets, such as photovoltaic inverters, electro-mobility, robotics, charging infrastructure, industrial power supplies, traction and variable speed drives. Since Infineon has already converted all its SiC manufacturing lines to 150mm SiC wafers, the agreement covers only this wafer diameter.

"We have known Cree for a long time as a strong and reliable partner with an excellent industry reputation," comments Infineon's CEO Reinhard Ploss. "Based on the secured long-term supply of SiC wafers, we strengthen our strategic growth areas in automotive and industrial power control," he adds.

"Infineon is a longstanding, valuable commercial partner with an excellent reputation," says Cree's CEO Gregg Lowe. "This agreement validates the quality of Cree's SiC wafer technology and our capacity expansion, as well as the accelerated adoption of SiC-based solutions that are critical to enabling faster, smaller, lighter and more powerful electronic systems," he adds.

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or contact us: x-fea-fuji-dc@fujielectric.com

Qorvo unveils highest-power GaN-on-SiC RF transistor

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has launched what it claims is the highest-power gallium nitride on silicon carbide (GaN-on-SiC) RF transistor (with engineering samples available now).

Operating at frequencies of 1.0–1.1GHz with a power of 1.8kW at 65V, the input-matched QPD1025 delivers the signal integrity and extended reach essential for L-band avionics and Identification Friend or Foe (IFF) applications, says the firm.

Linear gain is 22.5dB and typical power-added efficiency (PAE, for 3dB) is 77.2% at 1.0GHz load pull.

Supplied in 4-lead NI-1230 (earless) package, the new QPD1025 transistor offers "comparable pulsed power and duty-cycle performance to silicon LDMOS and silicon bipolar devices, but with a marked improvement in efficiency," comments Asif Anwar, executive director of market research firm Strategy Analytics' Strategic Technologies Practice. "Qorvo further achieves this high power and efficiency without introducing exotic materials such as diamond into the process flow for thermal management, ensuring a solution that is cost effective," he adds.

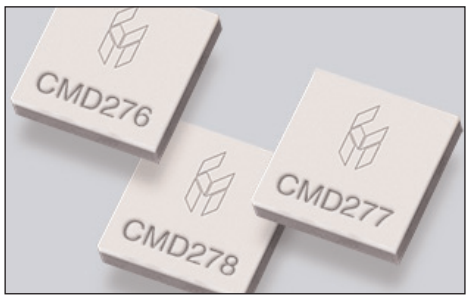
"This new high-power transistor will save customers time and money by eliminating the difficult exercise of combining amplifiers to create multi-kilowatt solutions," says Roger Hall, general manager, Qorvo High Power Solutions. "The QPD1025 has significantly better drain efficiency and beats LDMOS by nearly 15 percentage points of efficiency, which is significant in IFF and avionics applications," he claims.

www.qorvo.com/products/p/QPD1025

Custom MMIC launches GaN MMIC LNAs with output IP3 of +32dBm and high input power handling of 5W

Monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA says that its new CMD276C4, CMD277C4 and CMD278C4 gallium nitride (GaN) MMIC low-noise amplifiers (LNAs) deliver high-linearity performance with output third-order intercept point (IP3) of +32dBm while offering high input power handling of 5W.

The high input power handling feature enables system designers to avoid limiters and other protection networks, while still achieving extremely low noise figure over the operating bandwidth.



The CMD276C4 is a 2.6–4GHz (S-band) LNA delivering greater than 14dB of gain with a corresponding P1dB (output power at 1dB compression point) of +25.5dBm and a noise figure of 1.2dB.

The CMD277C4 is a 5–7GHz (C-band) LNA with 20dB of gain, P1dB of +26.5dBm and a noise figure of 1.2 dB.

The CMD278C4 is a broadband 8–12GHz (X-band) LNA with 15dB of gain, P1dB of +28dBm and a noise figure of 1.8dB.

Housed in a leadless 4mm x 4mm QFN package, the new MMIC LNAs are suited to radar and electronic warfare (EW) applications where high performance and high input power survivability are required.

www.custommmic.com/low-noise-amplifiers

Integra introduces fully matched high-power GaN-on-SiC transistor offering 50W at 5–6GHz

Integra Technologies Inc of El Segundo, CA, USA (which designs and makes high-power RF and microwave transistors and power amplifiers) has launched a fully matched high-power gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistor (HEMT) operating over a frequency range of 5.2–5.9GHz.

Designed for pulsed C-band radar system designs that require immediate full power and high gain, the IGT5259L50 is fully matched to 50Ω and supplies 50W of peak pulsed output power at 50V drain bias. Gain is 14dB and efficiency is 43% under 1ms/15% pulse conditions.

Housed in a RoHS-compatible metal/ceramic flange-mount package with gold metallization measuring 0.800" (20.32mm) wide and 0.400" (10.16mm) in length, the IGT5259L50 provides what is claimed to be excellent thermal dissipation.

Internal assembly is performed with a chip and wire approach. The IGT5259L50 is 100% high-power RF tested in a 50Ω RF test fixture and meets all specifications of MIL-STD-750D.

www.integratech.com

MACOM launches MAGM series of GaN-on-silicon MMIC power amplifiers for massive MIMO 5G

At the Mobile World Congress (MWC 2018) in Barcelona Spain (26 February – 1 March), MACOM Technology Solutions Inc of Lowell, MA, USA launched the MAGM series of gallium nitride on silicon (GaN-on-Si)-based MMIC power amplifiers (PAs) optimized for massive MIMO antenna systems targeting 5G wireless basestation infrastructure.

Providing wideband performance simultaneously covering bands 42 and 43 with flat power and superior power efficiency compared with legacy LDMOS silicon technology, the new MAGM PA Series is said to deliver GaN performance at LDMOS-like cost structures at scaled volume production levels in fully integrated MMIC packaging for simplified, cost-effective 5G base-station manufacturing.

MAGM Series MMIC PAs are tailored specifically for mainstream 5G base-station architectures, meeting the power density and thermal requirements of 64-element massive MIMO antenna arrays, with a pathway to exceeding the performance of LDMOS technology, at scaled volume level production cost structures and supply capacities that cannot be achieved with competing GaN-on-SiC technology, it is claimed.

Designed with MACOM's proprietary wideband circuit topology, the PAs meet the stringent 5G TDD linearity requirement using off-the-shelf digital-pre-distortion (DPD) systems.

Compared with earlier-generation multichip-format GaN-on-Si modules, costs are further lowered through a reduction in packaging and design complexity.

Leveraging this performance and cost with the capacity-scale manufacturing afforded by MACOM's partnership with STMicroelectronics of Geneva, Switzerland, MACOM expects its GaN-on-Si solutions to shorten customers' time to market.

"MACOM's new MAGM Series PAs combine the unique performance and cost benefits inherent to GaN-on-Si technology with the MMIC packaging efficiencies needed for commercial volume-scale 5G base-station manufacturing and deployment," says Amer Droubi, director product marketing. "Our continuous innovation in this domain sets a strong foundation for next-generation multi-function GaN-on-Si MMICs targeted to enable fully integrated front-end modules for massive MIMO 5G basestation architectures."

The first product in the MAGM Series (MAGM-103436-040AOP) is sampling to qualified customers now, with production availability scheduled for second-half 2018.

www.mobileworldcongress.com
www.macom.com/gan

MACOM showcases RF portfolio of MMICs, diodes and GaN-on-silicon devices at EDICON

At the Electronic Design Innovation Conference (EDI CON China 2018) at the China National Convention Center in Beijing (20–22 March), MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for RF, microwave, millimeter-wave and lightwave applications) showcased its RF portfolio of MMICs, diodes and GaN-on-silicon devices, as follows:

- MATK-102425-300: RF Energy Toolkit live demonstration;
- RF Plasma 'Torch' live demo;
- new silicon-based solutions for high-performance narrowband voltage-controlled oscillator (VCO) portfolio';
- complete portfolio of wireless access front-end components and modules for 4G and 5G applications;
- compact Tx and Rx front-end modules (FEMs) for 5G M-MIMO applications; and
- high-power PIN diode switches.

Also, MACOM representatives were present at the following workshops and panels:

- 5G Massive MIMO Panel By Microwave Journal — Anthony Fischetti;
- AM/PM Distortion of GaN HEMT Workshop — Mengsu Yang;
- GaN Technology Panel Session By Microwave Journal — Michael Ziehl;
- The Solid State RF Energy — Inroads to the Industrial Market Panel– Mark Murphy.

www.ediconchina.com

Transphorm releases 3.3kW high-voltage bridgeless totem-pole PFC GaN reference design

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified high-voltage (HV) gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — has released the TDTTP3300-RD, the first complete 3.3kW continuous conduction mode (CCM) bridgeless totem-pole power factor correction (PFC) reference design for high-voltage GaN power systems.

The technical blueprint is used to develop AC-to-DC applications including high-end front-end PFCs for merchant power supplies (servers, gaming, crypto mining, and similar multi-kW high-density applications), on-board chargers for plug-in hybrid (PHEV) and battery electric vehicles (BEV), and broad industrial power supplies.

The reference design delivers 99% efficiency using Transphorm's third-generation 650V GaN FET technology (TP65H050WS — 50mΩ on-resistance) in an industry-preferred, robust TO-247 power package.

The TDTTP3300-RD includes all the resources required to develop products quickly without the need for deep GaN design or DSP firmware coding expertise, including a test report, hardware design guide, firmware design guide (with downloadable firmware), design schematics and Gerber files, and bill of materials (BOM).

"As demonstrated by customer end-products, Transphorm's high Q+R (quality and reliability) devices are proven to deliver what high-voltage GaN has always promised. Increased power density, efficiency and performance with reduced system cost," says Philip Zuk, VP of technical marketing. "Now, we are helping designers quickly capitalize on those benefits by eliminating design knowledge gaps," he adds. "With our 3.3kW reference design, we are arming the industry with a roadmap that was several years in the making."

www.apec-conf.org
www.transphormusa.com/reference-design/tdttp3300-rd

TI expands GaN power portfolio with smallest and fastest GaN FET drivers

Expanding on its gallium nitride power portfolio, Texas Instruments (TI) has launched two high-speed GaN field-effect transistor (FET) drivers to create more efficient, higher-performing designs in speed-critical applications such as light detection and ranging (LiDAR) and 5G radio-frequency (RF) envelope tracking. The LMG1020 and LMG1210 can deliver switching frequencies of 50MHz while improving efficiency and enabling five times smaller solution sizes previously not possible with silicon MOSFETs.

With what is claimed to be an industry-best drive speed as well as a minimum pulse width of 1ns, the LMG1020 60MHz low-side GaN driver enables high-accuracy lasers in industrial LiDAR applications. The small wafer-level chip-scale (WCSP) package of just 0.8mm by 1.2mm helps to minimize gate-loop parasitics and losses, further boosting efficiency.

The LMG1210 is a 50MHz half-bridge driver designed for GaN FETs up to 200V. The device's adjustable dead time control feature is designed to improve efficiency by as much as 5% in high-speed DC/DC converters, motor drives, Class-D audio amplifiers as well as other power-conversion applications. Designers can achieve high system-noise immunity with what is said to be the industry's highest common-mode transient immunity (CMTI) of more than 300V/ns.

Features of the LMG1020 and LMG1210 include:

- High speed: The two devices' ultra-fast propagation delay (2.5ns for the LMG1020 and 10ns for the LMG1210) enables power solutions that are 50 times faster than with silicon drivers. Additionally, the LMG1020 is capable of delivering high-power 1ns laser pulses, enabling long-range LiDAR applications.
- High efficiency: Both devices enable high-efficiency designs. The LMG1210 offers a low switch-node capacitance of 1pF and user-adjustable dead time control to improve efficiency by up to 5%.
- Power density: The integrated feature of dead time control in the LMG1210 allows for reduced component count and higher efficiency, enabling designers to reduce power-supply size by as much as 80%. The increased power density of the LMG1020 enables the highest resolution in LiDAR in the industry's smallest package.

The LMG1020 and LMG1210 are the latest additions to the what is claimed to be industry's largest GaN power portfolio, ranging from 200V drivers to 80V and 600V power stages. With over 7 million hours of GaN process reliability testing, TI is addressing the need for proven and ready-to-use solutions through reliable GaN products, bringing decades of silicon manufacturing expertise and device-development talent to GaN technology.

www.ti.com/power-management/gan/overview.html

EPC launches eGaN ICs combining gate drivers with high-frequency GaN FETs for improved efficiency

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications — has launched the EPC2112 and EPC2115 enhancement-mode monolithic GaN power transistor with integrated driver products.

The EPC2112 is a 200V, 40mΩ eGaN FET plus integrated gate driver. In comparison, the EPC2115 is an integrated circuit with dual 150V, 70mΩ eGaN FETs plus gate drivers. Both products are capable of operating up to 7MHz and are available in low-inductance, extremely small (2.9mm x 1.1mm) ball-grid array (BGA) surface-mount passivated die.

The monolithic ICs can enable designers to improve efficiency, save space and lower costs compared with silicon-based solutions. The ultra-low capacitance and zero reverse recovery of eGaN FETs enable efficient operation in many topologies, says EPC.

In both products, the integrated driver is specifically matched to the eGaN device to yield optimal performance under various operating conditions. Performance is further enhanced due to the small, low-inductance footprint. Monolithic integration eliminates interconnect inductances for higher efficiency at high frequency. This is especially important for high-frequency applications, such as resonant wireless power, and high-frequency DC–DC conversion.

As design examples for the new ICs, two differential class-E amplifier development boards are available for order. The EPC9089 is an AirFuel Alliance-compatible class 4 (33W) and uses the EPC2112. The EPC9088 is a class 3 (16W) amplifier using the EPC2115. The EPC2112 is also featured in the new EPC9131 demonstration board for a 300kHz SEPIC converter low-voltage DC–DC application.

The EPC2112 monolithic integrated gate driver and GaN FET is priced at $3.29 each and the EPC2115 integrated gate driver with dual GaN FETs at $3.44 each, both for 1000-unit quantities.

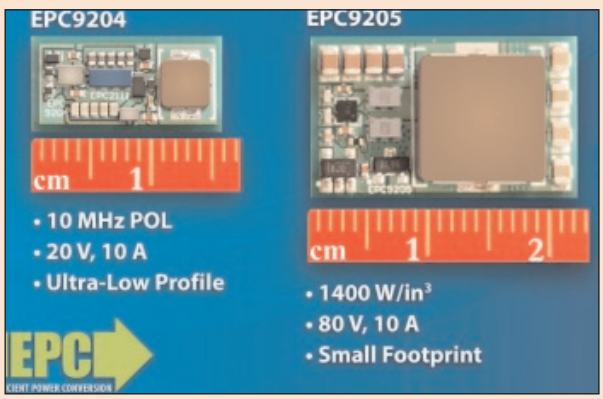
The EPC9088 and EPC9089 development boards are $158.13 and $159.13, respectively. The EPC9131 is priced at $215.62

All these products are available for order from EPC's distributor Digi-Key Corp.

www.epc-co.com

EPC9204 & 9205 GaN power modules deliver over 1400W/in³ for 48V–12V DC–DC and up to 10MHz for point-of-load power conversion

EPC has launched two new GaN power modules for DC–DC conversion, increasing efficiency across the 48V to point-of-load power architecture. The EPC9205 is a high-power density PCB-based power module for 48V–12V conversion while the EPC9204 addresses 20V–point-of-load conversion with an ultra-thin-profile PCB-based power module.



The EPC9205 is an 80V, 10A PCB-based power module featuring the 100V EPC2045 eGaN FET for plug & play evaluation of the high performance gained with GaN power transistors. The module exceeds 1400W/in³ per cubic inch in a 48V–12V application, and occupies less than one-tenth of a cubic inch of board space. Applications include the high-performance servers needed for demanding computing applications such as multi-user gaming systems, autonomous cars, artificial intelligence, and cryptocurrency mining.

The EPC9204 is a 20V, 10A PCB-based power module featuring the 30V EPC2111 eGaN IC capable of operating up to 10MHz. This high-frequency capability reduces the size of the passive components, resulting in an ultra-low profile of just 1.2mm from the PCB board. Applications benefitting include point-of-load power conversion for servers, thin-form-factor mobile devices, and USB-C.

"As expectations for increasingly power-hungry applications expand while the conflicting desire for equipment to be small and lightweight persists, reducing size and decreasing power consumption is critical," says CEO & co-founder Alex Lidow. "The efficiencies achieved by the EPC9204 and EPC9205 small form factors show how GaN-based power devices, available now, are driving the next generation of computing."

The EPC9204 and EPC9205 development boards are priced at $131.25 each and are available from distributor Digi-Key Corp. For reference and ease of use, Quick Start Guides (containing set-up procedures, circuit diagrams, performance curves, and bills of material) are provided on EPC's website.

Teledyne e2v, pSemi and GaN Systems unveil fastest hi-reliability GaN power solution, featuring GaN FET and half-bridge driver

Teledyne e2v inc of Milpitas, CA, USA (which provides solutions, sub-systems and components to the space, transportation, defense and industrial markets) is launching a complete gallium nitride (GaN) power solution based on technology from pSemi Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — and GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of GaN-based power switching semiconductors for power conversion and control applications). The solution features GaN field-effect transistors (FETs) and what is claimed to be the first rad-tolerant, half-bridge power driver for GaN high-reliability applications. The technology was demonstrated in the Teledyne Defense Electronics booth at Satellite 2018 in Washington DC (12–15 March).

After being used in power conversion in other industries, GaN devices are now available as radiation tolerant, space-qualified devices. The release of the GaN FETs and the industry's fastest half-bridge GaN driver provide the efficiency, size, and power-density benefits required in satellite systems' critical power applications. The device prototypes are now available for purchase.

Teledyne's ceramic TDG100E15 100V 15A FET and TDG100E30 100V 30A FET both utilize GaN Systems' patented Island Technology, which is a scalable, vertical charge-dissipating system that gives the power transistor ultra-low thermal losses, high power density, no-charge storage, and very high switching speeds. The use of industry standard SMD 0.5 ceramic packaging allows very high-frequency switching, excellent thermal characteristics, and a reduced time-to-market.

The second part of the GaN solution is what is claimed to be the industry's fastest half-bridge GaN driver, based on pSemi's UltraCMOS technology. The Teledyne TD99101 25MHz GaN driver features a ruggedized design and is qualified for operation in harsh environments, including space. It contains both high-side and low-side GaN drivers capable of sourcing 1A and sinking 2A of current. In addition, it is designed to work with the very low latency and high switching speeds required for GaN system-based Teledyne parts. The TD99101 is the only driver capable of extracting the highest performance and speed benefits of Teledyne's TDG100E GaN FETs.

To facilitate implementation of GaN technology from Teledyne, the TD99101-x00 evaluation kit is available, featuring both the TD99101 GaN driver and TDG100E15 100V, 15A GaN FET. The evaluation kit operates at frequencies up to 13MHz and allows customer to evaluate Teledyne's GaN parts quickly.

Manufactured on a MIL-PRF-38535 Class V-like flow, both devices are radiation tolerant, suitable for space applications, and have ceramic-packaged prototypes available now.

"Teledyne e2v has a proud heritage of space products, and we are excited to bring the unprecedented efficiency of GaN power to our customers," says the firm's VP of business development Mont Taylor. "The wide range of capabilities of these devices enable design engineers to create highly efficient power supply and motor control applications which can function in radiation environments."

http://2018.satshow.com
www.gansystems.com
www.psemi.com
www.e2v.com/products/semiconductors/power-solutions

GaN Systems makes available 5MHz buck converter evaluation board

GaN Systems has announced availability of its GS61008P-EVBHF 5MHz buck converter evaluation board, which uses GaN Systems' 100V enhancement-mode (E-mode) GaN transistor and the PE29101 integrated high-speed driver of pSemi of San Diego, CA, USA. The outputs of the pSemi driver can provide switching transition speeds in the sub-nanosecond range.

The evaluation board allows the benefit of higher switching speeds, enabling smaller peripheral components in a variety of applications including DC–DC conversion, AC–DC conversion, wireless power charging, and LiDAR.

"GaN has a robust ecosystem of quality partners like pSemi," says Peter Di Maso, director, product line management at GaN Systems. "Working with pSemi, we've been able bring faster switching, higher frequencies and higher-power-density solutions to customers. These benefits come together to reduce power losses, size, weight and system costs."

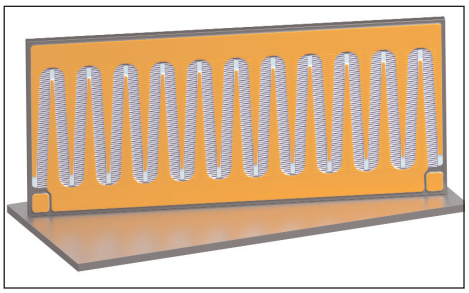
GaN E-HEMTs exhibit much higher efficiencies than MOSFETs and exceed performance in terms of switching speed, parasitic capacitance, switching loss, and thermal characteristics, says GaN Systems. The evaluation board highlights the high-frequency, high-speed, and high-efficiency performance of the firm's products.

GaN Systems launches highest-current GaN power transistor

At the Applied Power Electronics Conference & Exposition (APEC 2018) in San Antonio, TX, USA (4–8 March), GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) launched what it claims is the most powerful line of GaN transistors.

With power levels continuing to rise (creating the need for higher operating current), the advantages of gallium nitride can be applied to much higher power levels in the automotive, industrial and renewable energy industries, the firm notes.

With twice the current capability of GaN Systems' highest-rated-current part, the new GS-065-120-1-D 120A, 650V GaN enhancement-mode high-electron-mobility transistor (E-HEMT) effectively allows a doubling of power processing for the same volume, increasing the power density of 20–500kW power conversion systems, including automotive traction inverters, very high-power on-board chargers (OBC), large-scale energy storage systems, and industrial motor drives.



Sold as a die to customers building modules, the GS-065-120-1-D is reckoned to be the lowest-$R_{DS(on)}$, highest-current 650V GaN HEMT in the power semiconductor industry.

Modules are an important form factor in high-power electronics, constituting up to 40% of the market based on form factor. Customers can use the new die product in half-bridge, full-bridge and six-pack module topologies to create enhanced, high-power designs.

"This is the most pivotal GaN product on the market to be optimized for modules and is compatible with both embedded and traditional module technology," says CEO Jim Witham. "As an extension of our flagship product, it encompasses all the benefits of GaN technology and our approach to GaN power transistors — ease of use, high power density, and high efficiency — enabling power systems that are smaller in size and lower cost with unprecedented power levels."

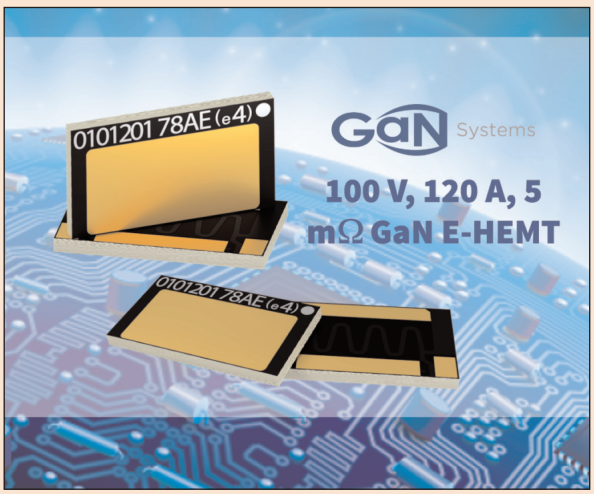
www.gansystems.com/apec2018

GaN Systems launches 100V/120A GaN power transistor

At APEC 2018, GaN Systems unveiled what it claims is the highest-current and most power efficient 100V GaN power transistor.

The GS-010-120-1-T 100V, 120A, 5mΩ GaN enhancement-mode high-electron-mobility transistor (E-HEMT) is 1.3x the current rating of GaN Systems' own 90A part and 2.4–4.6x the current rating of other high-current GaN in the industry, it is reckoned. The GS-010-120-1-T is an E-mode GaN-on-silicon power transistor that leverages all of the die design and packaging advantages delivered by GaN Systems.

The transistor is suitable for the growing 48V applications in the automotive, industrial and renewable energy industries which require power systems with high power levels in smaller-size form factors. GaN Systems says that bringing products like the GS-010-120-1-T to market results in realizations such as longer-range electrical vehicles, lower-operating-cost renewable energy equipment, and smaller, highly integrated industrial power equipment.



In addition, the new transistor enables greater design flexibility and affords options for immediate specification changes. It is footprint-compatible with GaN Systems' GS61008T 100V, 90A GaN E-HEMT, enabling customers to add further power by substituting the GS-010-120-1-T without changing their board. Increasing the current capability in the same size package allows an effective increase in power of 33% for the same system volume.

"Our technology roadmap is positioned to deliver to the growing need of best-in-class GaN technology solutions in 100V as well as 650V applications," says Larry Spaziani, VP sales & marketing. "The new 100V, 120A GaN E-HEMT — along with our recently announced 650V, 120A GaN E-HEMT — are among a significant number of recent high-performance GaN transistors and solutions we have introduced." The firm's intention is to "continuously provide products designed to exceed power system efficiency and reliability requirements in today's most demanding applications".

www.gansystems.com/gan-transistors/gs61008t

HRL to develop ultra-linear GaN transistors for mm-wave devices as part of DARPA's DREaM program

HRL Laboratories LLC of Malibu, CA, USA has received an award from the US Defense Advanced Research Project Agency (DARPA) to develop the next generation of gallium nitride (GaN) transistors with much improved linearity and noise figure at reduced power consumption for use in electronic devices that manage the electromagnetic spectrum from radio communications to radar.

With the Dynamic Range-enhanced Electronics and Materials (DREaM) program, DARPA is seeking new designs and materials for radio-frequency transistors with breakthrough dynamic range in millimeter-wave systems. HRL's role is to develop ultra-linear GaN transistors working in mm-wave frequencies that enable transmission and reception without distortion across the spectrum. The transistors will enable secure ultra-wideband communications with higher data rates, while reducing their draw on the prime power source of their eventual platforms, such as ships or aircraft.

"For this project we will research novel materials and devices to develop ultra-linear GaN transistors with manufacturability," says Jeong-sun Moon, HRL Labs' principal investigator on the DREaM program. Joining Moon on the HRL Labs team are Joel Wong and Andrea Corrion.

"Our goal is to break the historic gap of the 10dB rule of thumb in semiconductor transistor's linearity figure-of-merit — which is linearity divided by DC power consumption — by 100 times," adds Moon. "Spectrally pure linear amplification requires prime power consumption, so the power saving enabled by this improvement will be huge, while meeting the demand of modern communications for wider bandwidths and higher data rates, including 5G wireless communication."

www.hrl.com

Lockheed Martin completes acceptance test of first GaN-based TPS-77 Multi-Role Radar

Security and aerospace company Lockheed Martin of Bethesda, MD, USA has completed a site acceptance test of a TPS-77 Multi-Role Radar (TPS-77 MRR), marking on-time delivery of the first of three radars to the Ministry of Defense of the Republic of Latvia, and a step forward in strengthening Latvia's national defense.

As with current production TPS-77s and other next-generation Lockheed Martin radars, the TPS-77 MRR uses gallium nitride (GaN) technology in its design. By using GaN, the radar's high-power amplifiers consume much less power, ultimately increasing reliability, lowering life-cycle costs and extending the useful life of the radar.

The TPS-77 MRR improves the Latvian Air Force's airspace defense by increasing its low-level flight surveillance and identification capabilities, leading to enhanced early warning and situation awareness that can enable its armed forces to make more informed and efficient decisions in response to modern day threats.

The latest milestone is the most recent event in a 16-year partnership of radar development and training between Latvia and Lockheed Martin, including the 2015 contract for the three TPS-77 MRRs.

The TPS-77 MRR is the latest version in Lockheed Martin's product line of surveillance radars and was developed in response to the evolving needs of armed forces on the battlefield. The radar's multi-role single-scan technology allows operators to select multiple missions for the radar at a single time, such as long-range or medium-range low-level flight surveillance. As the radar rotates through each 360° scan, the system automatically adjusts to the selected mission. Changes can be easily made if the system is moved or mission is changed. Once set, no further operator inputs are required.

The TPS-77 MRR is designed for ultra-low power consumption and is the most transportable version of Lockheed Martin's TPS-77 product line. Latvia's variant of this radar can be truck mounted for operation at remote sites or dismounted for use at fixed sites.

As part of the TPS-77 MRR program, Lockheed Martin has engaged with local Latvian industry for procurement and production. These relationships will form the basis for long-term local maintenance and support of the new systems.

"The Latvian industry has been an important partner during the development and production of the Lockheed Martin TPS-77 MRRs. This support will help strengthen Latvia's Industrial Capability," said Rick Cordaro, program director, Lockheed Martin Ground Based Radar.

Lockheed Martin has produced and maintains more than 180 surveillance-range radars, all of which are operational around the world detecting targets at ranges up to 250 miles, 24 hours a day. There are three previously installed Lockheed Martin TPS-77 radars in Latvia, positioned in Calas, Lielvarde and Audrini. These radars can operate completely unmanned and many have performed for decades in remote, inhospitable areas and in a wide range of operational environments.

www.lockheedmartin.com/gbas

Northrop-built GaAs-based G/ATOR system approved for early fielding, prior to production of GaN-based systems

Northrop Grumman Corp of Redondo Beach, CA, USA says that its AN/TPS-80 Ground/Air Task-Oriented Radar (G/ATOR) has been approved for early fielding by the US Marine Corps (USMC), following delivery of the final Lot 1 and Lot 2 Low Rate Initial Production (LRIP) G/ATOR system. The USMC will field its first two systems by delivering them to Marine Air Control Squadrons 1 & 2 for operational use.

Early fielding — also known as Initial Operational Capability (IOC) — indicates that a system is ready for operational deployment. It is achieved when production systems, spares, logistic support items and documentation have been tested and validated through a rigorous process. As the developer and system integrator, Northrop Grumman has taken G/ATOR from concept through to production.

G/ATOR undergoes cold weather testing.

Northrop Grumman has delivered six G/ATOR systems with gallium arsenide technology to the Marine Corps in Lots 1 and 2. Beginning with Lot 3 deliveries and including all full-rate production systems, G/ATOR will incorporate high-power, high-efficiency gallium nitride antenna technology that can further enhance operational capabilities.

"Through our close partnership with the Marine Corps, we have been able to achieve this important early fielding milestone," says Roshan Roeder, VP, land & avionics C4ISR division, Northrop Grumman Mission Systems. "We are looking ahead to full-rate production and getting G/ATOR's unprecedented capabilities to the Marines in the field."

Under a separate contract, Northrop Grumman will provide logistics support to the Marine Corps for G/ATOR systems.

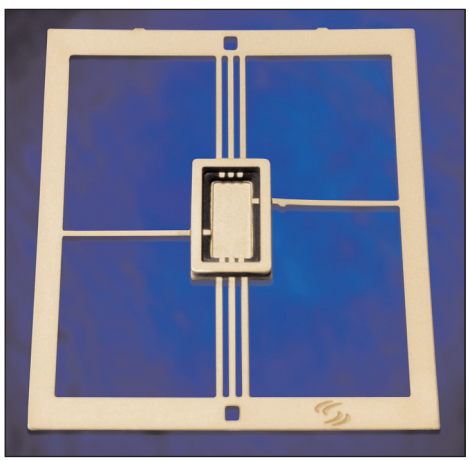
www.northropgrumman.com/Capabilities/GATOR

StratEdge displays DC–63GHz packages at IMAPS Device Conference

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) displayed its high-frequency and very high-power device packages at the IMAPS Device Conference in Fountain Hills, Arizona (6–7 March).

StratEdge packages come in leaded and leadless drop-in formats, leaded and leadless surface-mount formats, and specialty high-power and high-speed digital designs. Packages on display include:

- new, off-the-shelf molded ceramic packages that meet the requirements to handle 18GHz devices, including gallium nitride;
- LL family of high-power laminate copper-moly-copper (CMC) base packages with a ratio of 1:3:1 CMC that include both GaN transistor and MMIC device packages;
- SE50 series with what is claimed to be the industry's lowest-electrical-loss design for compound semiconductors operating at frequencies as high as 63GHz;
- MC Series of molded ceramic packages in standard, open-tooled configurations, which are all MIL-STD hermetic;
- leaded power amplifier packages for gallium arsenide power amplifiers (a proven design that has been used in many point-to-point, point-to-multipoint and VSAT applications);
- hermetic SMT packages in some of the most popular industry-standard, no-lead outlines for use where standard plastic packages cannot meet the reliability or performance requirements of a particular application;
- high-speed digital and mixed-signal packages that can be customized for speeds in excess of 40GB/s.



StratEdge's DC–63GHz-package.

"5G, and its high-power infrastructure, and IoT and advanced cellular technologies requiring RF and microwave frequencies will make package selection critical," says president Tim Going. "Packages can no-longer be an after-thought. They not only are necessary for heat dissipation, but also to ensure that the electrical connection is accurate and the device functions as intended, without electrical losses," he adds.

www.stratedge.com

JAXA evaluates Panasonic's X-GaN power transistors

Research Unit 1 at the Tsukuba Space Center of the Japan Aerospace Exploration Agency (JAXA) in Tsukuba City, Ibaraki Prefecture, has begun evaluation and validation of Panasonic Corp's X-GaN gallium nitride power transistors (which entered mass production in November 2016) for potential use in its development of space technologies.

"Space radiation can cause damage to electronic devices, so we need to have countermeasures," says Research Unit 1 member Eiichi Mizuta, who is specifically in charge of electronic devices.

Most semiconductors used in space are made of silicon, but there is a limit as to how much radiation they can withstand. "We performed radiation tests with Panasonic X-GaN using xenon ions, which we often use for space evaluation," says Mizuta. "These tests proved that the X-GaN is highly resistant to radiation. It is rare for a commercial-off-the-shelf device to be so robust against radiation, so we were really surprised."

Mizuta also stated that X-GaN devices enable faster switching. When applied to satellites, they can help to reduce payload mass, which makes them attractive since satellites have strict payload mass limitations. "Because GaN devices help save weight and thereby allow the weight to be used for other high-performance components, they are very effective for our space development," he comments.

"Panasonic's X-GaN has a high potential to become the next-generation space component," believes Mizuta. "We hope to continue to work closely with Panasonic to develop even better devices for space."

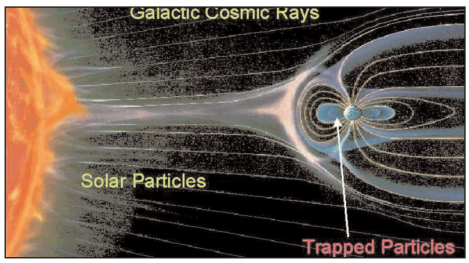
https://industrial.panasonic.com/ww/products/semiconductors/pow

SMI completes NASA Ga_2O_3 radiation hardness testing

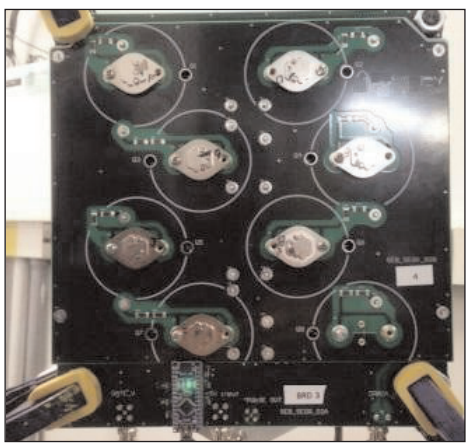
Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA has finished initial studies of the radiation hardness of gallium oxide (Ga_2O_3)-based power devices in accordance with a Small Business Innovation Research (SBIR) Phase I project funded by the US National Aeronautics and Space Administration (NASA Award No. NNX17CG70P).

The Ga_2O_3 films were grown on bulk doped and undoped Ga_2O_3 and other substrates in one of SMI's in-house metal-organic chemical vapor deposition (MOCVD) systems. Total ionization dose (TID) and single-event effect (SEE) were used as radiation hardness testing metrics. The radiation hardness testing was conducted to determine whether the Ga_2O_3-based power devices were a good candidate for NASA's Power Management and Distribution (PMAD) systems among other applications. Potential applications include power devices such as diodes and transistors that may be used in areas like power rectification and RF mixing, among many others.

"With the development of Ga_2O_3 power devices, we thought it important to further the determination of the space-worthiness/applicability of Ga_2O_3-based devices," says Dr Serdal Okur, principal investigator for SMI SBIR Ga_2O_3-related projects. "Testing actual devices made this project all the more relevant. We tested different combinations of device material properties, such as orientation, doping levels, substrate dopant, and crystal growth technique, including epilayers grown by MOCVD," he adds. "Fabricated devices included Schottky barrier diodes. The variables were strategically chosen to critically evaluate the potential of Ga_2O_3-based power device performance under different radiation exposures."



Types of space radiation of concern to NASA space missions. Credit: After Nikkei Science Inc, by K. Endo.



Ga_2O_3 power device testing set up.

The testing was carried out in stages during the Phase I project and was deemed to be a significant milestone in the overall assessment of Ga_2O_3 radiation hardness. All Phase I objectives were completed.

"The Phase I work of this project was implemented and successfully completed in a 6-month period, which is very impressive considering the amount of knowledge acquired from this study," says Okur. "We are also grateful for the contributions from all the personnel at various universities, research laboratories, and government agencies that were involved in this project."

There are three types of space radiation that are particularly concerning to space missions: particles trapped in the Earth's magnetic field; solar particle events (particles shot into space during solar flares); and galactic cosmic rays (high-energy protons and heavy ions from outside our solar system).

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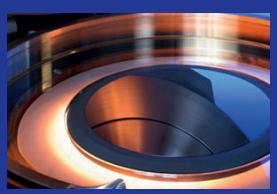

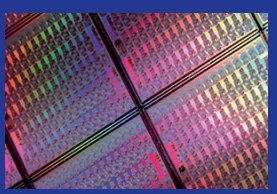

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Si2's Compact Model Coalition approves IC design simulation standards for GaN devices

The Silicon Integration Initiative (Si2) — an R&D joint venture that provides standard interoperability solutions for IC design tools — says that its Compact Model Coalition (CMC) has approved two integrated circuit design simulation standards that target the fast-growing market for gallium nitride (GaN).

The approved standards are the 12th and 13th models currently funded and supported by the CMC, a collaborative group that develops and maintains cost-saving SPICE (Simulation Program with Integrated Circuit Emphasis) models for IC design.

GaN devices are used in many high-power and high-frequency applications, including satellite communications, radar, cellular, broadband wireless systems and automotive. "Although it's currently a small market, gallium nitride devices are expected to show remarkable growth over the coming years," notes president & CEO John Ellis.

To reduce R&D costs and increase simulation accuracy, the semiconductor industry relies on the CMC to share resources for funding standard SPICE models. Si2 is an R&D joint venture focused on IC design and tool operability standards. "Once the standard models are proven and accepted by CMC, they are incorporated into design tools widely used by the semiconductor industry," says Ellis. "The equations at work in the standard model-setting process are developed, refined and maintained by leading universities and national laboratories. The CMC directs and funds the universities to standardize and improve the models," he adds.

"2015 and 2016 were exciting years for the gallium nitride power business," comments Dr Ana Villamor, technology and market analyst at Yole Développement. "We project an explosion of this market, with 79% CAGR (compound annual growth rate) between 2017 and 2022. Market value will reach $460m at the end of the period. It's still a small market compared to the impressive $30bn silicon power semiconductor market. However, its expected growth in the short term is showing the enormous potential of the power gallium nitride technology based on its suitability for high-performance and high-frequency solutions," she adds.

"Gallium nitride devices are playing an increasingly important part in the field of RF and power electronics," states CMC chair Peter Lee, manager at Micron Memory Japan. "With these two advanced models established as the first worldwide gallium nitride model standards, efficiencies in design will greatly increase by making it possible to take into account accurate device physical behavior in design, and enabling the use of the various simulation tools in the industry with consistent results."

www.si2.org/category/compact-model

RJR opens new Phoenix manufacturing facility and HQ

Factory enables capacity expansion for air-cavity plastic packages

US-based RJR Technologies Inc, a developer and manufacturer of liquid-crystal polymer (LCP) air-cavity packages (ACP) for RF and microwave applications, has moved its headquarters from Oakland, CA to its new manufacturing facility in Phoenix, AZ.

"RJR is making capital investments on a 30,000ft^2 building to house our corporate headquarters as well as expand our manufacturing operations to support our growth," says president & CEO Wil Salhuana. "We decided to move our headquarters from California to Arizona after working closely with the Phoenix Economic Development Council due to its friendly government, pro-business stance and available technical talent due to a strong semiconductor base," he comments. "We will maintain our Oakland facility to run our custom specialty product lines as well as a second source for our high-volume standard products."

RJR's new HQ and manufacturing plant.

"We moved into the building in April 2017 and have just received our first customer qualification and are starting our volume ramp," Salhuana continues. "Our air-cavity plastic (ACP) and RQFN packages offer a compelling value proposition in terms of high performance, low cost and faster time-to-market, and the packages have been widely accepted as the package of choice for the RF cellular base-station market," he claims.

RJR has already shipped millions of units of its new second-generation ACP2 packages to leading manufacturers in the RF market. The firm reckons that, over the next few years, its industry-standard ACP packages can deliver similar benefits to applications in the gallium nitride (GaN) market and RF energy applications, such as lighting, automotive ignition systems and consumer microwave appliances as well as new products that address other market applications.

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EpiGaN's GaN/Si RF material technology at core of EU's SERENA 5G project

Project to develop beam-forming system platform for mm-wave multi-antenna arrays

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 sensors applications — has a key position in the new 36-month European Union research project SERENA ('gan-on-Silicon Efficient mm-wave euRopean systEm iNtegration platform'), which began in January.

The project consortium unites ten industrial and academic partners: Austria's TECHNIKON GmbH (project leader), Sweden's Ericsson AB, Infineon Technologies Austria AG, Belgium's EpiGaN NV, France's Ommic SAS, Sweden's Totalförsvarets Forskningsinstitut, Germany's Fraunhofer Gesellschaft, Greece's Institute of Communication and Computer Systems, Sweden's Chalmers Tekniska Högskola AB and Germany's Technische Universität Berlin.

SERENA aims to develop a beam-forming system platform for millimeter-wave multi-antenna arrays and to enable the functional performance of a hybrid analog/digital signal processing architecture beyond mainstream CMOS integration.

The objective of SERENA is a proof-of-concept prototype for optimizing the power efficiency and cost of mm-wave multi-antenna array systems. The architecture will be suitable for a wide range of applications such as safety radar, high-speed wireless communications, as well as imaging sensors for 5G and autonomous vehicles, all of which rely on active antenna arrays and electronic beam steering. The fundamental challenge is to produce high-performance antenna systems for the mm-wave range at viable price-points and low energy consumption.

The SERENA value chain will be based on advances in GaN-on-Si technology and volume packaging, contributed by EpiGaN through its GaN epiwafer technology which, with its in-situ SiN capping layer, provides what is claimed to be superior surface passivation and device reliability. Also, it enables contamination-free processing in existing standard CMOS silicon infrastructures. In-situ SiN structuring allows the use of pure and ultra-thin aluminium nitride (AlN) layers as barrier materials. By reducing the short-channel transistor effects, this results in what is said to be superior mm-wave performance.

"RF-GaN technology offers crucial performance advantages over incumbent LDMOS or GaAs technologies, such as greater bandwidth and energy efficiency," says EpiGaN's CEO Dr Marianne Germain. "Our GaN-on-Si technology delivers excellent power density and power-added efficiency (PAE), superior gain, and low RF losses up to 100GHz," she claims. "By starting out with a fundamentally better semiconductor technology specifically designed for the mm-wave range, our customers realize superior and differentiating device performance for multiple RF applications."

GaN is a key enabler of 5G wireless communications, which requires exceptionally high-speed connections for multimedia streaming, virtual reality, M2M, or autonomous driving. A fully developed Internet of Things (IoT) will experience lower latency and promote both spectrum and energy efficiency, notes EpiGaN. To realize these benefits, 5G systems need to rely on new semiconductor technologies such as GaN to fuel these innovations, the firm adds.

www.epigan.com

IQE's record full-year 2017 results driven by adoption of VCSEL technology in mass-market consumer applications

Full-year 2018 to see 35–60% revenue growth in Photonics, 5% in Wireless, and 5–15% in InfraRed

In its final results for full-year 2017, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has reported revenue of £154.5m, up 16.4% on 2016's £132.7m (and above the guidance of "not less than £150m"). In particular, due to continued diversification, wafer revenue rose by 21.1% from £126m to £152.6m, with strong growth in high-margin product lines (particularly Photonics).

- Photonics revenue rose by 109%, more than doubling from £22.8m to £47.6m, due largely to the adoption of IQE's vertical-cavity surface-emitting laser (VCSEL) technology for mass-market consumer applications that ramped strongly in second-half 2017 (for which wafer revenue was up over 160% year-on-year) as the development program moved to mass-market production in June. "IQE leveraged its expertise of mass-market wireless supply to rapidly ramp the supply of this complex photonics material into unprecedented volumes," says the firm. The supply of materials into this ramp was delivered under multiple multi-year contracts.
- InfraRed revenue rose by 14% from £10.6m to £12m (exceeding the forecasted 10% growth).
- Wireless revenue was broadly flat at £91.6m (compared with 2016's £91.3m), affected by a £3m managed reduction in supplier-managed inventory (SMI) to focus capacity on the ramp in Photonics (SMI inventories are expected to replenish in 2018).
- CMOS++ revenue was flat, remaining at £1.4m.

Wafer sales hence continued to diversify, with Photonics rising from 18% of total revenue in 2016 to 31% in 2017, while Wireless fell from 72% to 60%, and InfraRed stayed at 8% and CMOS++ at 1%.

License income from sales to joint ventures fell from 2016's £6.7m (which included significant upfront license fees) to £1.9m in 2017.

Excluding license income, gross margin on wafer sales rose from 21.8% to 24.1%, primarily reflecting the benefit of a favourable sales mix with a greater proportion of higher-margin Photonics sales.

Selling, general & administrative (SG&A) expenses rose from £16.6m to £21.6m, reflecting investment for growth.

Adjusted operating profit rose from £22.1m to £26.4m, reflecting an increase in wafer-related profits from £15.5m to £24.5m (due to high operational gearing and the more profitable sales mix) partially offset by the £4.8m reduction in license income.

Adjusted operating margins for the primary segments were 15% for Wireless, 38% for Photonics and 27% for InfraRed. "These represent sustainable margins, and hence provide the opportunity for future margin expansion through continuing diversification of revenues," believes IQE.

Conversion of adjusted operating profit into operating cash rose from 102% to 113%.

Aiding diversification, to address near-term and foreseeable growth opportunities, capital investment has been increased from £19.1m to £28.2m. This comprises:

- Capital expenditure (CapEx) up by £0.3m to £11.3m in cash paid directly to equipment suppliers. In addition, IQE financed £6.6m of CapEx via finance lease (where the bank settled the purchase cost directly with equipment suppliers). This lease was settled prior to the year end (with title to the equipment passed to the group), so the cash flow is classified as part of the repayment of borrowings. Total cash invested in equipment was hence £17.9m (and total investment was hence £34.8m).
- Investment in product development up by £8.2m from £6.3m to £14.5m (due mainly to VCSEL technology that ramped into mass-market production through second-half 2017).
- Investment in intangible assets up by £0.6m to £2.4m. This comprises the purchase of patents from third parties (including a portfolio of 54 patents relating to quasi photonic crystals reported in December), the cost of patenting internally generated IP, and software.

In November, IQE issued 67.9 million new ordinary shares, raising gross proceeds of £95m, primarily to finance a capacity expansion program to deliver the scale needed to capture multiple high-growth market opportunities (particularly the continuing ramp in demand for VCSELs as adoption broadens) as well as enabling the acceleration of product development. Proceeds went partly to repay outstanding borrowings in order to save interest charges. Hence, versus net debt of £39.5m at the end of 2016, at the end of 2017 IQE had net funds of £45.6m.

"We continue to expand capacity to meet forecast increases in demand, as well as driving throughput and yield improvements to release latent capacity and drive margin expansion in our existing business," says CEO Dr Drew Nelson.

Central to the expansion is the creation of a new 'Mega Foundry' in progress in Newport, South Wales, which will house up to 100 tools. The first five are installed and on track for production in second-half 2018. A further five tools should be installed and commissioned by end the end of Q3/2018. "Initial building works only began in September,"

notes Nelson. Preparation is underway to acquire at least a further 10 tools in the next 12–18 months, as demand requires. The new foundry is being supported by £37.9m from the Cardiff Capital Region (CCR) City Deal's Wider Investment Fund, which (after a deal last May) is funding building of the infrastructure. IQE is leasing the building under an 11-year lease, which has a 3-year rent-free period and an option to purchase. This support has enabled IQE to focus its own investment on adding new tools, which requires upfront investment in both OpEx and CapEx. The lead time to get new tools into production is 9–12 months, so a fully utilized tool making VCSELs has a payback of about one year.

Progress with technology development includes demonstration of key enabling technology for high-performance wireless filters; cREO for integration of compound semiconductor materials technologies on silicon; and quasi photonic crystals and nano-imprint lithography for a wide range of optical technologies including distributed feedback (DFB) lasers, integrated 3D sensing, and silicon photonics applications.

Also, qualifications are in progress with IQE's gallium nitride on silicon (GaN-on-Si) technology for base-station and other high-power RF applications (providing a route to accelerating wireless growth).

Customer interactions are broadening for InfraRed, where IQE is working with OEM and device companies in developing IR products for mass-market consumer applications.

There has also been continued progress by IQE's joint ventures in the UK and Singapore. Significantly expanding external customer engagements and improving financial performance reflect the achievement of key milestones for these early-stage businesses.

Driven by expansion of existing business and qualifications of new business streams, in full-year 2018 IQE expects wafer revenue growth of 35–60% in Photonics (based on expansion of products currently in production and the completion of ongoing qualifications), up to 5% in Wireless (with supplier-managed inventories replenishing, and potential for revenue expansion as GaN products make stronger contribution), and 5–15% in IR (with customer engagement broadening).

In addition, in 2019 and beyond IQE believes that there is potential for strong growth from the following:

- increasing VCSEL adoption for 3D sensing accelerating across multiple smartphone OEMs, the introduction of world-facing 3D technology, and the first deployment of LiDAR (light detection and range-finding) and several other high-volume sensing applications;
- increasing deployment of indium phosphide (InP) for high-speed fiber-to-the-premises (FTTx) and data-center applications;
- increasing compound semiconductor content in 5G communication systems and adoption of GaN for base-station and other high-power RF applications (including consumer-driven opportunities);
- increasing use of IR products in mass-market consumer applications;
- revenues from both the power switching and non-terrestrial solar markets;
- the adoption of IQEs broad IP portfolio into multiple commercial applications utilizing cREO (rare earth oxide), nano-imprint lithography (NIL) and quasi photonic crystal (QPC) technologies; and
- multiple qualifications in progress with DFB laser products.

"The depth and breadth of customer engagements in Photonics provides a solid platform for continuing strong growth, with several new product launches forecast over the next 12–18 months for multiple OEMs," says Nelson.

Based on existing products, IQE expects compound annual growth rates (CAGRs) over the next 3–5 years of up to 10% in Wireless, 40–60% in Photonics, and 5–15% in InfraRed, with potentially higher growth via new product introductions.

www.iqep.com

IQE acquiring Translucent's cREO technology & IP portfolio for $5m

IQE has exercised its exclusive option to acquire the 'Rare Earth Oxide' (cREO) technology and IP portfolio of Translucent Inc of Palo Alto, CA, USA (a subsidiary of Australian-listed company Silex Systems Ltd). IQE will pay $5m, from either its existing cash resources or new ordinary shares of 1 pence each issued to the vendor, within 6 months following the exercise of the option.

IQE announced in September 2015 that it had agreed an exclusive 30-month licence for the commercialization of Translucent's unique cREO technology and an exclusive option (exercisable solely at IQE's discretion) on the subsequent acquisition of the technology.

cREO technology is said to offer a unique approach to the manufacture of a wide range of compound semiconductor on silicon products, including gallium nitride on silicon (GaN-on-Si) for the burgeoning power switching and RF technology markets. The original cREO technology is protected by a wide-ranging IP patent portfolio. This portfolio has been further enhanced by IQE since September 2015, across a range of new application areas including RF filters and silicon photonic applications, and includes a number of new materials configurations.

"This type of materials innovation is at the core of IQEs disruptive semiconductor materials solution strategy, as we move from a bespoke, customer-specification-led business model to a more broad-based materials-innovation-led model which offers customers new opportunities to develop disruptive end-market products," comments IQE's president & CEO Dr Drew Nelson.

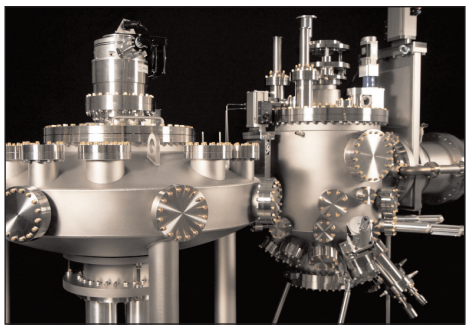
www.translucentinc.com

Veeco installs 100th automated MBE system

GEN10 MBE installed at Silanna for oxide R&D for opto devices

Veeco Instruments Inc of Plainview, NY, USA has completed installation of its 100th automated molecular beam epitaxy (MBE) system — specifically a GEN10 MBE installed in February at Silanna Semiconductor Pty Ltd in Brisbane, Australia. Founded in 2006, Silanna already operates a Veeco Dual GEN200 MBE system for the production of nitride-based devices including ultraviolet light-emitting diodes (UV-LEDs).

"Veeco has earned a reputation for consistently developing innovative and reliable MBE technology from research scale to production," comments Silanna's chief scientist Petar Atanackovic Ph.D. "The flexibility and deposition capability of the GEN10 system will enable us to develop new materials at the atomic level, allowing us to exploit new quantum properties," he adds.



Veeco's GEN10 MBE system.

"Veeco's technology portfolio and leadership in MBE systems provides us with a clear path to easily scale to volume production in the future."

Silanna is using the GEN10 system for advanced oxide R&D for opto-electronic devices. Veeco says that the GEN10 is built upon almost 20 years of cumulative automation knowledge and derived from the company's proven production MBE systems. Adopted by many corporations, institutions and universities for all major MBE applications, Veeco says that the GEN10 is often because of its flexibility, which allows configuration of the system for a particular application. This is said to give optimal performance with any material set, including those related to III–V group elements, oxides and nitrides.

"Silanna has achieved remarkable results on its previous MBE systems," comments Gerry Blumenstock, VP & general manager, Veeco MBE Products. "As our customers explore novel materials and new applications, they can rely on Veeco to deliver innovative MBE systems, sources and components for use in complex R&D, as well as high-volume production environments."

www.silanna.com
www.veeco.com/technologies-and-products/mbe-systems

Rochester Institute improves nano-structure fabrication

Use of InGaP with I-MacEtch process shows promise for more cost-effective fabrication and increased device performance

Rochester Institute of Technology (RIT) in the USA says it has found a more efficient fabricating process to produce semiconductors for electronic devices, and that the inverse metal-assisted chemical etching (I-MacEtch) method can help to meet the growing demand for more powerful and reliable nano-technologies needed for solar cells, smartphones, telecommunications grids and new applications in photonics and quantum computing (Wilhelm et al, 'Fabrication of Suspended III-V Nanofoils by Inverse Metal-Assisted Chemical Etching of $In_{0.49}Ga_{0.51}P$/GaAs Heteroepitaxial Films', ACS Applied Materials and Interfaces (2018) 10(2) 2058).

I-MacEtch combines the benefits of the two traditional methods of wet etching and reactive-ion etching (RIE). "I-MacEtch is an alternative to two conventional approaches and is a technique that has been used in the field — but the materials that have been explored are fairly limited," says Parsian Mohseni, assistant professor of microsystems engineering in RIT's Kate Gleason College of Engineering & director of the Epitaxially-Integrated Nanoscale Systems (EINS) Laboratory at the university. MacEtch has been used extensively for processing silicon. At the same time, assessments are underway of III-V semiconductor materials that may be conducive to this same type of fabrication with similar advantages.

Mohseni is looking at different alloys of III-V materials, namely ternary alloys such as indium gallium phosphide (InGaP). "For the first time we are looking at applying I-MacEtch processing to InGaP materials," he says. InGaP is one of several materials being tested to complement silicon as a means to improve the existing capacity of semiconductor processing. "This is a very well-known material and has applications in the electronics and solar cell industries," Mohseni adds. "We are establishing new protocols for treating the existing material that is more cost effective, and a more sustainable process."

The research highlights how the nanofabrication methodology was applied to InGaP and how it can impact the processing of device applications and generation of high-aspect-ratio and nano-scale semiconductor features, says microsystems engineering doctoral student Thomas Wilhelm (first author of the paper). It is reckoned that the novel processing method can be significant in the development of ordered arrays of high-aspect-ratio structures such as nanowires.

For solar cells, the aim is to minimize the cost-to-power-produced ratio. If it is possible to lower the cost of making the cell and increase the efficiency of it, then this improves the device overall. Exploring new methods of fabricating the existing materials in a way that allows for faster, less expensive and more controlled processing by combining the benefits of wet etching and RIE has been the focus of Mohseni's work. The improved process means avoiding expensive, bulky, hazardous processing methods.

"We are using a simple benchtop set up and we end up with very similar structures; in fact, one can argue that they are higher in quality than the structures that we can generate with RIE for a fraction of the cost and with less time, less steps throughout, without the higher-temperature conditions or expensive instrumentation," Mohseni says.

https://pubs.acs.org/doi/10.1021/acsami.7b17555

www.rit.edu/gis/nanopower/research/nanowire-devices

Aixtron returns to annual profit in 2017 after sale of ALD/CVD product line

Continuing business to grow revenue 20–35% in 2018 to €230–260m

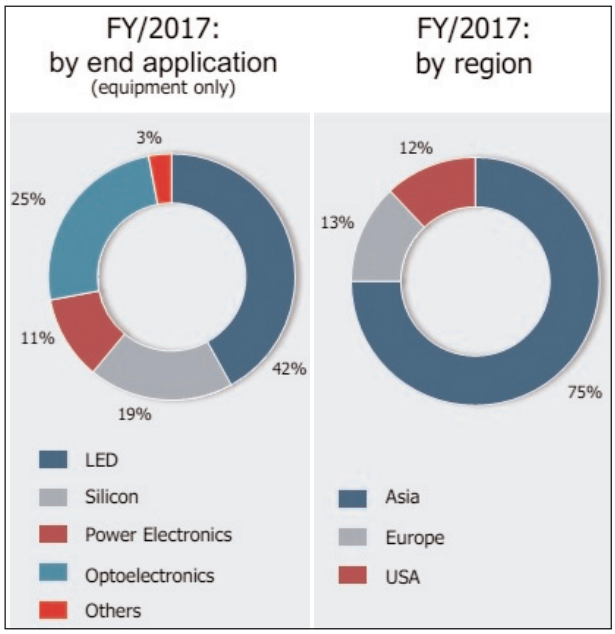
For fourth-quarter 2017, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €54.1m, down 13% on €62.2m last quarter and 39.8% on €89.8m a year ago.

However, full-year revenue was still €230.4m, up 17% on 2016's €196.5m, and slightly exceeding the guidance of €220–230m. "2017 was a good year for Aixtron, with revenues and orders at the best levels since 2011," notes VP of finance & administration Charles Russell.

In particular, equipment revenue grew by 21% from €155.7m to €188m (rising from 79% to 82% of total revenue), while sales of spare parts & services rose by just 4% from €40.8m to €42.4m (falling from 21% to 18% of total revenue).

Of equipment revenue, the proportion from metal-organic chemical vapor deposition (MOCVD) systems for the production of LEDs (including red-orange-yellow 'ROY' and specialty LEDs) rebounded from just 26% in 2016 to 42% in 2017 (€79.1m, including €25m from the sale of AIX R6 gallium nitride blue LED systems out of inventory). Meanwhile, systems for the production of Optoelectronics (excluding LEDs) fell from 34% to 25% (€47.8m), Power Electronics from 14% to 11% (€20.4m), and Silicon from 21% to 19% (including €38.8m from the atomic layer deposition/chemical vapor deposition (ALD/CVD) product line for memory chip production).

Asian revenue rebounded further from 65% of total revenue in 2016 to 75% in 2017 (growing from €128m to €172.3m, including China growing from €64.8m to €89.8m, Korea from €27.1m to €44.3m, and Taiwan from €22m to €25.7m). Meanwhile, the Americas fell further from 19% to 12% (from €37.7m to €28.9m) and Europe fell from 16% to 13% (from €30.8m to €29.2m).



Gross margin improved from 29% in 2016 to 32% in 2017, due mainly to a better product mix in second-half 2017 after the first half suffered from low-margin sales of AIX R6 MOCVD systems as well as write-downs from freezing activities in both III-V-on-silicon (TFOS) for microprocessor logic (on 300mm wafers) and in thin-film encapsulation (TFE) since Aixtron's organic light-emitting diode (OLED) activity is now focused on organic vapor phase deposition (OVPD) technology for depositing different layers of the OLED stack. "In the second half of the year gross margin reached 39–40%, reflecting the increasing sales of better-margin product based on the growing value of high-performance solutions to our customers," says president Dr Bernd Schulte. Quarterly gross margin was 39% in Q4/2017, down slightly from 40% in Q3/2017 but up from just 33% a year ago. "This is free from the effects of desired margin sales from the old or sold product lines and is therefore indicative of what we should expect in the coming periods," says Russell.

Full-year operating expenses (OpEx) have been cut from €77.7m (40% of revenue) in 2016 to €69.1m (30% of revenue) in 2017. This included restructuring effects of €12.8m from the freezing of TFOS and TFE activities as well as positive effects from the sale of the atomic layer deposition/chemical vapor deposition (ALD/CVD) product line for memory chip applications (based at US subsidiary Aixtron Inc in Sunnyvale, CA, USA) to Eugene Technology Inc (a US subsidiary of South Korea-based Eugene Technology Co Ltd) on 15 November (contributing to total Aixtron staffing falling during 2017 from 705 to 581).

In particular, selling expenses were €10.2m, down from 2016's €13.8m (although that included the closure of a demonstration facility in China). General & administrative (G&A) expenses were steady at €17.1m. R&D costs rose by 28% from €53.9m (27% of revenue) in 2016 to €68.8m (30% of revenue) in 2017, although this includes TFOS and TFE write-downs in first-half 2017 as well as increased spending on R&D particularly for OLED applications.

The full-year operating result (earnings before interest and taxes, EBIT) improved from –€21.4m in 2016 to +€4.9m (2% of revenue) in 2017. However, this was largely due to quarterly EBIT rising from just €4.6m in Q3 to €24.4m in Q4 after a profit of €23.9m on disposal of the ALD/CVD product line. This brought Aixtron into profit a year earlier than planned.

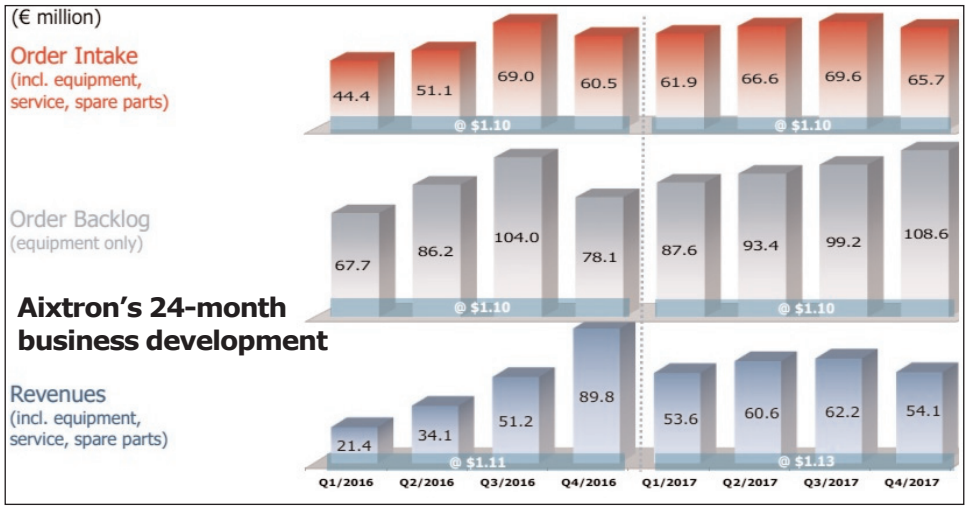
Driven mainly by the improved profitability, reductions in working capital, and ALD/CVD product line sale, full-year operating cash flow has improved from –€37.7m in 2016 to +€70.1m in 2017. Quarterly operating cash flow was €13.6m in Q4, up from €13.2m in Q3.

Free cash flow in 2017 was €91.4m (compared with –€42.9m in 2016), albeit due mainly to €51m from the sale of the ALD/CVD product line plus €39m in collections from the high level of receivables at the end of 2016. Capital expenditure (CapEx) totaled €9.7m (up from €5.3m in 2016). Cash and cash equivalents (including cash deposits with a maturity of more than 90 days) hence rose to €246.5m at the end of December, up €86.4m from €160.1m on a year previously.

Aixtron notes that, following its thwarted takeover by China's Grand Chip Investment in December 2016, its return to profit in 2017 was achieved by implementing a strategic reorientation of its technology portfolio to focus on product lines that either are profitable or promise to generate a significant return on investment in the near term, while freezing its activities in TFOS and TFE and divesting its ALD/CVD product line.

Also, on 1 October 2017 the subsidiary APEVA SE — to which Aixtron transferred its OVPD OLED deposition technology — officially began operation. Gen1 OLED systems are in operation at an Asian display manufacturer's R&D line. "Gen2 system will soon be installed at the customer facility in order to qualify the technology for mass production," says Schulte. "In addition, we are in discussions with several companies about a partnership [joint venture] in the OLED sector, which should complement APEVA's range of products and services," adds president Dr Felix Grawert.

For 2018, Aixtron continues to pursue its goal of returning to sustainable profitability in its operating business. This is supported by the continuing market demand, particularly in MOCVD systems for the production of vertical-cavity surface-emitting lasers (VCSELs) for 3D sensing and other lasers for applications such as optical communications, as well as ROY and specialty LEDs. In the medium term, the adoption of power electronics components based on the wide-bandgap materials gallium nitride (GaN) and silicon carbide (SiC) opens up further potential.



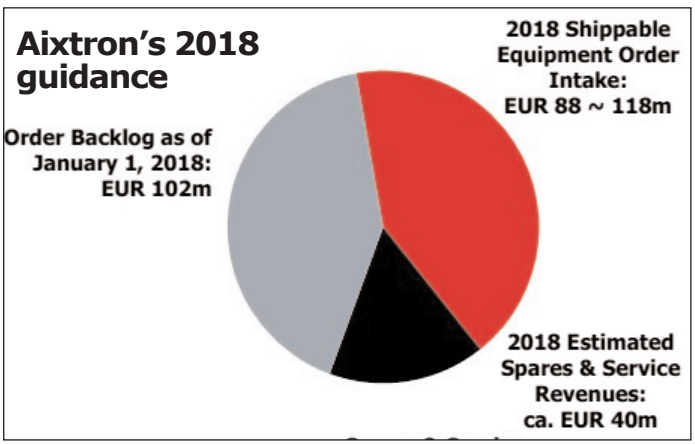
"With Aixtron's comprehensive reorientation, the company is focusing on its core MOCVD equipment business," says Grawert. "We supply systems in various end-markets with attractive growth potential and expect to be clearly profitable again in our operating business in 2018. This is supported by a strong order backlog and stable order intake," he adds.

Driven by the continued demand for MOCVD systems for the production of VCSELs and other lasers, ROY and specialty LEDs as well as power electronics and memory chips, order intake (including spare parts and service) in 2017 amounted to a better-than-expected €263.8m, up 17% on €225.1m in 2016. "The strong orders reflect improved conditions particularly in our two core markets MOCVD for LEDs and for optoelectronics," says Russell. Quarterly orders were €65.7m, down on €69.6m last quarter but up on €60.5m a year ago.

Equipment order backlog as of end-December 2017 rose to €108.6m, up 9% from €99.2m at end-September 2017 and up 39% year-on-year from €78.1m at end-December 2016.

Based on equipment order backlog of €102m on 1 January (at an internal budgeted exchange rate of $/€1.20 for 2018) joined by an estimated €88–118m of order intake shippable during 2018 plus an estimated €40m of spares & services revenue, for 2018 Aixtron expects both revenues and total orders of €230–260m, up 20–35% on 2017's €191.6m for continuing business (excluding €38.8m from the divested ALD/CVD product line in 2017). Due mainly to the larger proportion of higher-margin products, Aixtron expects gross margin to rise to 35–40% and EBIT to rise to 5–10% of revenue. OpEx should be about €75m. Operating cash flow should be positive, but lower than in 2017 (which included €51m from selling the ALD/CVD product line) due partly to including €11.7m for settling liabilities towards third parties of the ALD/CVD business. These expectations for 2018 include the results of subsidiary APEVA with all planned investments to further develop OLED activities.

www.aixtron.com



KLA-Tencor to acquire SPTS' parent firm Orbotech

Acquisition expands portfolio for semiconductor processing

Process control and yield management solutions provider KLA-Tencor Corp of Milpitas, CA, USA has agreed to acquire Orbotech Ltd of Yavne, Israel for $38.86 in cash and 0.25 of a share of KLA-Tencor common stock in exchange for each ordinary share of Orbotech — a total of $69.02 per share. The deal gives Orbotech at an equity value of $3.4bn and an enterprise value of $3.2bn.

KLA-Tencor has also announced the authorization of a $2bn share repurchase program, to be completed within 12–18 months following the close of the transaction.

With this acquisition, KLA-Tencor will diversify its revenue base and add $2.5bn of addressable market opportunity in the printed-circuit board (PCB), flat-panel display (FPD), packaging and semiconductor manufacturing areas. Its defect inspection and metrology products include systems for LED manufacturing. However, as well as providing yield-enhancing and process-enabling solutions for electronics production, Orbotech owns SPTS Technologies Ltd of Newport, Wales, UK (which manufactures etch, PVD and CVD wafer processing solutions for the MEMS, advanced packaging, LED, high-speed RF, and power management device markets). The broader portfolio of products, services and solutions, as well as increased exposure to technology megatrends, should support KLA-Tencor's long-term revenue and earnings growth targets, it is reckoned.

"This acquisition is consistent with our strategy to pursue sustained, profitable growth by expanding into adjacent markets," says KLA-Tencor's president & CEO Rick Wallace. "This combination will open new market opportunities for KLA-Tencor, and expands our portfolio serving the semiconductor industry," he adds. "Our companies fit together exceptionally well in terms of people, processes and technology. In addition, KLA-Tencor has had a strong presence in Israel over the years, and this combination further expands our operations in this important global technology region," Wallace notes.

"Together with KLA-Tencor, we will significantly increase growth potential, accelerate our product development roadmap, and enhance customer offerings," comments Orbotech's CEO Asher Levy. "Orbotech will continue to operate under the Orbotech brand as a standalone business of KLA-Tencor based in Yavne, Israel."

Total cost synergies are expected to be about $50m on an annualized basis within 12–24 months following the closing of the transaction, which is expected to be immediately accretive to KLA-Tencor's revenue growth model, non-GAAP earnings and free cash flow per share.

The deal has been approved by the board of directors of each company and is expected to close by fourth-quarter 2018, subject to approval by Orbotech's shareholders, required regulatory approvals and the satisfaction of the other customary closing conditions. No approval by KLA-Tencor stockholders is required. KLA-Tencor intends to fund the cash portion of the purchase price with cash from the combined company's balance sheet. In addition, it intends to raise about $1bn in new long-term debt financing to complete the share repurchase.

www.kla-tencor.com
www.spts.com
www.orbotech.com

MRSI-HVM3 die bonder enters volume production

MRSI Systems of North Billerica, MA, USA (which makes fully automated, high-precision, high-speed die bonding and epoxy dispensing systems) says that its new MRSI-HVM3 system — launched at the 19th China International Optoelectronics Exposition (CIOE 2017) in Shenzhen (6–9 September) — has entered volume production, using Demand Flow Technology (DFT) to satisfy worldwide customer demand.

The first wave of configured MRSI-HVM3 systems has been focused on chip-on-submount (CoS), chip-on-carrier (CoC), and chip-on-baseplate (CoB) processes, and have been installed in North America, Europe and Asia.

"Our new 3μm high-speed die bonder MRSI-HVM3 is exactly the solution the photonics market was looking for to address one of the most critical manufacturing bottlenecks," says Dr Yi Qian, VP of product management. "We listened to our customers and prospects and geared the roadmap towards the direction of high speed without sacrificing high accuracy, or high flexibility, to handle multi-chip multi-process production in one machine. As a result, the system is able to generate a great return on investment," he claims.

The new system helps photonic device companies to execute their strategy to have a fast-response high-volume manufacturing capability alongside the ability to maintain low manufacturing costs for the high demand driven by data-center applications, the firm says. "We also predicted the new system would need to allow the production of multiple products passing through the same production line without sacrificing throughput," says Qian. "Our assumptions have been validated by this first wave of customers with their test results on their facility floors."

www.mrsisystems.com

Picosun reports significant repeat sales of P-300F batch ALD production cluster tools

Atomic layer deposition (ALD) thin-film technology firm Picosun of Espoo, Finland has reported significant repeat sales of P-300F production cluster tools to major US industrial customers.

Even if most common ICs are produced on 300mm silicon wafers, sub-300mm manufacturing is increasingly important, especially for existing and emerging non-silicon-based devices, notes Picosun. Wafer materials limited to maximum 200mm diameter such as silicon carbide (SiC), gallium nitride (GaN), aluminium nitride (AlN), sapphire, gallium arsenide (GaAs), lithium niobate ($LiNbO_3$) and lithium tantalate ($LiTaO_3$) offer benefits over silicon and enable a generation of new end-products, adds the firm.

Picosun's core competence is cost-efficient, turn-key ALD production systems for the fast-growing More-than-Moore market, for which the P-300F is the flagship product. Specially designed to be run in cluster configuration under constant vacuum to enable fast and efficient high-throughput manufacturing, P-300F tools are connected together and operated in fully automatic mode with a central vacuum robot substrate handling and transfer system. The unique batch flipping mechanism in the P-300F is suitable for manufacturing lines where most of the process steps take place in a horizontal geometry. Cassette-to-cassette loading for up to 50-wafer batches of 200/150/100mm substrates, SEMI S2/S8 certification and a SECS/GEM option for factory host integration make the P-300F the optimal choice for demanding manufacturing needs for, for example, moisture barriers, capacitors and surface acoustic wave (SAW) and bulk acoustic wave (BAW) filters.

"The purity, uniformity and barrier properties of the ALD films deposited in these systems fulfil the strictest requirements of today's semiconductor industries, making the Picosun P-300F the tool of choice for the forerunners of semiconductor manufacturing," claims managing director Juhana Kostamo.

www.picosun.com

3D-Micromac unveils Clean Scribe technology on microDICE TLS laser micromachining system for particle-free dicing of SiC wafers

3D-Micromac AG of Chemnitz, Germany (which supplies laser micromachining systems and roll-to-roll laser systems for the photovoltaic, medical device and electronics markets) has unveiled its Clean Scribe technology, a new patent-pending feature for its microDICE laser micromachining system that enables particle-free scribing of silicon carbide (SiC) wafers without the need for expensive coatings and without impacting wafer dicing throughput. Clean Scribe works with 3D-Micromac's TLS-Dicing (Thermal-Laser-Separation) process integrated into the microDICE system to provide fast, damage-free and cost-effective wafer dicing with no additional material or equipment overhead, the firm says.

"Consumer demand for hybrid and electric vehicles, as well as growing use of automotive electronic systems for improved fuel efficiency and driver safety, is fueling the need for SiC-based power devices," notes product manager Hans-Ulrich Zühlke. "Maximizing yield on the production of power devices is paramount to ensuring consumer safety for these applications. At the same time, driving down costs throughout the SiC power device manufacturing process is crucial to enabling wider adoption of these advanced vehicles by consumers," he adds. "Our new Clean Scribe technology is the latest example of 3D-Micromac's commitment to continuous innovation of our TLS-Dicing process in order to achieve greater yield, throughput and cost savings in device pre-packaging as well as to expand the applications that can benefit from our technology."

New laser scribing approaches needed

Since scribing is an essential step in wafer dicing, 3D-Micromac's TLS-Dicing approach is a two-step process involving the use of a short ablation laser to produce an initial scribe at the beginning of each cut in the dicing street in order to initiate a crack. This 'dry' scribe process generates a very low number of particles. In the second step, a continuous-wave laser is passed along this line to heat up the material locally, which is then rapidly cooled by spraying with deionized (DI) water, cleaving the wafer.

To enhance the reliability and straightness of the cleave, the initial scribe can be performed across the entire length of the dicing street. However, this 'continuous scribe' can generate a greater number of particles, which may be too much for certain particularly demanding SiC applications. To avoid this, users previously needed to reduce the speed of the scribing process or apply an additional wafer coating step before dicing to prevent particles from falling into the dicing street. However, this step adds significantly to process complexity and cost.

3D-Micromac's new Clean Scribe technology uses a patent-pending laser scribing process that eliminates polyimide and metal particles in the dicing street, enabling a virtually particle-free surface without the need for expensive coatings. Clean Scribe replaces the 'dry' scribe approach with an aerosol spray that uses an extremely small amount of DI water (less than 20ml/min) to wash away the particles during the laser processing step. Since the TLS-Dicing process already uses DI water and compressed air for the cleaving step, no additional systems or consumables are needed with Clean Scribe.

At the same time, Clean Scribe achieves these results with no loss of throughput, enabling wafer dicing speeds of up to 300mm/s.

3D-Micromac showcased its new Clean Scribe technology on its microDICE laser micromachining system at SEMICON China 2018 at the Shanghai New International Exhibition Centre (14–16 March).

http://tls-dicing.com
http://3d-micromac.com

OIPT delivers record integrated 'Lab to Fab' solutions

UK-based plasma etch and deposition processing system maker Oxford Instruments Plasma Technology (OIPT) is celebrating a year of delivering a record number of integrated solutions, enabling customers to rapidly commercialize semiconductor devices, developed using Oxford Instruments 'Lab to Fab' solutions.

Oxford Instruments says that many of its customers are now converting their research into commercially available devices. The key to success is to transfer the results achieved in development and pilot facilities, and repeat them every day, every month in the fabrication facility, notes the firm. OIPT reckons that, due to its installed base of R&D tools, it is ideally placed to offer this 'Lab to Fab' solution.

"We've shipped over 600 of our high-technology process modules to leading production facilities and, with an increasing demand from the optoelectronics, power and other leading markets, our plasma process solutions are being utilized globally to achieve excellent device performance and throughput," says OIPT's sales & marketing director Paul Davies.

www.oxinst.com/plasma

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BluGlass collaborates with microLED firm to develop novel RGB display applications

BluGlass Ltd of Silverwater, Australia has entered into a collaboration agreement with a "well-funded European pioneer in the microLED industry" to investigate the use of BluGlass' proprietary remote-plasma chemical vapor deposition (RPCVD) manufacturing technology. The collaboration is exploring a novel application with what is described as significant commercial potential.

BluGlass is commercializing its proprietary low-temperature 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.

The two firms will work together to demonstrate proof of concept of a unique red, green and blue (RGB) microLED display application using the low-temperature process. BluGlass will be paid for its deposition services and retain all RPCVD-related intellectual property rights resulting from the collaboration.

"The microLED market is an enormous opportunity for RPCVD within one of the fastest-growing LED market segments, with applications in wearables (watches), mobile displays, next-generation TV displays, virtual reality (VR) and augmented reality (AR)," comments managing director Giles Bourne. "The inherent advantages of RPCVD lends itself to RGB LEDs, required in micro-displays," he adds. "Low-temperature RPCVD could be key to unlocking high performance of longer-wavelength LEDs (green and red LEDs) and be part of an enabling technology solution."

www.bluglass.com.au

BluGlass and Lumileds extend Phase II collaboration

BluGlass has agreed with LED maker Lumileds of San Jose, CA, USA to extend their existing Phase II collaboration in order to accelerate the development of new applications of LEDs using BluGlass' remote-plasma chemical vapor deposition (RPCVD) technology.

BluGlass is commercializing its proprietary low-temperature RPCVD process for manufacturing InGaN-based LEDs, power electronics and solar cells, offering advantages including higher performance and lower cost, it is claimed.

The agreement is one of several collaborations that BluGlass has as part of its continuing program to commercialize its RPCVD manufacturing technology, and to continue the development of IP in this field. BluGlass has patented hardware and processes targeting the production of more efficient semiconductor devices at lower cost, to address opportunities in the LED market.

BluGlass and Lumileds have identified strategies to speed development, including shortening turnaround times of project iterations.

"Lumileds is committed to this project and looks forward to realizing the benefits of this new technology," says Parijat Deb, senior director R&D at Lumileds.

"The Lumileds collaboration remains a key priority for BluGlass," comments BluGlass' managing director Giles Bourne. "We look forward to expediting progress and continuing to work with Lumileds towards identifying what new commercial opportunities might exist."

www.lumileds.com

Monocrystal delivers 55 million TIE sapphire substrates to LED market in 2017, taking 50% of market

Following 70% expansion, capacity to be expanded a further 50%

Monocrystal Inc of Stavropol, Russia, which manufactures large-diameter synthetic sapphire substrates and ingots for LED, optical products and RFIC applications, says that 2017 was another year of sustainable growth after delivering 55 million two-inch equivalent (TIE) sapphire products to the LED market. This gives Monocrystal a 50% share of a 110 million TIE market in sapphire for LEDs, says market research firm Yole Developpement.

"2017 was a year of rapid growth for the LED industry, and most of our clients significantly expanded their production," notes Monocrystal's CEO Oleg Kachalov. "Monocrystal successfully accomplished a challenging 70% capacity increase and provided all the requested volume to its customers. This contributes to a secure execution of our customers' expansion plans, which is crucial for obtaining leading positions on the highly competitive LED market," he adds.

"This year we will continue to build upon the momentum in the LED industry," says VP sales Mikhail Berest. "For this purpose, we are planning to add 50% to our capacities," he adds. "We are ready to help our customers meet their ambitious targets in 2018."

www.monocrystal.com

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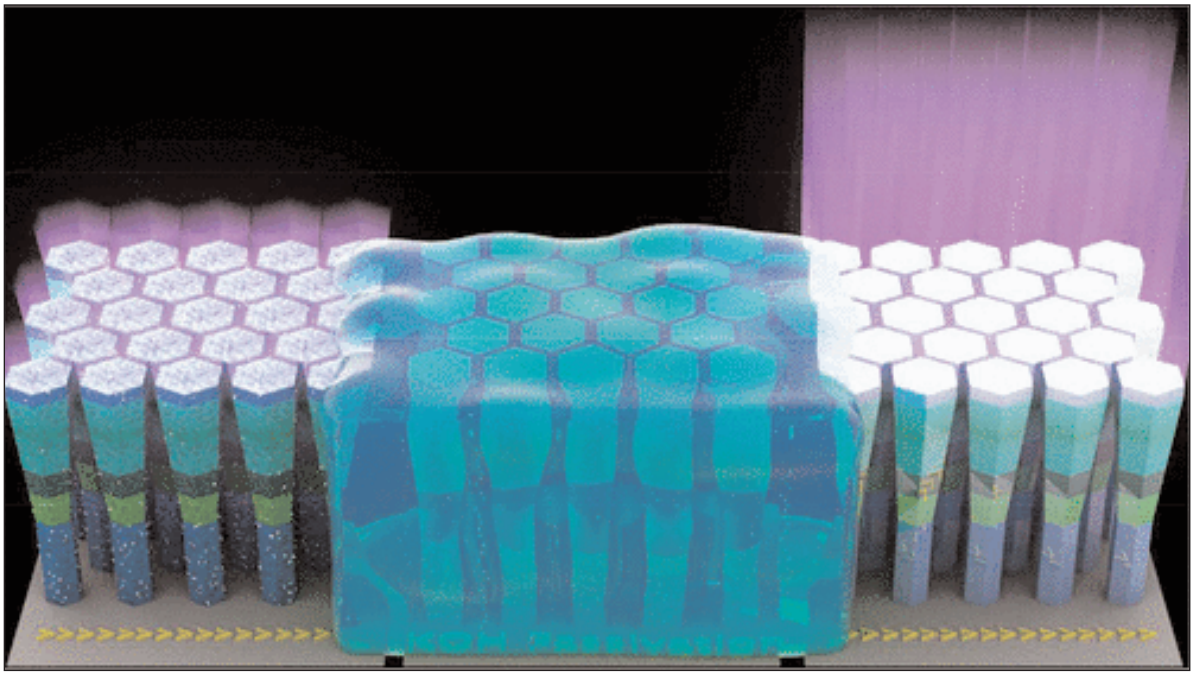
FerroTec

Simple chemical surface treatment improves light extraction from nanowire UV LEDs

Cleaning in potassium hydroxide suppresses surface reabsorption by removing dangling chemical bonds and preventing oxidization



AlGaN nanowires, treated with diluted potassium hydroxide solution to enhance UV light output .

King Abdullah University of Science and Technology (KAUST) has demonstrated a technique for reducing the loss of light at the surface of semiconductor nano-structures (H Sun et al, 'Surface-passivated AlGaN nanowires for enhanced luminescence of ultraviolet light emitting diodes', ACS Photonics (2018) 5 (3) 964).

Since gallium arsenide emits predominantly infrared light, for shorter wavelengths in the blue or ultraviolet (UV) region of the spectrum, gallium nitride is used. To tune down the emission wavelength further, aluminium can be added (altering the spacing between the atoms and increasing the energy bandgap).

However, numerous factors prevent all the radiation created in the semiconductor escaping the device to act as an efficient light source. Firstly, most semiconducting materials have a high refractive index, which makes semiconductor–air interfaces highly reflective — at some angles all light bounces back (total internal reflection). A second limitation is that imperfections at the surface (e.g. oxidation and high-density surface states) cause strong recombination, reabsorbing the light before it can escape.

Postdoctoral researcher Haiding Sun and his colleagues, including supervisor assistant professor Xiaohang Li, professor Boon Ooi and assistant professor Iman Roqan, have developed light-emitting diodes consisting of a tight array of dislocation-free nanoscale aluminium gallium nitride (AlGaN) nanowires on a titanium-coated silicon substrate. More light can be efficiently extracted due to the presence of the air gaps between nanowires via scattering. The trade-off however is that arrays of nanowires have a larger surface area than a planar structure. "Because of the large surface-to-volume ratio of nanowires, their optical and electrical properties are highly sensitive to their surroundings," says Sun. "Surface states and defects will lead to low-efficiency light-emitting devices."

Because of the large surface-to-volume ratio of nanowires, their optical and electrical properties are highly sensitive to their surroundings. Surface states and defects will lead to low-efficiency light-emitting devices

Sun and the team have shown that treating the nanowires in a diluted potassium hydroxide (KOH) solution — commonly used in semiconductor fabrication but barely used for surface passivation of self-assembled nitride-based nanowires — can suppress surface reabsorption. It does this by removing surface dangling chemical bonds and preventing oxidization of nitrides (forming Ga–O or Al–O bonds) at the surface. Their results showed that a 30-second treatment led to a 49.7% enhancement in the UV light output power compared with an untreated device.

"We aim to improve our device's performance in several ways," says Sun. "For example, we will optimize the nanowire growth conditions, we will use quantum-well structures in the active region, and we will use different metal substrates to improve the light-extraction efficiency."

https://pubs.acs.org/doi/10.1021/acsphotonics.7b01235

VueReal raises $10.5m in initial Series A funding

Micro-LED display technology developer VueReal Inc of Waterloo, ON, Canada has announced the initial closing of its $10.5m Series A funding round led by the venture arm of a large Asian firm and a leading North American vendor focused on startups with emerging technology.

VueReal is engineering electronic systems through mass integration of high-efficiency nano/micro- devices into large-area substrates (e.g. displays, sensors, system on panel etc). It initially targets making μ-LED displays affordable for all applications (TV, laptop, smartphone, virtual/augmented reality, etc). The firm's technology platform is based on the interplay of micro/nano-device processing, integration technologies and system design (hardware and software).

VueReal will use the new funding to accelerate development of μ-LED technologies by expanding its team and launching its micro-device development and characterization center. Due to interest from major industry partners, the firm is working to finalize the subsequent close of the Series A funding.

Industry analysts predict a scenario where the market for μ-LED displays could potentially reach 330 million units by 2025. However, development of such displays has been hindered by high material costs and low yield and throughput of μ-LED mass transfer technology.

"We are inspired by the confidence placed in us by our investors as VueReal drives high-performance, super low-power μ-LED displays that are cost competitive with other technologies used in smartphones and mid-to-large-size display applications," says CEO & founder Dr Reza Chaji. "The significant cost reduction is the result of VueReal's proprietary sub-10μm, high-efficiency μ-LEDs, along with our patented mass transfer process."

VueReal also announced that it is collaborating with technology enablers including epitaxial deposition and semiconductor equipment maker Veeco Instruments Inc of Plainview, NY, USA. VueReal claims that, working with industry partners like Veeco, it has developed key technologies and proprietary processes that solve many of the issues associated with manufacturing μ-LEDs. "We look forward to continuing our joint development work using Veeco's expertise to provide technical breakthroughs that advance the μ-LED display industry," states Chaji.

"Veeco has consistently proven technical superiority especially in the development of high-quality red, green and blue (RGB) epitaxy to meet device efficiency, uniformity and yield requirements for μ-LEDs," says Veeco's chief technology officer Ajit Paranjpe. "Veeco continues to take on tough technical challenges as we partner with developers like VueReal working on emerging technologies," he adds. "Our collaboration will accelerate the adoption of micro-LED displays."

www.vuereal.com

Seoul Semiconductor files three patent lawsuits and announces Acrich licensing program

South Korean LED maker Seoul Semiconductor Co Ltd, together with affiliate Seoul Viosys Co Ltd, has filed three new patent infringement lawsuits against a lighting company and distributors selling products that allegedly infringe its Acrich patents.

On 2 March, Seoul filed a patent infringement lawsuit in the Texas Northern District federal court accusing Service Lighting Electrical Supplies Inc of selling LED bulbs that infringe 10 patents relating to Acrich technology in the course of operating 1000bulbs.com, America's largest online retail channel for such bulbs.

Seoul also filed a patent infringement lawsuit in Nevada District Court against Philcort T.V. & Electronic Leasing Inc for infringement of eight Acrich patents.

Seoul has also filed a patent infringement lawsuit in California's Central District Court against Archipelago Lighting Inc for infringement of eight patents. Seoul had already filed a patent lawsuit in the same court last September alleging that Archipelago infringed 12 patents. Seoul subsequently became aware of additional products that it believes are infringing other Acrich patents.

In this series of patent litigations relating to Acrich technology, Seoul is focusing on various LED lamps, including LED filament bulbs, each of which is believed to infringe at least one or more of 20 different patents covering technologies for LED drivers for high-voltage operations, MJT (multi-junction technology), filament LED bulb structures, LED packaging, LED epitaxial growth, LED chip fabrication, etc.

Seoul says that Acrich technology is essential for products that feature high-voltage operation with a high power output yet which rely on only a small number of LED units. In general lighting products, such as streetlights or filament LEDs, demand has increased for LED products capable of more than 12V power. Acrich technology is also increasingly used for high-end televisions with ultra-high definition (UHD) displays because it makes it easy to implement local dimming functions, says Seoul.

"Seoul will continue to enforce its IP against lighting and electrical companies, as well as their retailers, who manufacture or sell infringing products," states general counsel & executive VP Yong-Tae Lee. "But for those companies who wish to conduct business fairly and without infringing Seoul's IP, we will soon be announcing a patent licensing program for Acrich technology. The new licensing program will offer reasonable terms to companies that wish to offer products incorporating Acrich technology essential for LED drivers, packages for high-voltage operations, and AC-operation LED drivers," he adds.

www.SeoulSemicon.com

Seoul Semiconductor demonstrates 150lm/W AC module

Seoul Semiconductor has demonstrated an AC LED module with a luminous efficacy of 150lm/W, developed using the NanoDriver Series LED driver configured for optimum efficiency and employing Acrich MJT 5630 LEDs characterized at a correlated color temperature (CCT) of 5000K and a color rendering index (CRI) of 80, at 25°C ambient temperature and operated at 6V.

Prior to its recent product introduction, Seoul Semiconductor says that many LED fixture designers perceived AC LED technology as a low-performance, low-cost solution, assuming that AC LED technology had compromised performance that restricted its applicability. The firm says the demonstration shows it is possible to get a high-efficacy, low-flicker solution using AC LED technology.

"The NanoDriver Series LED drivers will have a significant impact on LED fixture design by bringing a miniature, low-cost, high-performance module solution to the lighting industry," says executive VP Keith Hopwood.

"The NanoDriver Series devices enable fixture designers to significantly reduce the size, weight and volume of their luminaire designs," explained Hopwood. "The NanoDriver's efficacy, low flicker and miniature size is the result of Seoul Semiconductor's continued research and development into AC LED technology, delivering a less bulky and highly efficient design," he adds.

The NanoDriver Series is suitable for applications such as flush-mount, wall sconce, vanity and down-light applications. Their small size enables ultra-thin and novel fixture designs, making conventional lamp replacement possible without the need for a large volume recess for the driver, or a reduction in the light output, says the firm. Previously, it has been difficult to convert many conventional fixture designs to LEDs because there was no space for the LED driver.

The NanoDriver Series devices are suitable for luminaire designs up to 3000lm, making possible the integration of the control circuitry with the external converter. This allows the mounting of more light sources on board or reducing the total size of the fixture and mounting plate. The NanoDriver Series devices are small and lightweight enough to make airfreight economical, reducing lead time and streamlining the supply chain, the firm adds.

Everlight demos high-efficiency and horticulture lighting products at Light+Building

At the Light+Building 2018 show in Frankfurt, Germany (18–23 March), Taiwan-based Everlight Electronics Co Ltd demonstrated its 5630X-ELB LED series and horticulture-fit LEDs as well as all lighting and lighting-related products, such as luminaires for horticulture and fish lighting,

The 5630X-ELB series not only features luminous efficacy of 228lm/W (@65mA, 5000K, CRI>80) but also complies with the DLC4.0 standard with light-on tests in the high-temperature range (105ºC), L90>36,000 hours, and achieves/features a color tolerance less than 3SDCM (standard deviation of color matching). The 5630X-ELB series hence combines the advantages of luminous efficacy and stability to provide lighting for commercial, professional and industrial applications.

Everlight's 5630X and Horticulture LEDs 3535-ELB Horti, 3030-ELB Horti and 2835-ELB Horti.

Monochromatic light LEDs are widely applied for horticulture lighting, by combining colors to effectively meet the requirements of specific spectra and optical functions. Everlight has developed a special series of products based on monochromatic light wavelength to cover PAR 450–745nm, from high to low power via the SHWO 3535-ELB, 3030-ELB and 2835-ELB LEDs.

The new 2835 PC Red-ELB (2.8mm x 3.5mm x 0.7mm) with 5% blue intensity (CCT) can achieve a wall-plug efficiency (WPE) of 35% (0.5W) to simultaneously replace Royal Blue and Deep Red with a luminous efficacy of 15lm. The new 3535-ELB series (3.5mm x 3.5mm x 2.03mm) offers the advantages of high luminous efficacy, price–performance ratio and a WPE of 65%. In all colors, the products are tested to meet LM-80 (lumen maintenance) and effectively guarantee to meet the customer's requirements.

www.everlight.com

Samsung enhances chip-scale LED package lineup with highest luminous efficacies

Samsung Electronics Co Ltd of Seoul, South Korea has achieved what is claimed to be the industry's highest luminous efficacies for its fillet-enhanced chip-scale package (FEC) LED lineup — LM101B, LH181B and LH231B.

Initially chip-scale package (CSP) LEDs were not widely used in mainstream LED lighting markets due to relatively low efficacy levels compared with conventional LED packages. However, the newly upgraded FECs can be applied to most mainstream LED lighting environments, including ambient, downlight, spotlight, high-bay, canopy and street-lighting applications.

"Since introducing CSP technology to the industry in 2014, we have put extensive effort into advancing the performance levels and design flexibility of every one of our CSP LEDs," says Yoonjoon Choi, VP of the LED business team.

The enhanced FEC LEDs are based on Samsung's most up-to-date CSP technology, which builds titanium dioxide (TiO2) walls around the side surfaces of the chip to direct light output upwards. The technology is said to provide considerably higher light efficacy than conventional CSP LEDs while offering greater flexibility for luminaire designers. Moreover, dramatically reduced cross-talk between neighboring packages allows each package to be placed in close proximity to each other.

Building on these advances, the revamped FEC LED packages achieve what is claimed to be the industry's highest light efficacy levels, to suit a wider range of lighting applications. The LM101B features an increased efficacy of 205lm/W (65mA, CRI 80+, 5000K), which is said to be the highest among 1W-class, mid-power CSP LEDs. The 3W-class LH181B is said to provide the highest light efficacy in its class at 190lm/W (350mA, CRI 70+, 5000K), which represents a more than 10% enhancement over the previous version. The 5W-class LH231B package continues to offer 170lm/W (700mA, CRI 70+, 5000K), which is claimed to be the highest efficacy for the 5W class.

Samsung says that, due to the FEC's small form factor and reduced cross-talk, the LM101B is particularly suited to spotlighting applications where packages can be densely placed within a small light-emitting surface area. The firm also made the LM101B much simpler to mount (compared with other mid-power CSP LEDs) by modifying the electrode pad.

In addition, the LH181B operates at a maximum current of 1.4A, making it suitable for high-power LED luminaires requiring superior lumen density, says the firm.

Now in mass production, the FEC lineup is available in a full range of correlated color temperature (CCT) and color rendering index (CRI) options.

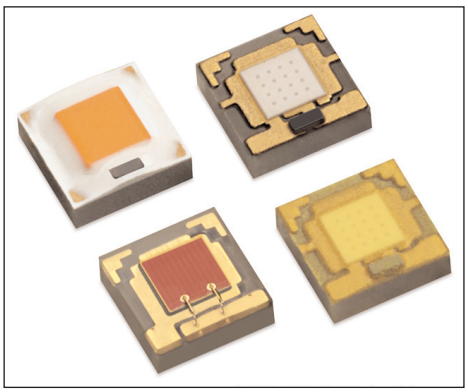
www.samsung.com

Lumileds' new LUXEON CZ LEDs build on LUXEON C Color Line, boosting intensity of narrow-beam-angle, undomed LEDs

To meet the recent market trend of color tuning fixtures with narrow beam angles and maximum punch, LED maker Lumileds of San Jose, CA, USA has launched the LUXEON CZ Color Line, a product line consisting of 21 LED color options including 13 color and 8 white LEDs, optimized to deliver maximum intensity. "The LUXEON CZ features up to 48% higher punch than any other undomed color LED," claims LUXEON Color Family product line director Jennifer Holland.

In addition, the LUXEON CZ Color Line makes fixture designs with narrow beam angles possible. "It is easier for optics to pick up all the light because the emitters cast minimal light below the horizon, unlike comparative products on the market," Holland adds.

In a narrow-beam system, the intensity of the light from the LUXEON CZ is nearly 30-50% higher compared with other undomed LEDs, it is claimed. The intensity of each color is similar, ensuring a consistent beam width and minimizing halos when color mixing.



The product line additionally eliminates crosstalk, ensuring a true color point when LEDs are packed closely together. Crosstalk can happen when direct color LEDs are closely spaced with phosphor converted LEDs. The photons from the direct colors can excite the phosphor in the surrounding phosphor-converted LEDs, making it appear as if the phosphor converted LEDs are on, when in reality only the direct color LED is illuminated. The LUXEON CZ Color Line ensures a true color point in compact designs and is especially suited to architectural lighting, entertainment lighting, dimmable lamps and fixtures and emergency vehicle lighting applications.

In addition, LUXEON CZ consists of the same robust buildings blocks as the LUXEON C Color Line. All LUXEON CZ and LUXEON C LEDs feature an identical focal length, leading to superior color mixing in all applications, it is claimed. To speed time to market and simplify designs, LUXEON CZ and LUXEON C are designed in the same footprint and are also hot tested at 85°C to ensure excellent performance at real-world conditions.

What is said to be the industry's lowest thermal resistance (3.2°C/W) helps to reduce the size of heat sinks for the most compact lamps or fixtures. A low thermal resistance is especially beneficial in densely packed applications because it significantly helps with thermal management. Leveraging the features and reliability of the LUXEON C, Lumileds has extended these benefits to LUXEON CZ, giving lighting manufacturers the flexibility to use them individually or even together, Lumileds adds.

www.lumileds.com/LUXEONCZ

Lumileds launches LUXEON 3030 2D with square LES, the highest-flux two-die mid-power LED for general lighting

Lumileds has added to its mid-power family of LEDs by launching the LUXEON 3030 2D with a square light-emitting surface (LES), which is specifically optimized for high flux and maximum reliability in general lighting applications including downlights, high-bay & low-bay fixtures and outdoor lighting.

Supplied in a 3.0mm x 3.0mm SMD package, the LUXEON 3030 2D uses two emitters in series to deliver luminous flux of more than 110lm at a warm-white correlated color temperature (CCT) of 2700K and 80 CRI (120mA, 6V). At a cool-white color temperature of 6500K, the performance increases to over 120lm at 80 CRI (maximum drive current of 240mA).

Flux performance is significantly improved over the company's existing LUXEON 3030 2D LED, which has a round LES. Existing customers will still have access to the LUXEON 3030 2D with the round LES, which has been adopted widely for downlight, industrial and A-lamp applications in particular.

"With the new LUXEON 3030 2D, we are able to offer the industry's highest flux in a two-die mid-power package, but also our hot-color targeted approach ensures superior color accuracy," claims product manager Mei Yi.

With hot-color targeting, components deliver specific chromaticity coordinates at the targeted operating temperature of 85ºC, resulting in minimal color shift in real-world operating conditions. Offered over the full range of ANSI CCTs, the emitter is 1/9th ANSI micro-color binned for tight color control.

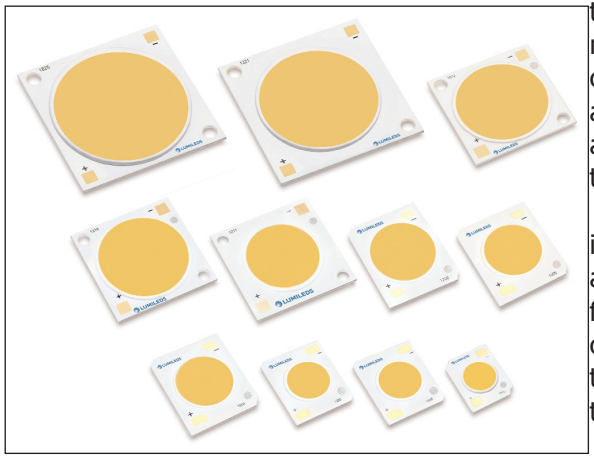
Both LM-80 and TM-21 data are available for the new LED.

www.lumileds.com/products/mid-power-leds/luxeon-3030-2d

Lumileds launches fourth generation of LUXEON CoB Core LEDs, boosting 90CRI performance by 12%

LED maker Lumileds of San Jose, CA, USA has introduced its fourth generation of LUXEON CoB (chip-on-board) Core Range LEDs, with what is claimed to be 5% greater efficacy than the nearest competitors.

In particular, efficiency is not compromised at high color rendering index (CRI). "The goal of Lumileds is to address the industry-wide issue of the efficiency gap between 80 and 90CRI CoBs," says Eric Senders, product line director for the LUXEON CoB Family. "With this new generation, we have limited this gap tremendously by increasing the 90CRI performance by 12% over the previous generation," he adds. "In the past, there was a tradeoff between light quality and efficiency, but customers no longer need to make that sacrifice with these products."



The LUXEON CoB Core Range (Gen 4).

Lumileds says that its ability to deliver luminous efficacy exceeding 130lm/W at 90CRI (and over 170lm/W at 70CRI) is largely due to its own phosphor development and engineering coupled with precise process and manufacturing controls at its manufacturing facilities.

Lumileds has hence also improved the thermal resistance of the CoBs by 25% further reducing the burden on heat sinks and shrinking the size of optics at the system level. The result is high fixture efficacy and smaller fixtures.

The LUXEON CoB Core Range (Gen 4) was displayed at the Light + Building show in Frankfurt, Germany (18–23 March).

www.lumileds.com/LUXEONCoBCoreRange
www.lumileds.com/products/cob-

Lumileds upgrades LUXEON 5050 LED to 175lm/W

Lumileds has introduced an upgraded LUXEON 5050 LED with what is claimed to be the best performance of all multi-die emitters on the market, reaching luminous flux of 350 lumens and luminous efficacy of 175 lumens per watt (lm/W) at 2W drive conditions, at a correlated color temperature (CCT) of 4000K, and a color rendering index (CRI) of 70 at 85°C.

With newly released LM-80 reliability data, the product also meets DLC Premium V4.1 requirements, enabling fixture manufacturers' access to high utility rebates and energy savings.

In addition, the round 4.6mm light-emitting surface (LES) eases optic design. "The majority of commercially available 2W optics can use LUXEON 5050, which leads to the best flux, efficacy and color over angle combination," says Kathleen Hartnett, senior director, product marketing. With what is claimed to be the industry's lowest thermal resistance (2K/W), LUXEON 5050 further enhances performance by removing heat and reducing heat-sink requirements, adds the firm.

The LUXEON 5050 is suitable for high-bay and street lighting applications. Typically for high-lumen fixtures that require high efficacy, a group of standard mid-power LEDs would be used, with the tradeoff of a large fixture size and weight. In contrast, using LUXEON 5050 enables a smaller overall system size, so very compact fixtures are possible.

The LUXEON 5050 is available in a range of correlated color temperatures (2700–6500K) and CRI levels (70, 80, 90) to meet a variety of high-bay and street lighting as well as indoor spotlighting needs.

www.lumileds.com/LUXEON5050

Lumileds appoints senior vice president of quality

Lumileds has appointed Kevin Martin as senior VP of quality. He has over 30 years of experience in quality, most recently as VP of global quality at Flextronics.

While at Flextronics, Martin led the worldwide Quality team, supporting global operations in North and South America, China, Europe and India. Previously, he was VP of total customer satisfaction at Nissan Motor, responsible for North and South America field quality and customer satisfaction for all Nissan and Infiniti vehicles. Prior to Nissan, he was general manager of customer quality engineering at Toyota.

In addition to roles in quality, Martin has held positions in production, manufacturing operations and engineering. He has a Bachelor's Degree in Manufacturing Engineering from Western Carolina University.

www.lumileds.com

Osram, Nichia expand nitride LED & laser IP cooperation

About 7000 new patent applications to be included since last cross-licensing agreement in 2010

At the Light+Building 2018 show in Frankfurt, Germany (18–23 March), Aldo Kamper, CEO of Osram Opto Semiconductors GmbH of Regensburg, Germany, and Hiroyoshi Ogawa, president of Japan's Nichia Corp, announced a strengthening of the two firms' cooperation on licensing.

Osram GmbH of Munich, Germany and Japan's Nichia Corp first entered into patent cross-license agreements in 2002 and 2010, allowing the firms to use each other's patents in their own nitride-based semiconductor products such as blue, green and white LED and laser components.

Ogawa and Kamper share the view that much has happened in the industry since the companies signed the last license agreement in 2010. "To further advance LED and laser technology, Nichia and Osram have spent, in total, more than €2.5bn in research and development since 2011," notes Kamper. The two firms have now agreed to enter into negotiations for a cross license covering about 7000 new patent applications including about 2000 granted patents from Nichia and Osram, covering automotive, general lighting, LCD backlights, display, medical and industrial applications and a full range of optoelectronics products.

"On all levels of the value chain from semiconductor epitaxy to phosphor material, packaging and further downstream technologies, significant progress has been made in the past eight years and protected by a variety of new patents on both sides," says Ogawa. To cover their technological achievements in all existing as well as emerging application areas for optoelectronics products and technologies, Osram and Nichia will discuss a cross license that spanning the many additional patents based on post-2010 inventions. "Our companies will be able to leverage each other's technological advancements, while both companies' customers will benefit from an industry-leading protection in IP-related matters," says Kamper.

www.nichia.com
www.osram.com

Osram Oslon Compact PL LEDs used in front headlights of new Audi A8

Osram Opto Semiconductors GmbH of Regensburg, Germany says its Oslon Compact PL LEDs for adaptive front lighting have been used for the first time by car maker Audi in its new A8 flagship model. In addition, the Oslon Black Flat S (in its three-chip version) provides an extended beam range. Also, Osram's tried and tested Topled is used in the car's daytime running lights (DRLs).

The innovative feature of the Audi A8's HD matrix headlights is that, for the first time, the Oslon Compact PL LEDs are arranged in two lines. Other road users are hence masked out even more precisely by the light beam and are not dazzled. The Oslon Compact PL has an electrically insulated thermal contact. By using appropriate PCB technologies the thermal connection can be significantly improved, yielding higher luminous flux. At the same time, notchless chip technology allows the optical systems to be more efficient. After market launch at the end of 2017, it is being used for the first time in the new Audi A8 as adaptive high beam and low beam.

The Oslon Compact PL for adaptive front lighting has been installed in the Audi A8 for the first time, the Oslon Black Flat S in its 3-chip version provides an extended beam range, and the Topled is used in the daytime running lights. Picture: Audi.

The Oslon Black Flat S family, which also features notchless chip technology and is celebrating its premiere, has now been installed in the Audi A8 for the first time in its three-chip version. The individually controllable chips allow the light beam to be adjusted to the environment (e.g. in city traffic or on the highway), increasing visual comfort.

"The lights now adapt even more precisely to complex traffic situations," says Peter Knittl, Osram Opto's general manager Automotive. "The surrounding area is illuminated in the best possible way without dazzling other road users," he adds.

www.osram-os.com

Osram unveils prototype Oslon Pure 1010 chip-scale package LED with high flux density for retail lighting

At the Light+Building 2018 show in Frankfurt, Germany (18–23 March), Osram Opto Semiconductors GmbH of Regensburg, Germany has unveiled the prototype of the Oslon Pure 1010 LED, targeted at use in spotlights for retail lighting (where exceptionally compact LEDs with high light output are needed to bathe articles on display in an attractive light). The scalability of the chip-scale package (CSP) LED enables flexibility in putting together individual lighting solutions.

Osram says that, with typical luminous flux of 100lm at a drive current of 350mA and a color temperature of 3000K, the prototype almost perfectly follows Lambert's law and achieves a flux density of 237lm/mm^2 when operating at 1000mA. The achieved luminance is then much higher for the same component size. This property is useful particularly if the new LED is used for illuminating merchandise in retail outlets.

Because of its compact 1.0mm x 1.0mm x 0.25mm dimensions, the Oslon Pure 1010 gives lighting designers a high degree of flexibility. The new LED comes without a primary lens, and the reduction in height is due to the chip-scale package. The light-emitting surface is contacted not in the usual way (with a bond wire from above) but within the component itself, without the need for bond wires. These properties, together with the small dimensions, enable multiple LEDs to be placed very close together in a small space. Warm-white and cold-white LEDs can be combined, so the number of individual LEDs, their arrangement and the relative proportions of warm-white and cold-white LEDs can be tailored to meet specific customer requirements.

If applications call for highly concentrated spotlighting, appropriate secondary optics can simply be added. Due to the compact dimensions and directional emission of the Oslon Pure, the secondary optics can also be very small, which in turn means that the overall solution will save even more space and cost.

At Light+Building, Osram Opto unveiled the prototype of the Oslon Pure 1010 in the CRI-80 version. The LED will be available as early as May. A CRI-90 version will then follow in fall 2018.

www.light-building.messefrankfurt.com

II-VI launches 1kW direct-diode laser engine

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA says that its DirectProcess 900 direct-diode laser engine is now available with 1kW continuous output power and network interfaces for Industry 4.0.

The growing number of applications in industrial materials processing (such as joining, cutting and hardening) is driving the demand for industrial lasers that are more energy and process efficient, says II-VI. The firm's DirectProcess 900 leverages its in-house design and manufacturing expertise in diode lasers, high-power laser optics and laser light cables to achieve high wall-plug efficiency. Its beam uniformity and top-hat intensity profile, with a beam parameter product (BPP) of less than 8mm x mrad, enable cutting with smooth edges and welding with clean seams, greatly reducing or eliminating post-process steps on metals such as aluminum, copper and steel, the firm claims.

"The ability of the DirectProcess 900 to operate at an output power of 1kW while maintaining low BPP enables a broad range of processing applications on materials such as aluminum and steel, and on mixed materials such as copper-aluminum used in car batteries," says Haro Fritsche, product line manager, II-VI DirectPhotonics.

"The state-of-the-art management interface to our laser engines greatly simplifies system integration and control of key laser parameters, enabling our customers to leverage the full benefits of direct-diode laser processing."

The DirectProcess 900 product platform can be programmed to perform precisely timed processes, and can be managed and diagnosed remotely through its TCP/IP or EtherCAT interfaces. II-VI says that its 1kW direct-diode laser engines are small, lightweight and only 2 RU (rack units) high, and can be deployed along with II-VI's laser processing heads and laser light cables.

www.ii-vi-photonics.com

II-VI ships 3 millionth pump laser module and half-millionth EDFA

II-VI Inc says its manufacturing operations have reached two shipment milestones: 3 million pump laser modules and half a million erbium-doped fiber amplifiers (EDFAs).

Advances in DWDM technology over the last two decades have enabled rapid scaling of optical communications infrastructure by several orders of magnitude, notes II-VI. The firm's pump lasers and EDFAs boost the power of optical signals at regular intervals along fiber-optic transmission lines.

"II-VI's high-performance gallium arsenide semiconductor lasers and differentiated EDFA design and manufacturing capabilities enable as much as 50% of all global internet traffic running through the optical transport network," reckons Sunny Sun, president of the firm's Photonics Segment. "Our pump lasers have stood the test of time and demonstrated decades of reliable operation, even on the ocean floor," he adds. "By leveraging our own pump lasers, thermoelectric coolers, micro-optics and leading-edge amplifier control electronics, our EDFAs reflect our expertise in vertical integration."

II-VI says that its GaAs lasers and EDFAs trace their intellectual property, technology and reliability heritage to industry pioneers. The lasers are designed and manufactured in Zurich, Switzerland, leveraging a legacy that spans more than 20 years. The laser chips are assembled on ceramic sub-mounts in Calamba, Philippines, and packaged on automated assembly lines in Shenzhen, China.

II-VI unveils 940nm edge-emitting DFB laser for 3D sensing

II-VI Inc has launched an edge-emitting distributed feedback (DFB) laser diode for 3D sensing.

New applications in augmented and mixed reality are driving rapidly growing demand for semiconductor lasers embedded in consumer devices, such as smartphones, headsets and smart glasses, notes II-VI. The new DFB laser diodes operate at 940nm and emit powers of more than 500mW, enabling consumer devices to digitally reconstruct surrounding scenes in 3D using the reflected laser light.

"This latest product leverages the deep expertise that we accumulated over our 20 year legacy in gallium arsenide lasers," says Karlheinz Gulden, general manager, II-VI Laser Enterprise. "Our customers can rely on our global design and manufacturing teams that recently demonstrated our ability to rapidly scale production of a new laser for consumer electronics to high volumes on a vertically integrated 6-inch GaAs technology platform," he adds.

II-VI says that its DFB laser diodes can be customized to achieve the optimum output power for the application. Engineering sample quantities are currently available for evaluation and design-in, as assemblies on ceramic carriers or in die form.

II-VI's portfolio of products for sensing includes vertical-cavity surface-emitting lasers (VCSELs) for proximity sensing and thumb navigation, and VCSEL arrays for 3D sensing. The portfolio also includes low-angle shift filters that select the reflected laser light over a wide field of view and reject other light to improve camera sensitivity.

www.ii-vi-photonics.com

II-VI to acquire CoAdna for $85m

Wavelength-selective switch firm to join II-VI's Photonics Segment

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA is to acquire CoAdna Holdings Inc of Sunnyvale, CA, USA for about $85m (which includes the acquisition of CoAdna's approximately $40m in cash).

Founded in 2000, CoAdna designs and manufactures highly integrated, intelligent optical components, modules and sub-systems, such as LC (liquid crystal) devices, wavelength-selective switches (WSS) and reconfigurable optical add-drop multiplexers (ROADMs) based on its patented LightFlow liquid-crystal platform.

Specifically, CoAdna produces wavelength-selective switches based on LightFlow and II-VI's micro-optics. Its WSS modules have a long history of field deployments and, over the years, have been integrated alongside II-VI's optical amplifiers, optical channel monitors and other components on reconfigurable optical add-drop multiplexer (ROADM) line-cards designed by II-VI, CoAdna and their customers.

"CoAdna and II-VI have been great business partners for many years, leveraging each other's complementary products and technologies to serve the optical transport market," comments Sunny Sun, president of II-VI Inc's Photonics Segment. "We are eager to realize our synergies to grow the WSS business over our strong sales channels and shorten the time to market for our new products," he adds. "With our manufacturing scale, unmatched vertical integration and broad product portfolio, we are well positioned for the growth in ROADM demand driven by metro network upgrades, new data-center interconnect architectures and the emerging 5G wireless infrastructure."

The companies' combined portfolio of products for ROADM line-cards will include fixed- and flex-band 1xN WSS, tunable mux/demux, dual-chip pump lasers, passive components, arrayed erbium-doped fiber amplifiers (EDFAs), high-resolution optical channel monitors (OCMs) and optical time-domain reflectometers (OTDRs). II-VI also designs and manufactures fully integrated ROADM line-cards. CoAdna will contribute to the joint product portfolio its OvS platform, which features a distributed cross-connect architecture for data-center networking.

The acquisition is expected to close in third-quarter 2018, subject to the approval of CoAdna's shareholders, regulatory approvals and customary closing conditions.

www.CoAdna.com
www.ii-vi-photonics.com

PIX4life announces SiN PICs for bio- and life-science

PIX4life — a European pilot line within the European Horizon 2020 initiative that offers photonic integrated circuits for biophotonics and life-sciences applications — says that, after two years of internal development, it is now offering its services to a limited set of external users on an open-access basis.

"While bulk optics and visible light sources have been commonly used in biology and life-sciences, many of the applications were restricted to laboratories employing large and expensive equipment," says Iñigo Artundo, CEO of photonic integrated circuit (PIC) design house VLC Photonics of Valencia, Spain. "The developments of the last decade in the field of photonic integration, stimulated by new advances in silicon nitride (SiN) fabrication capabilities, have led to a mature technology able to provide solutions for miniaturization, scalability and cost reduction," he adds. "These advances in light manipulation will support new applications for medical instrumentation, multi-wavelength sources, flow cytometry and photonic sensors. This is possible thanks to the reduction in cost and size of the required equipment from centimeter-scale optical systems to millimeter-scale photonic chips," he adds.

The PIX4life pilot line gathers the complete value chain required for a concept to become a reality, from design, to manufacturing, characterization and packaging of PICs. Since PIX4life focuses on PIC technology in the visible and short near-infrared, the technology is suited to addressing the needs of applications such as bio- and life-sciences.

Since late 2017, interested users can apply for open-access to the pilot line services. The 'early access' of these users to the service offerings is subject to an internal selection procedure, to promote the realization of promising life science concepts into prototypes.

PIX4life offers open access to several multi-project wafer runs (MPWs), where fabrications costs and wafer space are shared among participating users. These MPWs are organized for different technology platforms at two different silicon nitride PICs foundries. "End users can request technical support to choose the right implementation of their optical system into a photonic chip," says VLC Photonics' R&D manager Marco García. Once selected, users will be able to submit a design, which will be assigned to a certain area on the wafer, and each design will be replicated several times.

"PIX4life opens us the door to target new medical applications," says Sara Mas Gómez, R&D engineer at medical instrument firm MedLumics of Madrid (a partner in PIX4life).

www.pix4life.eu
www.vlcphotonics.com

CST Global adds 1490nm, 2.5Gb/s GPON lasers to standard product portfolio

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK (a subsidiary of Sweden's Sivers IMA Holdings AB) says that its 1490nm, 2.5Gb/s distributed feedback (DFB) lasers for Gigabit passive optical network (GPON) applications have been beta sampled and are now available to order from its standard product portfolio.

The 1490nm-wavelength laser transmits data downstream, from the optical line terminal (OLT) to the optical networking unit (ONU), positioned in the home or business premises. The transmission of data upstream, from the ONU to the OLT, is achieved using a 1310nm laser at either 1.25Gb/s or 2.5Gb/s data rate, which CST Global also produces within its standard product range.

DFB laser inspection at CST Global.

"Production of 1490nm, 2.5Gb/s DFB lasers for GPON applications has become increasingly difficult due to an evolving, industry build-standard," says Euan Livingston, VP sales & marketing. "We have successfully produced the 1490nm, GPON lasers, to the C++ specification, in a TO-can format. Additionally, we will support known good die on tape (KGDT) formats of these devices, if required," he adds.

"GPON markets are growing worldwide and sales into developing markets like China and India, where we sold over 2 million units in 2017, are continuing to expand," Livingston continues. "We identified the potential for 1490nm DFB lasers 18 months ago and invested in the staff, machinery and processes necessary to meet this escalating demand."

www.CSTGlobal.uk

CST Global samples 1270nm DFB lasers for 10G PON

CST Global has sampled its 1270nm 2.5Gb/s asymmetric and 10Gb/s symmetric distributed feedback (DFB) lasers for 10G passive optical network (PON) applications.

"CST Global is currently beta sampling its asymmetric 2.5Gb/s lasers and alpha sampling its symmetric 10Gb/s lasers," says technical director Andrew McKee, who is leading the DFB laser development. "The asymmetric beta samples, which are undergoing ITU-GR468 reliability testing, are available for customer trials in known good die on tape (KGDT) and TO56-can formats," he adds.

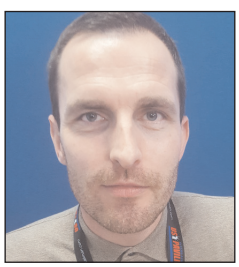
"The asymmetric 2.5Gb/s 1270nm DFB lasers allow the existing optical networking units (ONUs), found at the user end of fiber-to-the-home (FTTH) broadband solutions, to be re-used. As a result, we expect a fast uptake in 2.5Gb/s 1270nm lasers, which is why this solution has been a priority," McKee continues.

"The symmetric 10Gb/s 1270nm laser option requires a new design of ONU before a large-scale uptake is expected, but it is already in demand," McKee adds. "We are pleased to offer a solution for the two prevailing technologies in this growing market."

CST Global appoints manufacturing execution system technician for production and supply chain control

CST Global has appointed Jaimie McGinty as MES technician for production and supply chain control, reporting to Gary Palmer, VP operations.

McGinty manages the MES (management execution system), which enables the real-time accurate tracking of work in progress (WIP), statistical process control (SPC) data, and inventory. He was previously responsible for data management engineering at Jabil, Livingston, and was a reliability technician at Gemfire in Glasgow.



Jaimie McGinty.

"My prime duty is internal supply chain management; improving efficiency and productivity throughout the foundry, in line with our ISO 9001: 2015 quality standards," says McGinty. "CST Global's laser production is high volume, so barcoding and the electronic measurement of real-time work in progress are essential elements to implementing a lean production strategy for the company," he adds. "We are constantly aiming to improve production planning and delivery accuracy. We also gather data relating to quality and yield, for on-going process and supplier improvement."

CST Global proves feasibility of uncooled, ridge-waveguide CWDM DFB lasers for transmitting 25Gbps

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK (a subsidiary of Sweden's Sivers IMA Holdings AB) says that — as part of its involvement in the UK government-funded SUPER 8 research project — it has proven the feasibility of its uncooled ridge-waveguide CWDM distributed feedback (DFB) lasers to transmit at 25Gbps.

"The SUPER 8 project uses CWDM (coarse wavelength division multiplexing) architecture to provide optical filtering, so that eight 25Gbps data channels, each with its own laser, can be transmitted simultaneously, at different wavelengths, on the same optical fiber," says Euan Livingston, VP sales & marketing. "The uncooled ridge-waveguide DFB lasers we have made, and successfully tested, form part of a low-cost solution with reduced power and increased reliability over existing DWDM technology," he adds.

"The feasibility shows that a 200Gbps ultra-high-speed data communications platform for use by hyper-scale cloud data centers is now proven," Livingston continues. "High-capacity networks of this type, with greater transmission rates and a lower cost base, will also be essential to cloud services, video-on-demand and IoT [Internet of Things] markets. It clearly shows that the CWDM DFB lasers being developed within the SUPER 8 project are on track for full commercialization."

SUPER8 project funding totals £1.1m, of which CST Global will receive £318,039 — a joint venture between Cardiff University and epi-wafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — and photonic integrated circuit (PIC)-based transceiver manufacturer Kaiam of Newark, CA, USA (which has a primary manufacturing plant in Livingston, Scotland, UK).

www.compoundsemiconductorcentre.com

Infinera unveils first 2.4Tb/s optical engine

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), has added to its family of Infinite Capacity Engines by unveiling ICE5, which is claimed to be the first 2.4 terabit per second optical engine.

ICE5 is targeted at internet content providers (ICPs) scaling connections between data centers and communications service providers (CSPs) planning fiber-deep architectures including distributed access architecture (DAA) and 5G mobile backhaul. Optical engines play a key role in maximizing both the technical and economic performance of optical network systems. Infinera say that it is building on the ICE4 optical engine in metro, long-haul and subsea applications to introduce ICE5 and demonstrate an increasing cadence toward ICE6.

Gartner's forecast for cloud computing anticipates a compound annual growth rate (CAGR) of 19% through 2020 and the Ericsson Mobility Report expects total mobile data traffic to rise at a CAGR of 42% through 2022, accelerating demand for optical network capacity at ICPs and CSPs worldwide.

ICE5 builds on ICE4's optical performance and economics by integrating Infinera's fifth-generation photonic integrated circuit with a FlexCoherent digital signal processor (DSP) and fine-grain software control to deliver 100–600Gb/s per wavelength in a 2.4Tb/s optical engine. ICE5 is claimed to unlock unprecedented capacity, reach, spectral and power efficiency, designed for over 40Tb/s on a single fiber within a fraction of a data-center rack, increasing capacity by up to 65% over currently deployed networks while reducing power by 60%.

Infinera Instant Network enables software automation of ICE-based platforms, allowing users to pay for capacity as they need it, matching expense to revenue, increasing network agility, and lowering total cost of ownership. Over 70 customers (including the top three subsea customers and more than 60% of data-center interconnect customers) rely on Infinera Instant Network to scale capacity on demand.

"Cloud and fiber-deep architectures will accelerate the demand for optical network capacity," comments Jimmy Yu, market analyst firm Dell'Oro Group's VP of Optical Transport and Mobile Backhaul. "This means future optical DWDM systems will have to deliver higher single-wavelength speeds sooner and be agile enough to be used in metro as well as long-haul environments. Infinera's plan for ICE5 fits well with our five-year projection that DWDM demand will grow faster in metro access and aggregation locations due to data-center interconnect, 5G backhaul, and fiber-deep," he adds.

"With ICE5 we are bringing our leading-edge technologies to market faster than ever, enabling our ICP and CSP customers to respond quickly to explosive bandwidth growth," says Infinera founder, chief strategy and technology officer Dr Dave Welch.

Infinera Intelligent Transport Network platforms with ICE5 are planned for availability in early 2019.

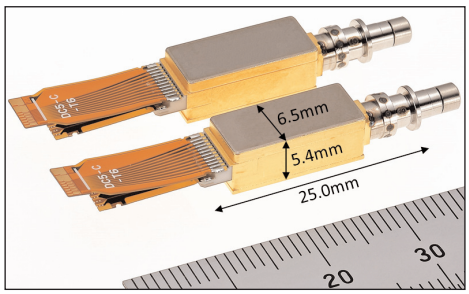
www.infinera.com/ice5-innovation-on-fast-forward

Mitsubishi Electric to launch compact integrated 400Gbps EML-TOSA for high-speed and large-capacity fiber communications

Tokyo-based Mitsubishi Electric Corp has begun shipping a laser-diode transmitter optical subassembly (TOSA) capable of supporting 400Gbps optical transmissions.

In response to the demand for increasing data capacity, Mitsubishi Electric's new laser-diode TOSA offers 400Gbps transmission capability for large-capacity communication facilities (data centers, etc) and high-speed optical transmission networks.

Specifically, used in a set of two, the TOSA (in a 6.5mm x 25.0mm x 5.4mm package) is claimed to be the first electroabsorption modulated laser diode (EML)-TOSA solution for IEEE 400GBASE-LR8 applications — compliant with common specifications for CFP8 optical transceivers



Compact integrated 400Gbps EML-TOSA FU-402REA-41 (top) and FU-402REA-42 (bottom).

— via multiple transmission of eight wavelengths at 50Gbps/wavelength achieved with 4-level pulse-amplitude modulation (PAM4).

Due to the EML chip having a high extinction ratio (6dB typical) and high operating power (2W maximum), the compact integrated 400Gbps EML-TOSA is capable of transmission over a reach of 10km.

The two models are:

- the FU-402REA-41 (for short wavelengths) has an electroabsorption modulated laser diode with an emission wavelength of 1273.54, 1277.89, 1282.26 or 1286.66nm;
- the FU-402REA-42 (for long wavelengths) has an electroabsorption modulated laser diode with an emission wavelength of 1295.56, 1300.05, 1304.58 or 1309.14nm.

The new devices were displayed at the Optical Fiber Communication Conference & Exhibition (OFC 2018) in San Diego, CA, USA (13–15 March).

www.ofcconference.org
www.mitsubishielectric.com/semiconductors/products/opt

Integrated Compound Semiconductors launches 10–25G InGaAs–InAlAs PIN and APD detectors

Chip-scale sampling of discrete single-channel devices to be followed by custom array variants for multi-channel 100G+ transceivers throughout 2018

Integrated Compound Semiconductors Ltd (ICS) — a spin out from the University of Manchester that designs and manufactures RF, sensing and optical devices — has announced the availability of a new product line of high-speed InGaAs–InAlAs PIN and avalanche photodiode (APD) detectors.

The portfolio includes three-pad (G-S-G) and dual-pad variants for 10Gb/s and 25Gb/s datacom and telecom applications, developed on a 4" indium phosphide (InP) wafer process platform in partnership with the Compound Semiconductor Centre (CSC) — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK.

The 25G PIN platform offers proven performance of >22GHz (3dB) bandwidth, for a top-entry-illuminated design with a responsivity of 0.8A/W for a 20μm aperture in both single-element and quad (4x1) arrays. The 10G APD platform offers 7–9GHz (3dB) bandwidth, for a 30μm-aperture top-entry-illuminated design with a responsivity of > 0.8A/W and sensitivity of –27dBm with appropriately matched transimpedance amplifiers (TIAs). Currently, ICS is undertaking chip-scale sampling of discrete single-channel devices, and is planning to extend the portfolio to offer custom array variants for multi-channel 100G+ transceiver architectures throughout 2018.

"The rapid growth of the high-speed optical transceiver market is an exciting opportunity for the in-house skills at ICS as the demands of the 100G markets require a deep understanding of RF component design to complement high-quality optoelectronic device manufacture," says ICS' founder professor Mohamed Missous. "The relationship with CSC offers a rapid scale to volume through the connection with IQE," he adds.

"ICS is one of our lead industrial engagements and it is pleasing to see the business model of the CSC working to deliver real tangible benefits to the supply chain for high-speed optical components for ultrafast fiber broadband communication systems," says CSC director Dr Wyn Meredith.

www.icsld.com

POET and Accelink to co-develop transceivers for 100/400G markets

Low-cost transceivers based on POET's Optical Interposer Platform

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 entered into a memorandum of understanding (MOU) for the co-development of products with Accelink Technologies Co Ltd of Wuhan, China, a manufacturer of optical components and subsystems for the datacom, telecom and network access markets. As 'preferred co-development partners' the MOU outlines a path for mutual cooperation with the aim of developing, qualifying and selling a family of transceivers based on POET's low-cost, high-performance Optical Interposer Platform.

More specifically, the MOU is targeted at rapidly commercializing a series of multi-channel (100/400G) transmit and receive devices for the datacom markets and low-cost single-channel (10/25G) products for telecom applications. POET will provide engineering samples of its optical engines to Accelink on a preferred basis for internal testing and initial qualification.

"As one of the largest suppliers of transceivers both in China and globally, Accelink is an ideal initial partner for POET to commercialize its optical interposer platform and to rapidly bring products to market," comments POET's CEO Dr Suresh Venkatesan. "We are thrilled to be engaged in this effort with a forward-looking partner with leading products and solutions in the highest growth segments of both datacom and telecom. This is a watershed event for POET as we now have a clear path to commercialization of our Optical Interposer Platform technology with an industry leader," he adds.

"POET's Optical Interposer Platform is a step-change advancement compared to other approaches in gaining lower cost of integration and offering a superior method to scale-up to the higher data rates demanded by our customers," comments Dr Ben Chen, technical director of Accelink's Datacom & Access Product Department. "Upon successful qualification, we believe we will have an opportunity to gain rapid penetration into key customers and markets, based on both cost and performance advantages."

Except for the confidentiality and intellectual property provisions, the terms and conditions outlined in the MOU are non-binding, and either party maintains the right to discontinue its cooperative participation without notice.

www.accelink.com
www.poet-technologies.com

POET appoints Charbonneau to board and audit committee

POET has appointed Peter Charbonneau to its board of directors, as well as to its audit committee.

Charbonneau was general partner at Skypoint Capital Corp for almost 15 years, jointly responsible for the placement of $100m of capital in early-stage telecom and datacom companies. Prior to Skypoint, he held executive and operational roles at networking companies including March Networks and Newbridge Networks, where he was president and chief operating officer. In 2000, representing Sir Terence Matthews, he facilitated the purchase of the communications business systems division of Mitel Corp, which has since operated as Mitel Networks.

"Peter is an excellent addition to POET's board with his unique combination of experience in venture capital and networking infrastructure," comments executive chairman David Lazovsky. "He brings expertise from both the telecom and datacom industries, spanning early-stage companies to billion-dollar enterprises," he adds. "Peter is joining POET at a pivotal period in the company's growth and development, as we increase the number of engagements with potential strategic partners and customers… Peter's experience and extensive network of contacts will allow him to contribute meaningfully toward our continued progress on the commercialization of POET's integrated photonics technology."

Charbonneau currently serves on the board of directors at Mitel Networks (a provider of cloud and on-site business communications and collaboration solutions) and Teradici Corp (the creator of PCoIP protocol technology and Cloud Access Software). He previously served as chairman of the board of trustees for the CBC Pension Board and a director on the board of the Canadian Broadcasting Corporation as well as many technology and networking companies, including March Networks Corp, TELUS Corp, BreconRidge Manufacturing Solutions and Dragonwave Inc.

Charbonneau has a B.Sc. from the University of Ottawa and a Master of Business Administration from the University of Western Ontario. He is also a member and elected Fellow of the Institute of Chartered Professional Accountants of Ontario and has received the ICD.D designation from Institute of Corporate Directors of Canada.

QSFP-DD MSA releases QSFP-DD thermal white paper

At the Optical Networking and Communication Conference and Exhibition (OFC 2018) in San Diego (11–15 March), Molex, Cisco, Juniper Networks and other multi-source agreement (MSA) group members released a white paper focused on the Quad Form Factor Pluggable Double Density (QSFP-DD).

In total, 62 firms are supporting the QSFP-DD MSA to address the need for a high-density, high-speed networking solution. Established in March 2016, the QSFP-DD MSA group accepted the challenge to meet market demand for a next-generation high-density, high-speed pluggable backwards-compatible module form factor, and has succeeded in releasing a 3.0 Hardware specification with broad market support that overcomes the technical challenges of specifying a QSFP28-compatible double-density interface.

The white paper addresses how the thermal performance of the QSFP-DD module is evaluated for use in a high-performance data-center environment. Thermal test data is presented and analyzed showing temperature rise versus air flow. Feasibility of 15W QDFP-DD modules is shown.

"Building and sustaining the pipeline of interoperable interconnect solutions is absolutely critical to support advances in transceiver modules, switch technologies and servers," says Molex's group product manager Scott Sommers. "Through QSFP-DD strategic collaborations, we have provided the expertise needed within the industry to meet the rising demands for high-speed network solutions," he adds.

"Cisco has always had confidence in QSFP-DD being the right choice for broad industry adoption as the market moves to 400GbE. This white paper shows that any concerns with a system vendor's ability to effectively integrate and cool these modules into their networking products is overblown," believes Mark Nowell, distinguished engineer, Cisco Data Center Switching.

"The QSFP-DD form factor with system cooling support of 15W of dissipated power for data-center applications is direct leverage of industry knowledge gained over many generations of adoption of form factors such as those defined by the SFF Committee and the CFP MSA along with innovation in system air-flow characteristics," says Jeffery Maki, distinguished engineer II, at Juniper. "Thermal management is seen primarily as a system responsibility, which leaves open opportunity for even further innovation over system generation," he adds.

www.qsfp-dd.com

Molex & Innovium debut scalable QSFP-DD solution

High-speed fiber-optic interconnect firm Molex Inc of Lisle, IL, USA has joined with Silicon Valley-based Innovium (a provider of switching silicon for data centers) to create a solution for customers migrating to QSFP-DD (Quad Small Form Factor – Double Density) 400G, showcased at the 2018 Open Compute Project (OCP) US Summit in San Jose, CA (20–21 March).

Molex recently launched its QSFP-DD Interconnect System and Cable Assemblies — designed to meet or exceed Ethernet, Fibre Channel and InfiniBand port-density requirements in high-speed enterprise, telecom and data networking equipment — to meet the rising demand for 100, 200 and 400Gbps networking solutions. Bringing together that system with Innovium's TERALYNX switch chip means better performance and operational efficiencies for data-center customers.

"By leveraging the combined capabilities of Innovium's TERALYNX 12.8Tbps switch chips and Molex QSFP-DD interconnect technology, we enable state-of-the-art next-generation data-center topologies," says Molex's group product manager Scott Sommers.

What is claimed to be the smallest 400Gbps Ethernet module providing the highest port bandwidth density, Molex's QSFP-DD form factor features an 8-lane electrical interface that transmits up to 28Gbps NRZ (non-return-to-zero) or 56Gbps PAM-4 (4-level pulse amplitude modulation) for an aggregate bandwidth of up to 200Gbps NRZ or 400Gbps PAM-4, with an upgrade path toward 800Gbps PAM-4 using 112Gbps PAM-4. Molex's QSFP-DD pluggable modules and connectors, cages and cables are backward compatible with existing QSFP+ interconnects for functionality across a wide variety of legacy and next-generation technologies and applications.

"Innovium's TERALYNX was developed using innovative design techniques based on a ground-up architecture, delivering to data-center customers the highest-performance network switch silicon with superior buffering, latency and programmability," says Amit Sanyal, Innovium's VP of product management and marketing.

The TERALYNX product line delivers what is claimed to be the fastest and most scalable Ethernet switch silicon family with leading analytics, programmability, and power efficiency. TERALYNX is also claimed to be the first switch that achieves 12.8Tbps performance in a single chip, while delivering robust tunneling, large buffers, line-rate programmability, best-in-class low-latency and breakthrough telemetry, resulting in a 6x advantage compared with alternatives. It includes broad support for 10/25/40/50/100/200/400GbE Ethernet standards that can be flexibly configured to deliver 128 ports of 100GbE, 64 ports of 200GbE or 32 ports of 400GbE in a single device.

www.molex.com/opticalsolutions
www.innovium.com

Phononic launches non-hermetic compatible thermoelectric cooler platform for laser packages

Phononic of Durham, NC, USA (which provides solid-state thermoelectric cooling solutions) has unveiled its proprietary non-hermetic compatible thermoelectric cooler (TEC) platform designed to provide high reliability and cooling performance, coupled with lower power consumption, for laser packaging. Building on its expertise in precision-cooled, solid-state refrigeration and freezing technologies, Phononic says that the advance brings to market a solution to meet both performance and reliability targets for sub-components within telecom and data center applications.

Since most optical components manufacturers have experience in designing either cooled laser packages or non-hermetic laser packages, Phononic notes that it has experience in both of these areas, with its cooled, non-hermetic laser package design creating a pathway to large reductions in package costs.

"Optical component and module suppliers are under pressure to both rapidly innovate optical communications technology and, at the same time, meet aggressive price points to keep up with competition," comments Vladimir Kozlov, founder & CEO of optical communications market research company LightCounting. "These trends have led to increased demand for more cost-effective sub-components," he adds.

"Laser performance can be significantly hindered by environmental challenges inside laser packages," says Phononic's general manager & VP of sales Kevin Granucci. "Humidity, condensation, corrosion and even ice formation are all potential impediments that can degrade laser slope efficiency or increase coupling losses, which reduce data transmission rate, reach and the usable lifetime of a TOSA [transmitter optical subassembly]. Hermetic packaging to safeguard against these conditions has historically been challenging and expensive to implement," he adds.

"Non-hermetic laser packaging that not only overcomes reliability and cost obstacles, but is cooled as well, could greatly advance today's optical communications technology, further accelerating the global transition to wireless 5G networks."

The new non-hermetic TEC platform can be applied to a wide range of TEC designs, and Phononic encouraged customers to work with it to create application-specific solutions. The firm's technical team offers thermal design experience to facilitate rapid deployment of a non-hermetic laser package that is insulated from the performance and reliability risks of high humidity and heat. Combined with Phononic's platform, this support enables customers to avoid possible pitfalls early in the design cycle and optimize performance in even the most challenging of environments, without increasing power consumption or compromising performance for cost, says the firm.

www.phononic.com/optoelectronics
www.ofcconference.org

Molex Ventures invests in Elenion to jointly develop, manufacture and promote silicon photonics products

Collaboration to develop interconnects scaling to 400Gbps & beyond

Molex Ventures LLC, a subsidiary of Molex Electronic Technologies LLC of Lisle, IL, USA (which makes electronic components including connectors, cable assemblies, antennas, optical solutions, printed-circuit products, automation and lighting products), has announced a strategic investment and collaboration between the Molex Optical Solutions Group (OSG) and New York-based Elenion Technologies LLC (which designs silicon photonics-based system-on-chip solutions for high-bandwidth communication and networking applications). The firms aim to jointly develop, manufacture and promote silicon photonic-based products. Leveraging CMOS and high-volume manufacturing processes, the firms will collaborate to develop advanced interconnect solutions that scale to 400Gbps and beyond.

"High-speed silicon photonic-based technologies represent a cost-disruptive solution to bandwidth scalability needs in hyperscale data centers in the high-growth optoelectronics sector," says Molex Ventures' vice president Lily Yeung. "This investment and collaboration combines Elenion's key strength in advanced silicon photonics core technology with Molex core capabilities in complex product integration, efficient manufacturing, and global sales and marketing," he adds.

"Collaborating with Molex will significantly accelerate production and deployments of our silicon photonic technology serving global customers that demand an ever-increasing pace of innovation for high-speed optical communication solutions," believes Elenion's CEO Larry Schwerin. "We now have a great alliance to fulfill our vision to be an industry leader in driving silicon photonics for a broad range of applications in high-bandwidth data networks."

www.elenion.com
www.molex.com/opticalsolutions
www.molex-ventures.com

Luxtera achieves record optical performance with new TSV-enabled silicon photonics platform at TSMC

Fabless silicon photonics firm Luxtera of Carlsbad, CA, USA says significant performance gains have been achieved in the new through-silicon via (TSV)-enabled silicon photonics platform in development at Taiwan Semiconductor Manufacturing Corporation (TMSC, the world's biggest semiconductor wafer foundry).

Announced last year, Luxtera and TSMC have jointly developed a unique silicon photonics platform in TSMC's 300mm CMOS wafer foundry. Leveraging TSMC's process capabilities, Luxtera's new device library has demonstrated the key performance parameters needed to lead the industry in speed, power, density, cost and system-on-chip (SoC) integration, it is claimed.

Luxtera says it has now demonstrated multiple record-breaking elements for silicon photonic integrated circuits (PICs). These elements are scalable to high-volume manufacturing and operate at 1310nm and all standard CWDM wavelengths. Record performance has been achieved for over 50 new device library elements, including low-loss grating couplers with losses under 1dB for light coupled in and out of the PIC, low-loss waveguides, a high-efficiency PM phase modulator with 3dB bandwidth >50GHz that can be built in various system architectures (traveling-wave MZI, segmented MZI, and rings to supports NRZ, PAM, QAM), and germanium waveguide photodetectors with responsivity over 1A/W and 3dB bandwidth higher than 45GHz.

These devices are fabricated using TSMC's process technology on a 300mm silicon-on-insulator (SOI) wafer optimized for O-band operation. The PICs will then be integrated with Luxtera's internally developed companion CMOS ICs, which will be fabricated in TSMC's 7nm process. Luxtera's designs include trans-impedance amplifiers (TIAs), clock & data recovery (CDR) ICs, Mach–Zehnder interferometer (MZI) modulator drivers and digital signal processors (DSPs) that achieve high levels of performance and power efficiency. Luxtera says that these advances are crucial in providing a differentiated portfolio of high-performance optical transceiver products, starting with next-generation PAM-4 100G/λ single-wavelength and multi-wavelength transceivers (which begin shipping in 2019). Luxtera's latest innovations were on display at the Optical Networking and Communication Conference & Exhibition (OFC 2018) in San Diego (13–15 March).

"TSMC's industry-leading manufacturing capability, coupled with Luxtera's world-class silicon photonics design, together provide the highest-performance and lowest-cost optical transceivers available to our hyperscale, cloud, enterprise and 5G mobile infrastructure customers," claims Luxtera's president & CEO Greg Young.

www.luxtera.com
www.tsmc.com
www.ofcconference.org

Mellanox surpasses 1 million 100Gb/s ports with LinkX optical transceivers and cables

Mellanox Technologies Ltd of Sunnyvale, CA, USA and Yokneam, Israel (a supplier of end-to-end InfiniBand and Ethernet interconnect solutions for data-center servers and storage systems) says that its volume shipments of LinkX optical transceivers, active optical cables (AOCs) and direct attach copper cables (DACs) have surpassed 1 million 100Gb/s QSFP28 ports.

Already offering what is claimed to be one of the industry's largest portfolios of interconnect products, Mellanox expanded its 100Gb/s LinkX product family to include: a DynamiX QSFP-to-SFP port adapter; 100Gb/s active optical splitter cables; and new optical transceivers for 1310nm PSM4, CWDM4 and LR4.

"Our early 100Gb/s sales were driven by US-based hyperscale companies who were the first to deploy 100G Ethernet," says Amir Prescher, senior VP of business development & general manager of the interconnect business. "Now, China Web 2.0, Cloud computing networks, and OEMs worldwide are moving to 100G. Customers select us because of our high-speed experience, our capacity to ship in volume, and the quality of our products," he adds.

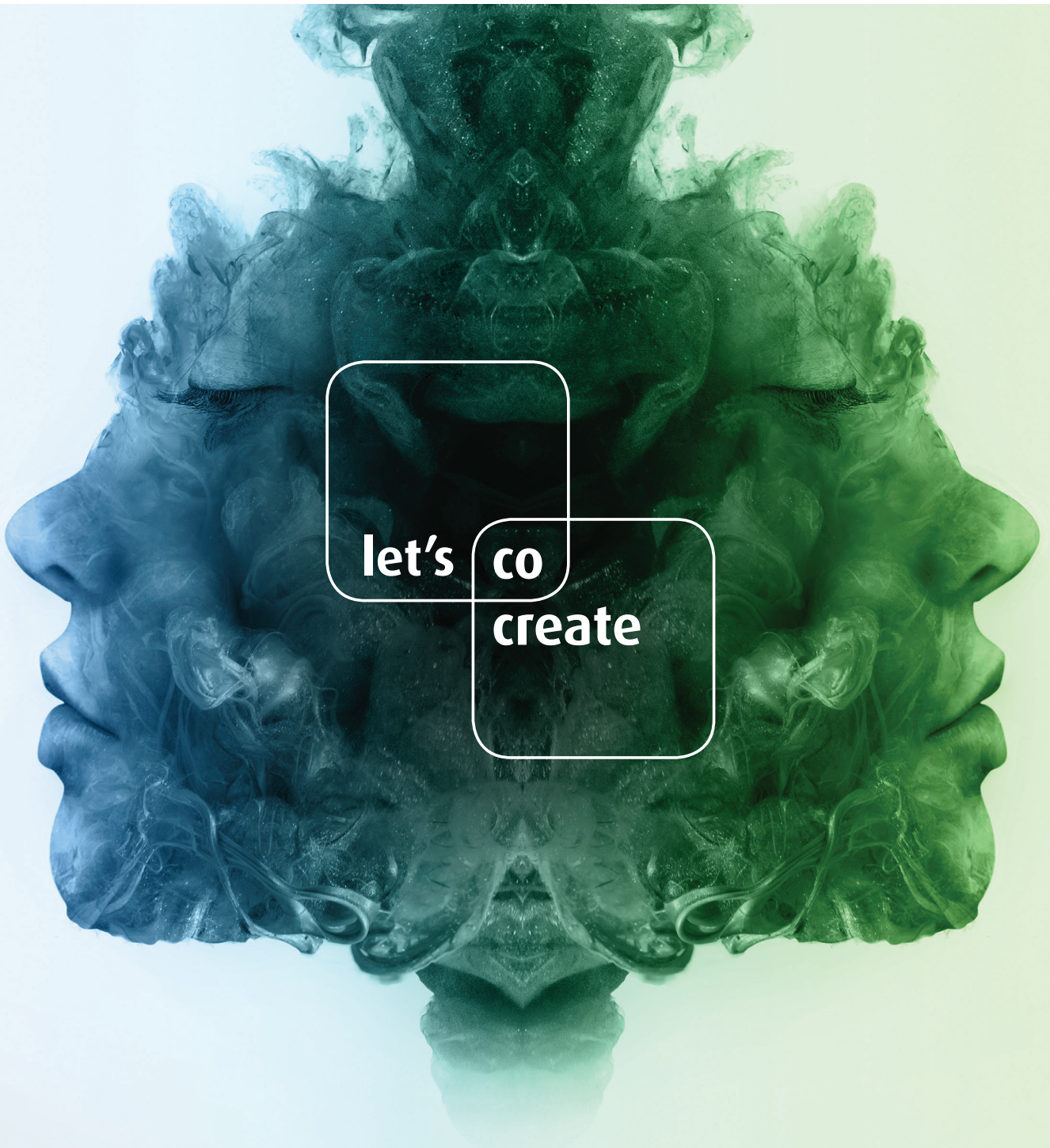
"We see rapid growth in the 100Gb/s optical transceiver market continuing through at least 2021," comments Dale Murray, principal analyst at LightCounting Market Research. "400Gb/s networks are coming, but there is plenty of headroom for 100Gb/s products until the deployment of end-to-end 400G Ethernet."

Mellanox exhibited its new 100G and 200G/400G LinkX products at March's Optical Networking and Communication Conference & Exhibition (OFC 2018) in San Diego.

The booth also featured demos of its new LinkX products including:

- 200Gb/s in QSFP56 form factor;
- 400Gb/s in OSFP and QSFP-DD form factors;
- a full line of 100Gb/s transceivers for hyperscale and data-center use;
- LinkX 25G/50G/100Gb/s DAC and AOC cables and 100G SR4, PSM4, CWDM4 and LR4 transceivers.

www.mellanox.com/products/interconnect



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TowerJazz announces first open foundry silicon photonics design kits with EDA tool support

Collaboration with Cadence, Synopsys and Lumerical enables platform for design of silicon photonics ICs for optical transceivers

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 announced the first open silicon photonics (SiPho) manufacturing process (PH18MA) offered by a commercial foundry, with a design platform targeting optical networking and data-center interconnect applications.

TowerJazz says that its 'open' platform is offered to all silicon photonics customers, unlike other 'closed' processes only offered to certain customers or restricted to low-volume prototyping. The firm's SiPho process complements its silicon germanium (SiGe) BiCMOS processes, which are currently qualified in two of its worldwide fabrication facilities, providing manufacturing assurance and flexibility.

The overall silicon photonics market will rise at a compound annual growth rate (CAGR) of over 20% to 2023, according to a report from MarketsandMarkets. Silicon photonics holds the potential to become a cost-effective, scalable technology for the production of electro-optical integrated circuits and transceivers for data centers and high-performance computing, telecoms, military, defense and aerospace applications, it is reckoned. TowerJazz says that its SiPho process addresses the high-performance requirements of these applications, such as reduction in power consumption, high bandwidth and high data transfer capabilities.

TowerJazz and silicon photonics electronic design automation (EDA) software providers Cadence, Synopsys and Lumerical have collaborated to develop design enablement for this platform. TowerJazz's electronic photonic design automation (EPDA) process design kit (PDK) provides an integrated design environment through the Cadence Virtuoso platform, enabling fast time to market. TowerJazz says that it brings specialty foundry experience and decades of electronic design enablement, while Cadence provides photonic schematic capture, layout and circuit simulation, Synopsys supplies the photonic integrated circuit (PIC) layout synthesis capability, and Lumerical is the industry leader in photonic simulation.

"Closely coupled to TowerJazz's SiPho process, the widely adopted Cadence Virtuoso custom IC design platform gives customers familiar tools to more easily develop and implement integrated photonics systems," says Glen Clark, corporate VP, R&D, Custom IC & PCB Group at Cadence. "Designers now have access to a bi-directional, integrated design flow spanning from co-simulation with Lumerical to layout generation that is built around a golden electro-optical schematic in the advanced Virtuoso platform," he adds. "With the Virtuoso platform's integration into our packaging and system analysis tools, customers can now access an entire silicon design and analysis environment for electronic and photonic design, enabling more predictable design cycles."

The firm's SiPho process complements its SiGe BiCMOS processes, which are currently qualified in two of its worldwide fabrication facilities, providing manufacturing assurance and flexibility

The PDK includes several flavors of components needed for silicon photonics design such as single-mode silicon waveguides, high-speed germanium photodetectors, p–n junction modulators, and enablement for edge and grating couplers.

To ensure robust design manufacturability, Synopsys' PhoeniX Software OptoDesigner uses photonic synthesis to map design intent into a design-rule clean circuit layout targeted to the TowerJazz SiPho process. "Designers can use our integrated photonic simulators to optimize their designs and layout to meet their performance requirements and minimize time from concept to tape-out," says Niek Nijenhuis, global business development manager of PhoeniX Software tools at Synopsys.

"We have worked closely with TowerJazz's industry leading PH18MA process and device experts to provide customers with unmatched simulation capability using Lumerical's photonic integrated circuit simulator INTERCONNECT," says Lumerical's chief technical officer Dr James Pond. "In addition to standalone PIC simulation, the compact model library (CML) we developed for TowerJazz enables the industry's most advanced co-simulation framework for electrical/optical circuits using INTERCONNECT and Spectre AMS Designer, all driven from within the Virtuoso platform," he adds.

A demo of the TowerJazz SiPho design enablement platform took place in both the TowerJazz and Cadence booths at the Optical Networking and Communication Conference & Exhibition (OFC 2018) in San Diego (13–15 March).

www.towerjazz.com
www.ofcconference.org

GlobalFoundries extends silicon photonics roadmap to meet demand for data-center connectivity

First 90nm process on 300mm wafers qualified, and 45nm process scheduled for production in 2019

GlobalFoundries of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with operations in Singapore, Germany and the USA) has revealed new details of its silicon photonics roadmap to enable the next generation of optical interconnects for data-center and cloud applications. The firm has now qualified what is said to be the first 90nm manufacturing process using 300mm wafers, while also unveiling its upcoming 45nm technology to deliver greater bandwidth and energy efficiency.

GlobalFoundries' silicon photonics technologies are designed to support the massive growth in data transmitted across global communication infrastructure.

"The explosive need for bandwidth is fueling demand for a new generation of optical interconnects," says Mike Cadigan, senior VP of sales and ASIC business unit. "Our silicon photonics technologies enable customers to deliver unprecedented levels of connectivity for transferring massive amounts of data, whether it's between chips inside a data center or across cloud servers separated by hundreds and even thousands of miles," he adds. "Combined with our advanced ASIC and packaging capabilities, these technologies allow us to deliver highly differentiated solutions to this market."

GlobalFoundries' silicon photonics technologies enable the integration of optical components side-by-side with electrical circuits on a single silicon chip. This monolithic approach leverages standard silicon manufacturing techniques to improve production efficiency and reduce cost for deploying optical interconnect systems.

GlobalFoundries' current-generation silicon photonics offering is built on its 90nm RF silicon-on-insulator (SOI) process, which leverages its experience in manufacturing high-performance radio-frequency chips. The platform can enable solutions that provide 30GHz of bandwidth to support client-side data rates of up to 800Gbps, as well as long-reach capabilities of up to 120km.

Previously manufactured using 200mm wafer processing, the technology has now been qualified on larger-diameter 300mm wafers at GlobalFoundries' Fab 10 facility in East Fishkill, NY. The migration to 300mm enables more customer capacity, greater manufacturing productivity, and up to a 2x reduction in photonic losses to improve reach and enable more efficient optical systems.

The 90nm technology is supported by a full process design kit (PDK) for E/O/E co-design, polarization, temperature and wavelength parametrics from Cadence Design Systems, as well as differentiated photonic test capabilities including five test sectors from technology verification and modeling to multi-chip module (MCM) product test.

GlobalFoundries' next-generation monolithic silicon photonics offering will be manufactured on its 45nm RF SOI process, with production slated for 2019. By leveraging the more advanced 45nm node, the technology will enable reduced power, smaller form factor and significantly higher-bandwidth optical transceiver products to address next-generation terabit applications.

www.globalfoundries.com

NeoPhotonics appoints senior VP of global sales

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 appointed Yang Chiah Yee as senior VP of global sales, succeeding Ben Sitler.

Yee has more than 25 years of experience in the semiconductor industry, including 15 years in senior sales management roles, most recently as senior VP of worldwide sales at IDEX ASA. Previously, he was VP of worldwide sales at Atmel Corp, VP of APAC sales at Xilinx, and president of APAC at Memec Corp. Yee received a Bachelor of Electrical Engineering degree from Nanyang Technological Institute, National University of Singapore, and he is a graduate of the Stanford–NUS Executive program.

"Yang Chiah's extensive experience in the semiconductor industry will directly benefit bringing our optical semiconductor device, component and module solutions to the expanding high-speed market and will allow us to serve both existing and new customers within the changing commercial structure of our industry," comments chairman & CEO Tim Jenks.

"The accelerating demand for connectivity is creating new opportunities for photonic integration with both traditional communications equipment companies and new mega-data content providers," comments Yee. "I look forward to using my experience in the semiconductor industry to bring NeoPhotonics' innovative optical and semiconductor solutions to both existing and new markets."

www.neophotonics.com

NeoPhotonics reports revenue up 8% in Q4 to $76.9m

Chinese customer inventories back down to normal, driving volumes, but price reduction to delay revenue growth and profit until second-half 2018

For full-year 2017, 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 $292.9m, down 28.8% on 2016's $411.4m. This was driven by delays in China tenders, an inventory overhang after a strong 2016, and the sale of the firm's Low Speed Transceiver Product assets in January 2017 (to APAT Optoelectronics Components Co Ltd of Shenzhen, China). Excluding Low Speed Transceiver Products (which contributed $63.6m, or 15% of total revenue, in 2016), revenue fell by 16%. High Speed Products (for 100G-and-beyond) comprised 83% of revenue in 2017 (up from 67% in 2016), with Networking Products & Solutions comprising the other 17%.

Of total revenue, 55% came from China and 20% from the Americas.

For fourth-quarter 2017, revenue was $76.9m, down 30% on $109.8m a year ago (or down 20.7% on $97m, excluding Low Speed Transceiver Products) but rebounding by 8% from $71.1m last quarter (and above the $69–74m guidance range). Sales of High Speed Products comprised 84% of total revenue.

"Driving this growth was a combination of increasing demand from our Chinese customers [up 9% on last quarter], and stable demand in the other regions we serve," says chairman & CEO Tim Jenks.

Of total Q4 revenue, 57% came from China (down from 65% a year ago but level with last quarter) and 21% came from the Americas (down from 23% last quarter).

China's Huawei Technologies (including affiliate HiSilicon Technologies) was again the largest customer, at 42% of total revenue (still down from 53% a year ago, but rebounding further from 39% last quarter). The next four biggest customers represented 41% of total revenue (including US-based Ciena at 19%, up from 14% last quarter). For full-year 2017, Huawei comprised 40% of total revenue (down from 50% in 2016) and the next four contributed 39%.

"In early 2017 the industry was made aware of a substantial inventory overhang of optical and semiconductor components in the Chinese Telecom OEM supply chain and, as a result, much of the reduced demand we experienced throughout 2017 was a result of our customers working through this inventory," says Jenks. "In the fourth quarter we saw customer inventory levels reduce to the 3–4 week target range set by our customers — down from several months of inventory in mid-2017," he adds.

Consequently, aided also by reducing factory loading, during Q4 NeoPhotonics' net inventory was cut by more than $15m, from $82.8m to $67m, from 123 days to 99 days of inventory on hand.

On a non-GAAP basis, full-year gross margin has fallen from 29.9% in 2016 to 22.5% in 2017. Quarterly gross margin was 21.3% in Q4, down from 29.9% a year ago but recovering from a low of 18.6% last quarter. This was aided by lower inventory write-offs but partially offset by the initial impact of annual price negotiations plus lower-than-expected output from the firm's Japan fab, where full qualification and integration of new equipment for laser manufacturing lines has taken longer than expected: "While the main causes of this have been addressed and remediated, an approximately $3m adverse impact will carry over into Q1," notes senior VP & chief financial officer Elizabeth Eby.

Although full-year operating expense (OpEx) rose from $96.1m in 2016 to $103.2m in 2017, quarterly OpEx has been cut from $24.7m (34.7% of revenue) in Q3 to $24.1m (31.3% of revenue) in Q4. However, excluding one-time charges (officer severance costs and a bad debt write-off of $0.5m), OpEx has been cut by $1.5m. "Our restructuring announced in Q3 [involving a staff reduction, real-estate consolidation, an inventory write-down for certain programs, and a write-down of idle assets] is complete, with savings in Q4 of $1.5m in operating expenses and $0.4m in cost of goods sold," notes Eby.

Compared with net income of $6.3m ($0.13 per diluted share) a year ago, net loss has increased from $10.9m ($0.25 per diluted share) last quarter to $11.7m ($0.27 per diluted share, worse than the expected $0.23–0.13). However, this was driven by a one-time tax impact of $3.4m ($0.08 per share) related mainly to restructuring actions at the firm's China subsidiary. Despite this, net loss remained 15.3% of revenue from Q3 to Q4. Full-year net loss of $39.9m ($0.92 per diluted share) in 2017 compares with net income of $23m ($0.50 per diluted share) in 2016.

Cash provided by operations was $8m. Capital expenditure (CapEx) was $6m (down from $7m last quarter, and much less than the expected $10m). Free cash flow was hence $2.5m. During the quarter, cash and cash equivalents, short-term investments and restricted cash rose from $73.7m to $93.9m.

NeoPhotonics completed the annual renewal of its credit agreement with China's CITIC Bank for RMB250m ($40m). After the end of the quarter, the firm repaid $17m drawn on the expired CITIC Bank credit line and borrowed $17m on ►

the new credit line. NeoPhotonics has also entered into a new seven-year loan agreement with Japan's Mitsubishi Bank for ¥850m ($8m). Part of this was used to repay the previous ¥500m ($5m) long-term loan.

"Specific to China, we believe customer inventory levels have normalized for our products," says Jenks. "More importantly, [in Q4] we began to see them pull a larger volume of our products, and thus far in Q1/2018 we have seen this trend continue… Despite typical seasonality in the first quarter, we see Q1 volumes increasing modestly over Q4 levels," he adds. "The elimination of the inventory overhang at our customers is a meaningful first step to growth in 2018."

"With input from both China customers and carriers, we believe this near-term increase in demand is a step up to specific customer shipment volumes and is not yet a firm indication of increasing end-market demand from either additional domestic provincial tenders or in support of initial 5G trials," says Jenks. "The expectation from our customers is that both of these end-market growth drivers will materialize to some degree later in 2018 [with second-half 2018 being much stronger than first-half 2018]."

"Outside of these China-specific dynamics, in the fourth quarter we saw modest increases with strong traction in our mid- and long-term growth drivers," says Jenks. "We are seeing design-win strength in our new 400G and 600G product offerings across all three of our leading components, including our ultranarrow-linewidth tunable laser, 400G and 600G micro coherent driver-modulator and coherent receiver, as well as with our CFP-DCO [digital coherent optics] and multi-cast switch modules. In the fourth quarter we began shipping coherent DCO modules to initial customers and we expect volumes will grow through 2018 from a low starting base. We see strengthening demand for our multi-cast switch platform and we have increased our shipment rate accordingly," he adds.

"The adoption of 400G and 600G data rates in data-center interconnect (DCI) and metro networks, initially in North America and subsequently in Europe and China, will provide accelerating demand for our next-generation products. We believe we are very well positioned for this next-generation growth driver with the introduction of our 400G and 600G product suite, new 1.2T applications and the growth of contentionless networks," says Jenks. "As China continues to build out national backbone, provincial and metro networks later in the year, advance in data-center deployments and prepare for 5G wireless, we expect continuing growth in this key market. However, in the first half of 2018, there is uncertainty around when the next tenders or deployments within China may occur," he cautions.

In first-quarter 2018, volumes are expected to increase modestly as inventory levels return to normal. But Q1 is typically NeoPhotonics' seasonally lowest quarter due to annual price negotiations and the impact of Chinese New Year. "Given industry oversupply, price reductions were toward the high end of the historical range of 10–15%," notes Eby. "As typically occurs, these price reductions began to take effect in the fourth quarter with the full impact occurring in the first quarter followed by cost reductions throughout the year to mitigate the impact on gross margin," she adds.

As China continues to build out national backbone, provincial and metro networks later in the year, advance in data-center deployments and prepare for 5G wireless, we expect continuing growth in this key market

As a consequence, for first-quarter 2018 (with higher volumes but lower prices) NeoPhotonics expects drops in revenue to $67–73m and in gross margin to 16–20% (impacted by the $3m lower output from the Japan fab). However, aided by the increased volumes, NeoPhotonics' inventory should be reduced further, from 99 days to 90 days on hand, and under-absorption of overheads should be relatively low. OpEx should be cut slightly to $23–24m, helping to hold net loss per share to $0.32–0.22.

For full-year 2018, NeoPhotonics sees 100G port count in China rising by 10% or more, so increased volumes will outweigh price reductions (which are mitigated through the year), leading to China revenue being flat to slightly up. Overall (globally), the increase in port count will be offset by price reductions, leading to flat revenue on the basis of the same product mix. However, since some of NeoPhotonics' new products are generating revenue now, total revenue should grow for full-year 2018.

"We are focused on cash, cash flow and a return to profitability," says Eby. "Operating expense reductions are complete, we have made good progress reducing inventory, and we believe that our customer's inventories have reached normal levels," she adds. "As we complete amortization of under-absorption charges, we remain committed to reaching breakeven with revenues in the mid-80s [of millions of dollars] and will continue actions to further reduce our breakeven point."

"While continuing uncertainty around the timing of provincial and 5G trial tenders within China may overshadow growth from our new products in the short term, we believe the mid- and long-term market drivers for our business are compelling," says Jenks. "These drivers, complemented by our success in new product introductions, will help us drive top-line growth in 2018 and to second-half profitability."

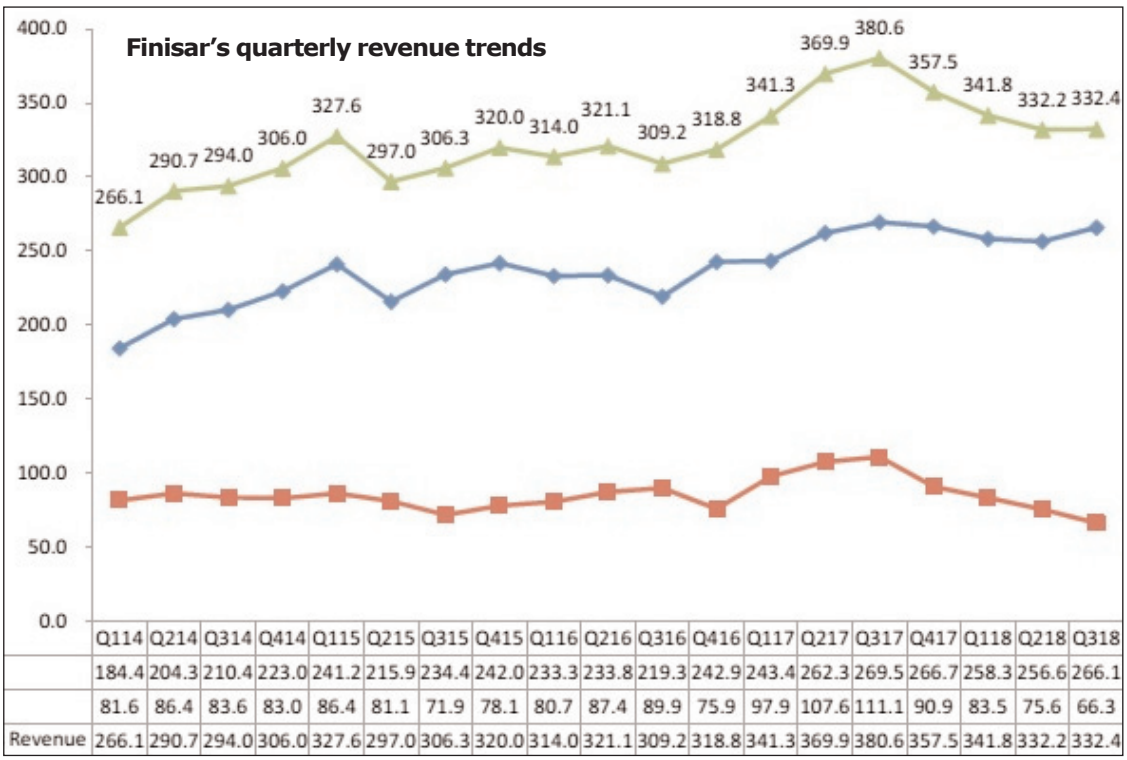
www.neophotonics.com

Finisar's quarterly revenue growth in 100G QSFP28 transceivers for data centers compensates for lower China telecom sales

Ramp-up of VCSEL capacity in second-half 2018 to aid margin recovery

For fiscal third-quarter 2018 (ended 28 January), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of $332.4m, down 12.7% on $380.6m a year ago and roughly level with $332.2m last quarter.

Datacom product sales were $266.1m, down 1.3% on $269.5m a year ago but up 3.7% on $256.6m last quarter, due mainly to record revenue from 100G QSFP28 transceivers for data centers (growing by about $15m from roughly $100m last quarter) as well as strong growth for vertical-cavity surface-emitting laser (VCSEL) arrays for 3D sensing (which began shipping in production quantities from the firm's 4"-wafer fab in Allen, Texas, only late last quarter), offset by lower sales of 40G QSFP and 100G CFP and CFP2 Ethernet transceivers.



	Q114	Q214	Q314	Q414	Q115	Q215	Q315	Q415	Q116	Q216	Q316	Q416	Q117	Q217	Q317	Q417	Q118	Q218	Q318
	184.4	204.3	210.4	223.0	241.2	215.9	234.4	242.0	233.3	233.8	219.3	242.9	243.4	262.3	269.5	266.7	258.3	256.6	266.1
	81.6	86.4	83.6	83.0	86.4	81.1	71.9	78.1	80.7	87.4	89.9	75.9	97.9	107.6	111.1	90.9	83.5	75.6	66.3
Revenue	266.1	290.7	294.0	306.0	327.6	297.0	306.3	320.0	314.0	321.1	309.2	318.8	341.3	369.9	380.6	357.5	341.8	332.2	332.4

Telecom product sales were $66.3m, down 12.3% on $75.6m last quarter (driven primarily by the impact of one month of the annual telecom price reductions as well as lower revenue from Chinese OEM customers) and down 40.3% on $111.1m a year ago. In particular, revenue for wavelength-selective switches (WSS) for reconfigurable optical add/drop multiplexers (ROADMs) was flat to down a bit (compared with strong revenue last quarter).

Like last quarter, Finisar had two 10%-or-greater customers. The top 10 customers represented 63.3% of total revenue (up from 60.2% last quarter).

On a non-GAAP basis, gross margin has fallen further, from 37% a year ago and 30.3% last quarter to 28.6% (below the 30–31% guidance). This is due mainly to unfavorable product mix, the impact of one-month of the annual telecom price reductions (which were at the higher end of the usual 10–15% range, due to the poor demand environment), and the non-cash impact of an increase in inventory reserves.

"Last calendar year, we were largely in a constrained environment in our 100G QSFP28 product line and a relatively benign pricing environment. Now that there's more of an equilibrium between supply and demand we are definitely seeing stronger price erosion and competition as it relates to that 100G QSFP28 product line," notes executive VP & chief financial officer Kurt Adzema. "We are not producing and selling as many VCSEL arrays as we would like," he adds. "We're working on our yields; they're not where we would like them to be."

Although still up on $70.5m a year ago, operating expense (OpEx) was $72.4m, cut from $74.6m last quarter (and below the expected $75m).

Due mainly to the lower gross margin, operating margin has fallen further, from 18.5% of revenue a year ago and 7.8% last quarter to 6.8% (below the 7.5–8.5% guidance).

Likewise, net income has fallen further, from $67.2m ($0.59 per diluted share) a year ago and $26.1m ($0.23 per diluted share) last quarter to $22.8m ($0.20 per diluted share, below the expected $0.21–0.27). This is due mainly to the lower gross margin as well as non-GAAP taxes rising by $0.8m to $3m as a result of an unrealized gain in China from the weakening US dollar relative to the Chinese Renminbi (with an impact of about $0.01 per diluted share).

Capital expenditure (CapEx) was $38.6m (less than the forecasted $50m). Finisar also spent $20.2m on the purchase of the new 700,000ft^2 facility in Sherman,

Texas (to be used to expand manufacturing capacity for VCSELs using 6-inch wafers).

During the quarter, cash and short-term investments hence fell from $1.233bn to $1.216bn.

For fiscal fourth-quarter 2018 (to end-April), Finisar expects revenue to fall by about $22m to $300–320m, due mainly to lower demand for VCSEL arrays, lower revenue from 40G datacom transceivers, and lower telecom revenue driven primarily by the full three-month impact of the telecom price reductions from 1 January. Gross margin should hence fall slightly to 27–28%. With OpEx expected to be relatively flat, operating margin should fall further to about 4%. Earnings per fully diluted share are expected to drop to $0.09–0.15.

CapEx should be $45m, including about $8m for the continuing construction and fit out of the third building of Finisar's Wuxi manufacturing site (due for completion in calendar second-half 2018). Separately, uplift of the building and additional equipment at the Sherman facility should add another $55m in CapEx. This should be followed by another $55m on Sherman in fiscal Q1/2019, then the remainder of a total $150m investment in the first phase of capacity expansion at Sherman in fiscal Q2/2019.

"While our third quarter financial performance is disappointing, and the outlook for the industry in the next few quarters is expected to be challenging, I'm optimistic that we can ultimately improve our financial results through a combination of improved execution and a healthier demand environment," says CEO Michael Hurlston. "We do expect some improvement in the back half of the [calendar] year, primarily coming from our WSS product line. We expect some uplift in the Chinese market and we should see some improvement there," he adds.

"We are currently reviewing all aspects of how we do business in the markets we participate in," Hurlston continues. "While I believe the near-term will remain challenging for the industry, this type of environment often creates exciting opportunities. In addition, I believe we can ultimately restore the company's gross and operating margins back to historic levels over time."

In particular, whereas the 4"-wafer VCSEL fab in Allen, Texas was running at less than half of its $20m+ quarterly capacity in the January quarter, the April quarter should see $20–25m of output. Also, the new 6"-wafer VCSEL fab in Sherman should enter production in calendar second-half 2018, with quarterly revenue capacity of $50–60m. "We can certainly in the first phase build Sherman to a capacity of $80m plus," believes Hurlston. "As we go out some distance and time and build on multiple phases, I think then you can see $100m," he adds. "Our intention is to consolidate Sherman and Allen. But I don't think that we're going to run simultaneously for very long in Sherman and Allen."

"Uptick in gross margin, especially as it relates to the Sherman facility, is going to come down to volume and yields," notes Adzema. "There will be a ramp period of course, but we expect our VCSEL arrays for 3D sensing to be margin accretive."

www.finisar.com

Finisar launches smallest fully integrated coherent optics assembly

At the Optical Networking and Communication Conference & Exhibition (OFC 2018) in San Diego (13–15 March), Finisar launched what it claims is the smallest fully integrated coherent optics assembly — the Integrated Tunable Transmitter and Receiver Assembly (ITTRA) product family — complementing its line of coherent components and ACO (analog coherent optics) transceivers. Designed for easy customer integration into coherent line cards or DCO (digital coherent optics) transceivers, the ITTRA enables users to accelerate their time to market and reduce program and development costs, it is claimed.

In a footprint that is 70% smaller than the size of a CFP2 module, the ITTRA provides the same functionality as a CFP2-ACO. All key building blocks of an ACO interface (tunable laser, optical amplifier, modulators, drivers, coherent mixer, photodiode array, and TIAs) are incorporated in a single optical sub-assembly, which is combined with a miniature controller board that provides a standardized management interface. Since the ITTRA is a fully calibrated and tested assembly instead of a disaggregate set of components, it is reckoned to yield operational cost savings for the line-card or module integrator because test times of the end product are greatly reduced.

"A turn-key solution like the ITTRA greatly reduces the development effort for the line-card or module integrator, allowing them to rapidly respond to new market opportunities," says John DeMott, senior director of marketing.

The demonstration at OFC showed the 32Gbaud ITTRA transmitting and receiving data at 200Gb/s using DP-16QAM modulation. The product will be sampling in second-quarter 2018.

In addition, Finisar demonstrated the WaveShaper A Series of programmable optical processors with the newly released WaveShaper App revision 1.3. This software supports arbitrary power splitting on up to 16 ports with ratios of up to 100 to 1. Finisar is also providing a technology demonstration of a WaveShaper processor covering the extended C+L band with a total wavelength range larger than 100nm. Arbitrary filtering of attenuation and phase is supported across the entire range.

www.ofcconference.org

Lumentum to acquire Oclaro for $1.8bn

Oclaro stockholders to own 16% of combined company

A definitive agreement has been signed (unanimously approved by the boards of directors of both companies) for Lumentum Holdings Inc of Milpitas, CA, USA (which makes photonics products for optical networking and commercial lasers for industrial and consumer markets) to acquire Oclaro Inc of San Jose, CA, USA (which provides optical components and modules for the long-haul, metro and data-center markets).

For each share held, Oclaro stockholders will be entitled to receive $5.60 in cash and 0.0636 of a share of Lumentum common stock. The transaction values Oclaro at $9.99 per share or about $1.8bn in equity value, based on the closing price of Lumentum's stock on 9 March of $68.98. This represents a premium of 27% to Oclaro's closing price on 9 March and a premium of 40% to its 30-day average closing price. Oclaro stockholders are expected to own about 16% of the combined company at closing.

"Joining forces with Oclaro strengthens our product portfolio, broadens our revenue mix, and positions us strongly for the future needs of our customers," says Lumentum's president & CEO Alan Lowe. "Oclaro brings its leading indium phosphide (InP) laser and photonic integrated circuit (PIC) and coherent component and module capabilities to Lumentum. The combined company will drive innovation faster and accelerate the development of products," he reckons.

"Together, we will be an even stronger player in fiber-optic components and modules for high-speed communications and a market leader in 3D sensing," believes Oclaro's CEO Greg Dougherty.

The transaction is expected to generate more than $60m of annual run-rate synergies within 12–24 months of the closing and be immediately accretive to non-GAAP earnings per share.

Lumentum intends to fund the cash consideration with a combination of cash on hand from the combined companies' balance sheets and $550m in debt financing. The transaction is expected to close in second-half 2018, subject to approval by Oclaro's stockholders, anti-trust regulatory approval in the USA and China, and other customary closing conditions.

One member of Oclaro's board of directors, as mutually determined, will join Lumentum's board upon closing of the transaction.

www.oclaro.com
www.lumentum.com

Oclaro ships first fully tunable SFP+ I-temp transceiver

Availability simplifies operation of DOCSIS 3.1 cable access networks, delivering 10G full-duplex to Remote Phy nodes

Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has announced production shipments of what is claimed to be the first fully tunable SFP+ industrial temperature range (TSFP+ I-temp) transceiver. Availability is said to represent a milestone for cable companies deploying the latest DOCSIS 3.1 standard, which pushes fiber installation much deeper into the hybrid fiber coax (HFC) network to reach next-generation Remote Phy nodes.

Cable networks need to offer best-in-class bandwidth to retain their customers and enable premium services, says Oclaro. With more than 50 million homes served by multi-service operators (MSOs) in the USA alone and up to 1 million new nodes, the deployment of 10G full-duplex per node over the next 4–5 years can only be achieved with products such as fully tunable DWDM lasers that are easy to install, configure and monitor.

"Fully tunable DWDM laser technology is critical to enable large-scale fiber deep deployment while minimizing operations cost and eliminating human errors," says chief strategy officer Yves LeMaitre. "With tunable lasers capable of operating from –40°C to 85°C, we believe the days of analog optics or fixed WDM lasers are counted," he adds. "Once you start using tunable products, the operational benefits such as automatic configuration and reduced sparing are just too great to go back to legacy optics."

The TSFP+ is Oclaro's latest product to include I-temp and follows the firm's 10G TSFP+ C-temp (commercial temperature) and E-temp (extended temperature), which are both shipping now. The TSFP+ is vertically integrated through the use of Oclaro's in-house ILMZ (integrated laser Mach–Zehnder) chip and its custom-designed transmitter optical sub-assembly (TOSA) and receiver optical sub-assembly (ROSA) technology. Due to the unique material composition of the ILMZ chip and custom tuning of thermal and electronic control components, the product is capable of operating from –40°C to 85°C. The TSFP+ I-temp is available now for volume production orders.

www.oclaro.com

Oclaro announces availability of 100G PAM4 EML lasers to meet demand for 400G high-speed interconnects

Fab capacity upgrades added for DML and EML production

Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has announced general market availability of its 100G PAM4 electro-absorption modulated distributed feedback (EA-DFB) laser (EML) chips for next-generation transceiver applications.

The firm says that its EML chips operating at 53Gbaud with up to 40GHz bandwidth (@20°C) and 6dB extinction ratio (@70°C) are suitable for use in 4-level pulse amplitude modulation-based (PAM4) transceivers, enabling 100Gbps per wavelength. Combining high performance and low power consumption, the EML chips pave the way for the next wave of 200Gbps and 400Gbps in data-center networks.

Oclaro also announced additional wafer fab capacity upgrades for directly modulated laser (DML) and electro-absorption modulated laser (EML) production, providing greater availability for its components. The firm says that the newly installed production capacity will enable it to satisfy the increasing demand for cost-effective high-speed transceivers.

"With the explosive growth of large-scale data centers, the demand for these lasers has never been greater and, by increasing our manufacturing capacity, Oclaro can ensure its customers have the supply they need," says chief strategy officer Yves LeMaitre.

Oclaro reckons that its high-speed 25G DML chips, which have been produced in high volume for the last two years, are well suited for 100Gbps CWDM4 transceivers. They can also be used in low-cost SFP28 modules and other 25Gbps products for high-volume, low-cost applications. The firm's EML devices provide the high bandwidth and linearity needed for next-generation 200Gbps and 400Gbps transceivers using PAM4, while still maintaining small size and low cost.

Oclaro's laser chips support both CWDM4 and LAN-WDM wavelength standards and, in many applications, uncooled operation and non-hermetic packaging can be employed for low-cost, high-performance module solutions, including PAM4 transceivers for higher data rates.

Oclaro's 100Gbps PAM4 electro-absorption modulated laser chips are ready for sampling now.

www.oclaro.com

Oclaro samples first ultra-high-bandwidth 1310nm DFB-MZ PICs for select 100G/400G PAM4 applications

Oclaro is sampling what is claimed to be the first family of high-bandwidth 1310nm photonic integrated circuits (PICs) that integrate a distributed feedback (DFB) laser with a Mach–Zehnder (MZ) modulator for intra-data-center applications using CWDM wavelengths. Leveraging Oclaro's expertise in 1310 DFB lasers for shorter-reach applications with its indium phosphide (InP) high-bandwidth modulator technology, the new family of chips will enable higher-speed connectivity across data-center campuses.

The 1310nm DFB-MZ PIC has been engineered to address the most challenging configurations where high bandwidth and optical signal purity are critical to overcome potential fiber and connector impairments. The new product complements Oclaro's full suite of InP directly modulated laser (DML) and electro-absorption modulated lasers (EMLs), all specifically designed to address data-center single-mode fiber infrastructure requirements.

"The need for ever-increasing capacity within the data center is making it critical to develop higher-speed and more integrated component technology," says Beck Mason, president of Oclaro's Integrated Photonic business. "Oclaro has a long history of delivering proven direct-detect and coherent technology and we are pleased to be the first supplier to now offer a 1310nm DFB-MZ PIC capable of supporting the demanding 100Gbps per wavelength PAM4 (4-level pulse amplitude modulation) applications."

The 1310nm DFB-MZ PICs take advantage of proven elements that have been in production at Oclaro for many years, including DFB lasers and PICs with integrated Mach–Zehnder modulators, all based on InP. These elements are brought together to form a new PIC to tackle the complex task of high data rate, high extinction ratio and good linearity for PAM4 modulation. The PICs are available in 50Gbps per wavelength and higher-bandwidth 100Gbps per wavelength versions supporting all four CWDM fixed wavelengths.

Oclaro's family of DFB-MZ chips is sampling now, with volume production expected to begin by July.

Oclaro showcased its product portfolio at the Optical Networking and Communication Conference & Exhibition (OFC 2018) in San Diego, CA, USA (11–15 March).

www.ofcconference.org

Magnolia to develop cost-effective, thin-film GaAs-based solar cells for reliable portable power

Nano-enhanced thin III-V absorbers with light-trapping structures allow single-junction devices to avoid need for multi-junctions

Magnolia Optical Technology Inc of Woburn, MA, USA (which develops thin-film and nanostructure-based technologies spanning the ultra-violet, visible and infrared spectrum for military sensors and commercial applications including solar cells) is working with the US Defense Advanced Research Projects Agency (DARPA) under a Phase II Small Business Innovation Research (SBIR) program 'Development of High-Performance Thin-Film Solar Cells for Portable Power Applications' (contract no. D15PC00222).

Photovoltaic devices can provide a portable source of electrical power for a wide variety of defense and commercial applications, including mobile power for dismounted soldiers, unmanned aerial vehicles (UAVs) and remote sensors. "The goal of the current program is to develop high-efficiency gallium arsenide (GaAs)-based solar cells that maintain their performance over changing environmental conditions, and that are thinner and thus more cost-effective to produce," says chief technical officer Dr Roger Welser. "By combining thin III-V absorbers with advanced light-trapping structures, single-junction GaAs-based devices provide a means to deliver high-efficiency performance over a wide range of operating conditions at a fraction of the cost of the multi-junction structures typically employed for space power. In addition, the incorporation of nano-enhanced III-V absorbers provides a pathway to extend infrared absorption and increase the photovoltaic power conversion efficiency of cost-effective thin-film solar cells," he adds.

"Changes in the solar spectrum can dramatically degrade the performance of traditional multi-junction devices — changes that occur naturally throughout the day, from season to season, and from location to location as sunlight passes through the earth's atmosphere," says Magnolia's president Dr Ashok Sood. "Moreover, multi-junction III–V cells require thick, complex epitaxial layers and are therefore inherently expensive to manufacture," he adds. "The technology under development as part of this DARPA-funded program addresses these key weaknesses in the established high-performance photovoltaic technology."

www.magnoliaoptical.com
www.sbir.gov/sbirsearch/detail/873321

First Solar chosen by Vectren for 50MW solar array in Southwestern Indiana

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA says that it has been selected to build the 50MW solar array outlined last month as part of the long-term electric generation transition plan of Vectren Energy Delivery of Indiana.

During the past few months, Vectren has been working with Orion Renewable Power Resources LLC of Oakland, CA, USA (a joint venture between Orion Renewable Energy Group and MAP Renewable Energy) to select, secure and eventually develop the property in Troy, Indiana.

Sited on 300 acres of land and will consist of about 150,000 solar panels, the solar array will be mounted on a single-axis tracking system (enabling the panels to automatically pivot to enhance energy generation as the sun's rays move across the surface of the Earth). The facility, which should be fully operational in the fall of 2020, is expected to generate enough power to meet the needs of more than 11,000 households per year.

"This significant renewable resource will be connected to our system to serve our local customers," says Vectren's chairman, president & CEO Carl Chapman.

Construction will begin after the Indiana Utility Regulatory Commission authorizes the project (a decision is expected in first-half 2019). The initial construction phase will require establishing a sub-station to interconnect with Vectren's power grid and will begin immediately upon regulatory approval. Construction of the solar array (which will provide up to 250 jobs) will begin in mid-late 2019.

"First Solar's expertise in design and construction of solar power plants aligns perfectly with Vectren's Smart Energy Future strategy," says Eran Mahrer, VP – markets, origination & government Affairs for First Solar. "Using our high-performance Series 6 thin-film modules and a plant design approach tailored to utility ownership values, we will contribute significantly to Vectren's commitment to deliver clean, reliable and reasonably-priced energy to its customers."

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Questioning carrier distributions in III-nitride LEDs

Researchers suggest that the behavior of external quantum efficiency with varied multiple quantum wells is described by a more uniform carrier distribution.

University of Bath and University of Cambridge in the UK have reinterpreted the ABC model of recombination in indium gallium nitride (InGaN) multiple quantum well (MQW) light-emitting diodes (LEDs) to suggest that the carrier distribution across the wells is more uniform than presently believed [M. A. Hopkins et al, J. Appl. Phys., vol122, p234505, 2017]. In particular, the reinterpreted model is used to study the variation of the modified constants with the number of wells of fabricated LEDs.

Non-uniformity of the hole carrier distribution is thought to be one cause of efficiency droop in InGaN LEDs at high current. Drift-diffusion transport of carriers is used to explain the non-uniformity. The researchers comment on their results against the consensus: "The implications of the reported results are that drift-diffusion plays a far lesser role in cross-well carrier transport than previously thought; that the dominant cause of efficiency droop is intrinsic to the quantum wells and that reductions in the density of non-radiative recombination centers in the MQW would enable the use of more QWs and thereby reduce Auger losses by spreading carriers more evenly across a wider emissive region."

The ABC model uses three parameters, A–B–C, to describe the radiative recombination of injected carriers. The desired radiative recombination of electrons and holes into photons is related to the B-term, which is proportional to the product of the electron and hole densities. The A-term, proportional to the minority carrier density, is related to Shockley–Read–Hall recombination through intermediate defect energy levels in the bandgap. The final C-term, where one of the densities is given a single power and the other is squared, is traditionally attributed Auger processes where electron-hole recombination is aided by energy transfer to another carrier. However, there are also other explanations given for the C-term.

The researchers grew blue 2.4nm/7.0nm InGaN/GaN MQWs by metal-organic chemical vapor deposition (MOCVD) on c-plane sapphire. The material had a threading dislocation density of around $4x10^8/cm^2$. The barriers were grown in two temperature steps, first ramping to 846°C after the $In_{0.12}Ga_{0.88}N$ well deposition, and then increasing to 880°C for most of the growth.

The layers before the MQW active region consisted of 2.0μm GaN, 2.5μm n-GaN, 23nm $In_{0.05}Ga_{0.95}N$, and 3nm GaN. After the MQW came a 12nm p-$Al_{0.17}Ga_{0.83}N$ electron-blocking layer and a 120nm p-GaN layer.

Lateral 420μmx400μm devices were fabricated with annealed nickel/gold interdigitated electrodes for more uniform current spreading across the LED. To further equalize the current density across the device, a thin nickel layer was deposited on some of the electrode and p-contact structures. The effect of the extra nickel layer was small and had little effect on the subsequent ABC modeling. The researchers comment: "From this, we conclude that non-uniform current spreading had little influence on the efficiency droop observed in our LEDs."

The mesa and transparent p-GaN contact areas were $1.48x10^{-3}cm^2$ and $1.17x10^{-3}cm^2$, respectively. The number of wells varied between 3 and 15. The researchers found that devices with more wells suffered from less droop in external quantum efficiency (EQE) at high current.

The researchers applied the ABC model to their results with provision for tunneling and overflow currents. Unlike most modeling, the team considered that the photon-emitting recombining carriers were spread across the wells rather than restricted to the wells near the p-contact end. Hence they expected their $\alpha\beta\gamma$ modified coefficients would have different proportionalities to the number of wells (N, Figure 1).

Drift-diffusion plays a far lesser role in cross-well carrier transport than previously thought...

The dominant cause of efficiency droop is intrinsic to the quantum wells...

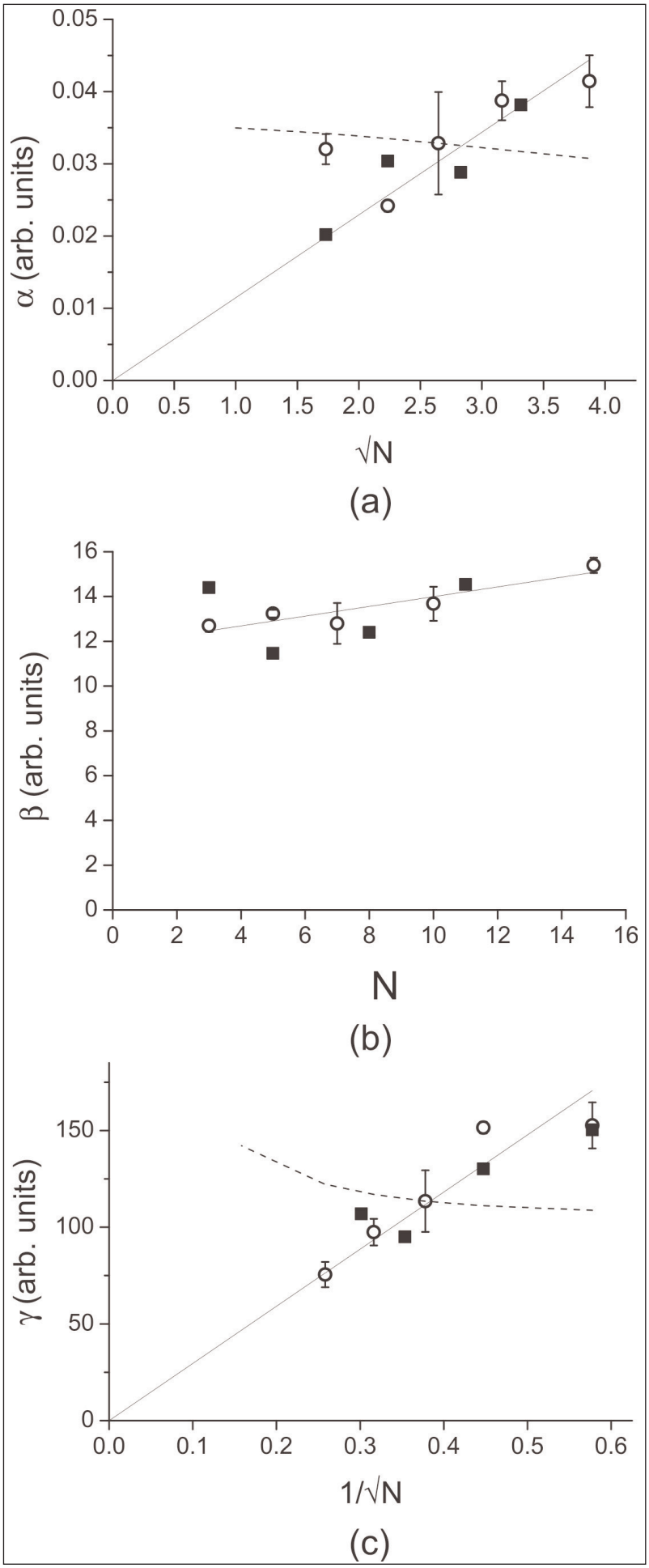

Figure 1. (a) α versus √N, (b) β versus N, and (c) γ versus 1/√N. Open-circle data points obtained from fits to EQE measurements. Black lines are straight line fits to results. Trend lines forced through origin for α (3-well point excluded) and γ. Closed-square symbols are from fitting of data of Zhang et al (excluded from trend line fitting). Dashed lines in (a) and (c) show trends that would be seen if exponentially decaying distributions of electrons and holes occur in MQW.

The team suggests that, under forward bias, electrons and holes are injected into the superlattice-like band-like states arising from the periodic structure of the QWs. "Such direct carrier injection into the superlattice-like states of the quasi-saw-tooth band profile is likely to promote still further rapid transport of both electrons and holes to yield more nearly uniform steady-state distributions across the MQW," they write. The saw-tooth potential profile arises from the charge polarization changes of the different c-plane III-nitride layers, giving rise to electric fields.

The researchers sought further confirmation of their ideas by fitting the results of another group to the model [Zhang et al, Opt. Express, vol23, pA34, 2015]. Also, they developed a model to reflect the more usual drift-diffusion mechanism with non-uniform carrier distributions (dashed lines in Figure 1).

Of course, the idea that the carrier distribution is non-uniform is not just due to simulations. Some experiments have varying well widths to give different wavelength emissions to help determine carrier distributions empirically. The team comments: "The presence of a deeper or wider QW in a super-lattice or MQW will both introduce electron and hole states localized to the different wells and disrupt the formation of the quasi-extended states by which free carriers would otherwise spread through the MQW by thermally assisted tunneling."

The researchers believe that the cause of drooping is intrinsic to the MQWs, giving three possible mechanisms: "Auger recombination, carrier density activated defect recombination (DADR), and tunneling-assisted non-radiative recombination, the latter including trap-mediated Auger effects." They add that their results do not enable them to distinguish the primary mechanism from this menu. For semi-polar/non-polar LEDs, the contribution of thermally assisted tunneling could be reduced or even absent. ■

https://doi.org/10.1063/1.4986434

Author:
Mike Cooke

Boosting InGaN LEDs on silicon with tensile stress

Tension increases wall-plug efficiency and reduces droop at high current.

South China University of Technology has improved the performance of indium gallium nitride (InGaN) light-emitting diodes (LEDs) on silicon through increasing tensile stress in the photon-generating active region [Zhiting Lin et al, J. Appl. Phys., vol122, p204503, 2017]. Although stress engineering has been a critical factor in enabling III-nitrides to be grown on low-cost silicon, overcoming 16.9% lattice and 54% thermal mismatching, the researchers note that the effect of stress on "performance of LEDs by modifying the band structure and the carrier recombination process, seems to be neglected".

LED material (Figure 1) was grown by metal-organic chemical vapor deposition (MOCVD) on (111) silicon. The stress state of the 'luminous' multiple quantum well (MQW) upper layers was controlled by varying the thickness of underlying undoped u-GaN and AlN layers (Table 1). The crystalline quality was assessed through full-width at half maximum (FWHM) measurements of peaks in x-ray rocking curves (XRCs) and microscopic inspection of cracks in the surface. Raman spectroscopy was used to derive the stress state of the MQW. Increasing GaN thickness and removal of the AlN interlayer increased tensile stress. However, if taken too far, cracks appear.

The material was fabricated into 1mmx1mm LED chips. The light output power (LOP) of LED C with most tensile stress was 19.4% greater than that of LED A (Figure 2). The 35A/cm^2 forward voltage (V_f) for LED C was also lowest, giving the least power input at the given current injection and further boosting wall-plug efficiency (WPE). At 70A/cm^2, the WPE droop was 36.5% for LED C. This droop was the smallest among the devices. The researchers say that the LOP of 528mW at 35A/cm^2 for LED C is greater than the ~508mW of devices on silicon reported by other groups.

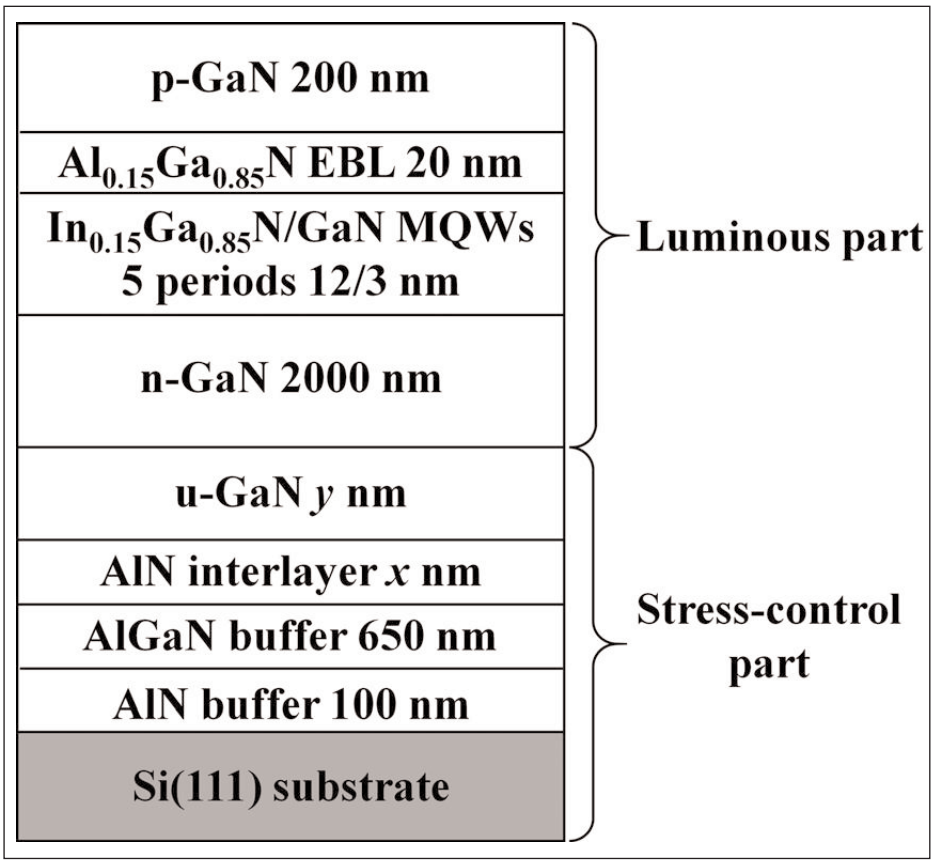

Figure 1. Experimental LED structure.

Table 1. Material and photoelectric properties of LEDs A to D, including thicknesses of AlN interlayer and u-GaN that provide stress variation.

Sample	LED A	LED B	LED C	LED D
AlN interlayer (nm)	20	20	0	0
u-GaN (nm)	400	800	800	1200
GaN(0002) XRC FWHM (arc sec)	368	355	350	352
GaN(10$\bar{1}$2) XRC FWHM (arc sec)	434	433	430	435
Stress (GPa)	−0.63	0.13	1.03	0.71
Crack density (/mm^2)	0	0	0	2.45
LOP at 35A/cm^2 (mW)	442	510	528	482
V_f at 35A/cm^2 (V)	3.11	3.08	3.05	3.17
WPE at 70A/cm^2	32.2%	38.3%	40.0%	34.1%

Despite its higher tensile stress, the performance of LED D was worse than that of LED B. "The cracks of LED D may induce some connotative damage during the fabrication of LED chips, resulting in the degradation of the light output power and the increment of electric resistance," the team comments.

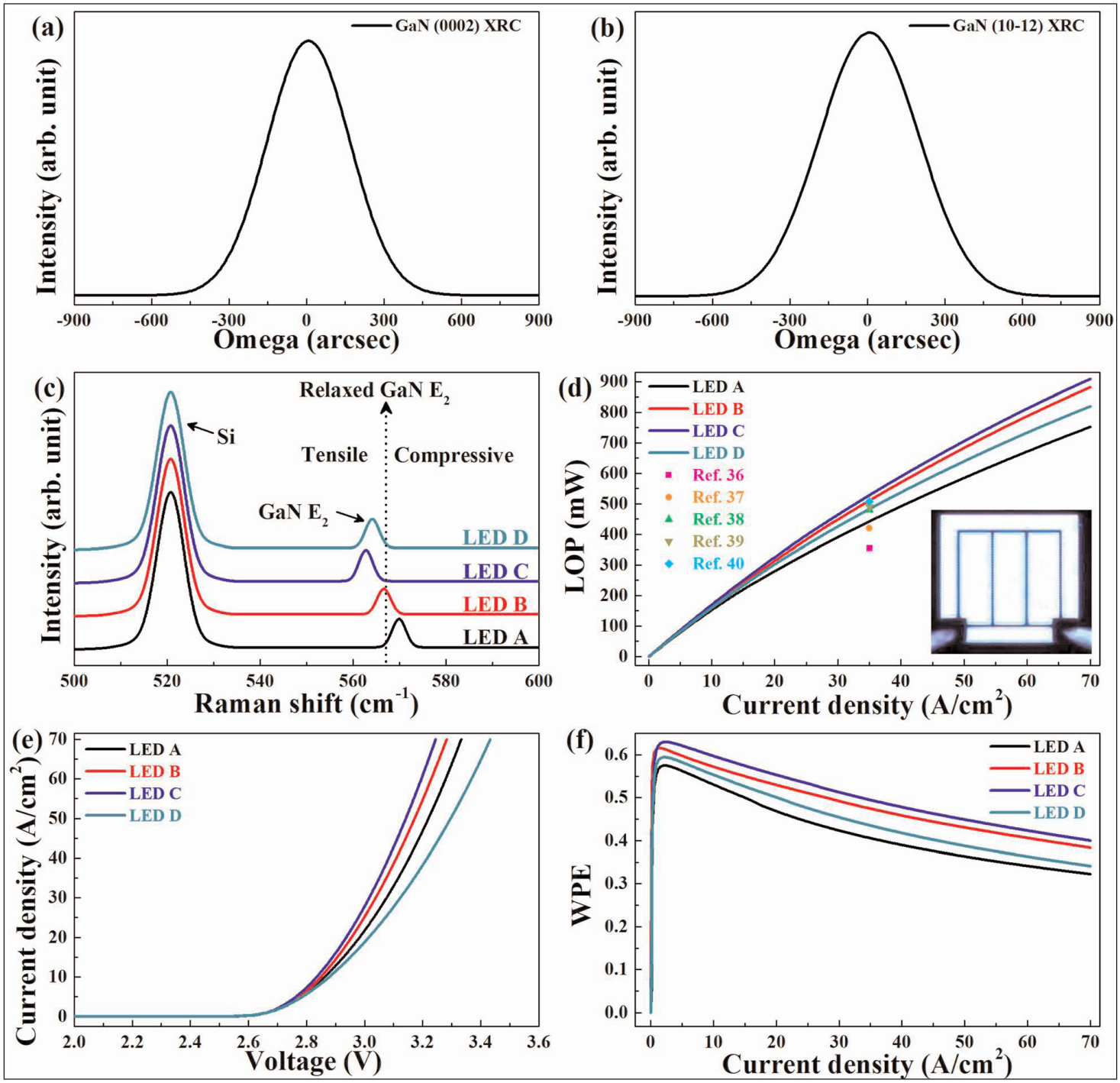

Figure 2. (a) GaN(0002) and (b) GaN(10$\bar{1}$2) XRCs for LED C, (c) Raman spectra of LEDs A to D. (d) Experimental light output power versus current density, (e) current density versus voltage, and (f) wall-plug efficiency versus current density for LEDs A to D.

Simulations suggested that going from compressive stress of −3GPa to tensile stress of +5GPa should improve luminous output and generally reduce forward voltage for an injection current density of 35A/cm^2. Actually, the lowering of forward voltage only continued up to +4GPa. Increasing the tensile stress up to +8GPa impaired the projected LED performance beyond that at −3GPa compression. On the other hand, at low current injection the +8GPa model gave the best performance.

Charge polarization due to the partial ionic nature of the III-N bonds gives rise to sheet charges at heterointerfaces and hence electric fields in the structures. The effect is altered by different stress states and can impact band structure, carrier recombination, and carrier concentration in MQWs.

The researchers comment: "It is demonstrated by simulation that tensile stress in the underlying n-GaN alleviates the negative effect from polarization electric fields on multiple quantum wells, but an excessively large tensile stress severely bends the band profile of the electron blocking layer, resulting in carrier loss and large electric resistance." ■

https://doi.org/10.1063/1.4993985

Author: Mike Cooke

III–nitride prospects for VLC applications

Mike Cooke reports on some recent research on various laser and non-laser emitters, along with detectors and waveguides.

Visible light communication (VLC) has been going on for a long time, from semaphore between ships to waving lanterns about to direct smuggling operations. And of course, sign languages date from prehistory and are still used by deaf communities and desperate tourists. Historical communication is based on writing. And at the dawn of the electronic age, Alexander Graham Bell experimented with a 'photophone' in the 1880s.

Electronic VLC systems need transmitters, receivers and a transmission medium. Although air is the most common medium, there is also interest in underwater optical communication (UWOC) and various waveguide materials such as short-range plastic optical fiber (POF) communication. For transmission, the use of smart lighting as transmitter could avoid the extra energy consumption needed for dedicated systems.

The III-nitride family provides a range of materials that can emit and detect light efficiently from green (570nm-) to deep into the ultraviolet (-200nm) range of wavelengths.

Silicon platform

Although silicon (Si) absorbs visible light, there is much interest in integrating visible light emitters with the complementary metal-oxide-semiconductor (CMOS) Si-based circuits used in the vast digital consumer market.

Researchers in China have successfully fabricated an indium gallium nitride (InGaN) microdisk laser on silicon that operated at room temperature under electrical pumping [Meixin Feng et al, Optics Express, vol26, p5043, 2018]. "This is the first observation of electrically pumped lasing in InGaN-based microdisk lasers grown on Si at room temperature," the team from Suzhou Institute of Nano-Tech and Nano-Bionics, University of Science and Technology of China, and Changchun Institute of Optics Fine Mechanics and Physics, writes.

Generally, reported microdisk lasers on silicon have been optically pumped, reducing their usefulness. Microdisk lasers use whispering-gallery modes of light reflecting/echoing around a circular structure to create a resonant cavity for laser excitation that can efficiently couple to on-chip waveguides.

The researchers used a sandwich structure on silicon (Figure 1) rather than the more usual stem-and-cap mushroom format normally employed for optically pumped microdisk lasers. The team adopted the sandwich format to give more robustness and to reduce the electrical and thermal resistance of the n-side of the device.

Since aluminium gallium nitride (AlGaN) has a lower refractive index than GaN, it was used as lower cladding, confining most of the optical field away from the absorptive highly defective buffer.

However, the sandwich structure did require a thicker buffer structure to overcome the 17% lattice mismatch and 54% thermal expansion coefficient difference with silicon. The buffer layers consisted of 370nm AlN nucleation, 280nm $Al_{0.35}Ga_{0.65}N$, 415nm $Al_{0.17}Ga_{0.83}N$, and 1μm GaN.

The n-contact layer was 1.6μm n-GaN. The n-side continued with 1.3μm $Al_{0.07}Ga_{0.93}N$ cladding and 80nm GaN lower waveguide.

The active region consisted of three well/barrier pairs of 2.5nm/7.5nm $In_{0.1}Ga_{0.9}N/In_{0.02}Ga_{0.98}N$. The upper 60nm GaN waveguide was undoped. The p-type layers were a 20nm $Al_{0.2}Ga^{0.8}N$ electron-blocking layer (EBL), 100x(3nm/3nm) $Al_{0.11}Ga_{0.89}N$/GaN superlattice cladding, and 30nm GaN contact.

Circular microdisks were fabricated using a nickel mask and dry etching. Sidewall damage was removed with tetramethyl ammonium hydroxide (TMAH) wet etching, smoothing the surface and reducing surface recombination centers and associated optical losses. The TMAH treatment reduced threshold currents for microdisks from ~1500mA to ~1000mA.

The researchers also fabricated micro-ring devices that concentrated current injection at the periphery for more efficient excitation of whispering-gallery modes (Figure 2). This also avoids Joule heating of the central region that can degrade performance. The micro-ring injection was ensured by removing the p-GaN and part of the p-AlGaN/GaN superlattice cladding from, and by depositing silicon dioxide (SiO_2) in, the center of the disk.

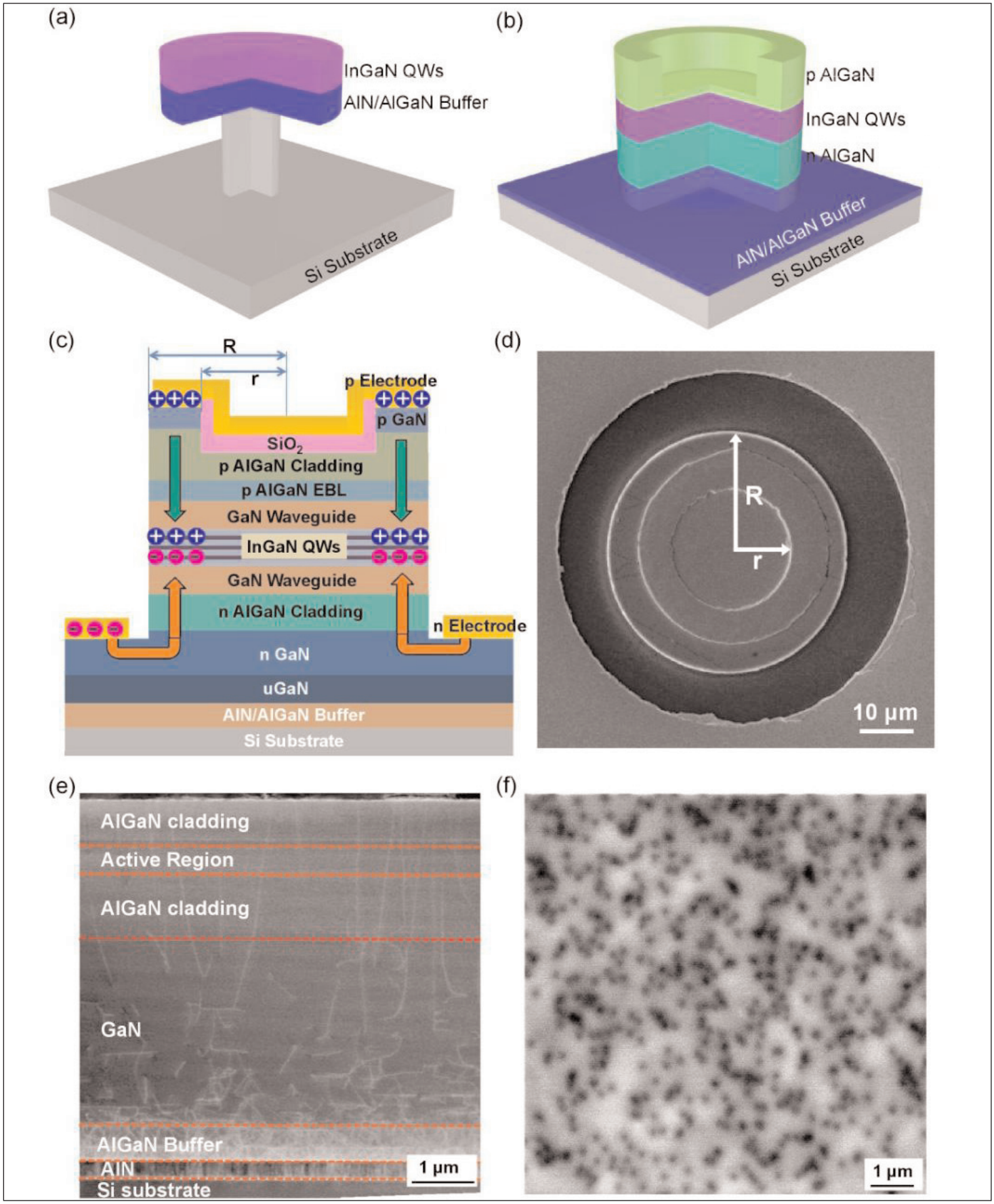

Figure 1. (a) Conventional 'mushroom-like' InGaN-based microdisk laser on Si with undercut structure and (b) 'sandwich-like' InGaN micro-ring laser grown on Si with AlGaN cladding layers. (c) Schematic structure of InGaN micro-ring laser. (d) Scanning electron microscope image. (e) Cross-sectional high-angle annular dark-field scanning transmission electron microscope (STEM) image. (f) Panchromatic cathodoluminescence image of GaN film grown on silicon, giving density of threading dislocations (TDs) of ~6x10^8/cm^2.

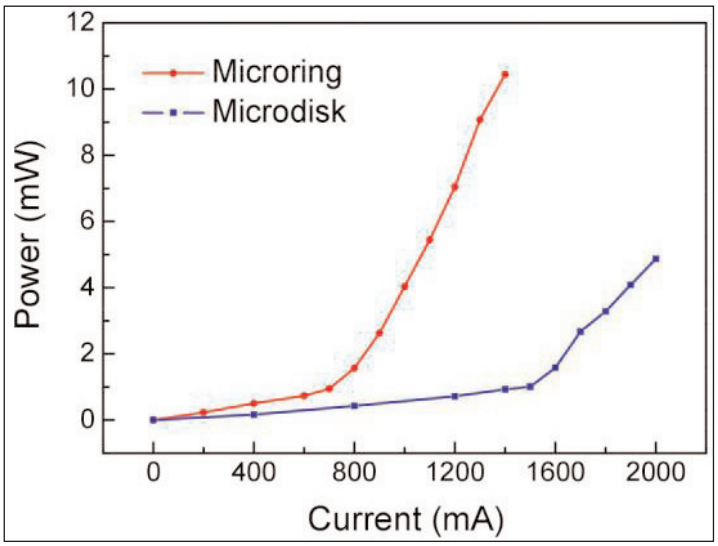

Figure 2. Peak light output power of InGaN-based micro-ring laser and microdisk laser grown on silicon measured under various 400ns, 10kHz pulsed currents at room temperature.

The researchers comment: "Compared with the conventional microdisk resonators, micro-ring resonators have more compact cavity volume and better high-speed modulation characteristics due to less effect of carrier space hole-burning and diffusion."

A micro-ring laser with outer and inner radii of 10μm and 5μm, respectively, emitted a peak wavelength of 412.4nm with 0.4nm full-width at half maximum (FWHM) under 250mA pulsed current at room temperature. Over a range of devices, the threshold occurred between 200mA and 450mA. Without TMAH treatment, micro-ring lasers had a threshold of ~800mA.

Nanjing University of Posts and Telecommunications and Zhengzhou University in China have also been developing III–nitride technology for VLC on a monolithic silicon platform [Xumin Gao et al, Optics Letters, vol42, p4853, 2017].

In particular, the team created a system of an LED transmitter and photodiode receiver linked by an InGaN waveguide in AlGaN cladding.

Contact	p-GaN	38nm
Cladding	p-AlGaN	600nm
Waveguide	InGaN	80nm
Multiple-quantum well	InGaN/GaN	120nm
Waveguide	n-InGaN	90nm
Cladding	n-AlGaN	1500nm
Contact	n-GaN	1500nm
Buffer	n-GaN	1500nm
Buffer	AlGaN	490nm
Nucleation	AlN	280nm
Substrate	(111) Si	2-inch diameter

Figure 3. Epitaxial structure.

Transmission at up to 200Mbits per second (Mb/s) was demonstrated for both in-plane and out-of-plane set ups. The in-plane transmission to an on-chip receiver could be used in practice as a power monitor.

The team sees particular benefit arising for 'Internet of Things' applications, along with integrated biomedical analysis systems and monolithic photonic circuits. "From a mass-production point of view, the III–nitride-on-silicon platform offers a feasible approach that is compatible with Si-fab for wafer-level fabrication," the researchers add.

The device fabrication was performed on 2-inch III–nitride on Si substrates produced by metal-organic chemical vapor deposition (MOCVD, Figure 3). The further processing (Figure 4) consisted of 590nm mesa isolation etch, formation of annealed nickel/gold (Ni/Au) p-contact, etching to the n-contact layer, plasma-enhanced chemical vapor deposition (PECVD) of 200nm SiO_2 isolation, buffered oxide etch of elec-

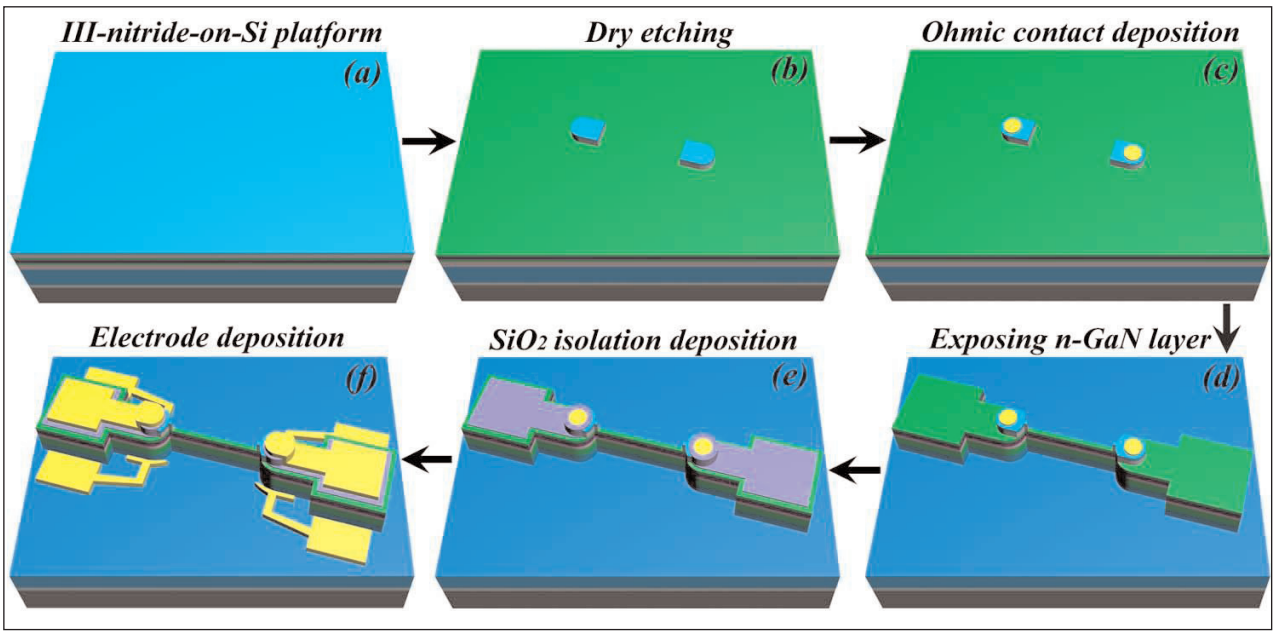

Figure 4. Fabrication processes of multi-component system on III–nitride-on-Si platform.

trode regions, and titanium/platinum/gold (Ti/Pt/Au) metalization. The transmitter and receiver were isolated from each other by the removal of the p-GaN layer from the top of the waveguide.

The photonic circuit consisted of an 8μm-wide 200μm-long InGaN waveguide connecting transmitter and receiver. The transmitter was found to emit radiation with a wavelength around 452nm. The transmitter diode turn-on voltage was around 2.5V. The capacitance of the device was around 2.33pF at 500kHz. A lower capacitance would improve the modulation capability.

The photocurrent through the receiver diode was found to follow the increased emission from the transmitter with increased current injection. The response to an on-off keying modulation, pseudo-random binary sequence (PRBS) data stream gave 'open eye' diagrams with rates up to 200Mb/s, the limit of the measurement system.

Out-of-plane light was collected by 20x objective lens with 0.5 numerical aperture (NA) and transmitted through a confocal system to a photodiode (Figure 5). Under 200Mb/s data streams the system again gave open-eye diagrams.

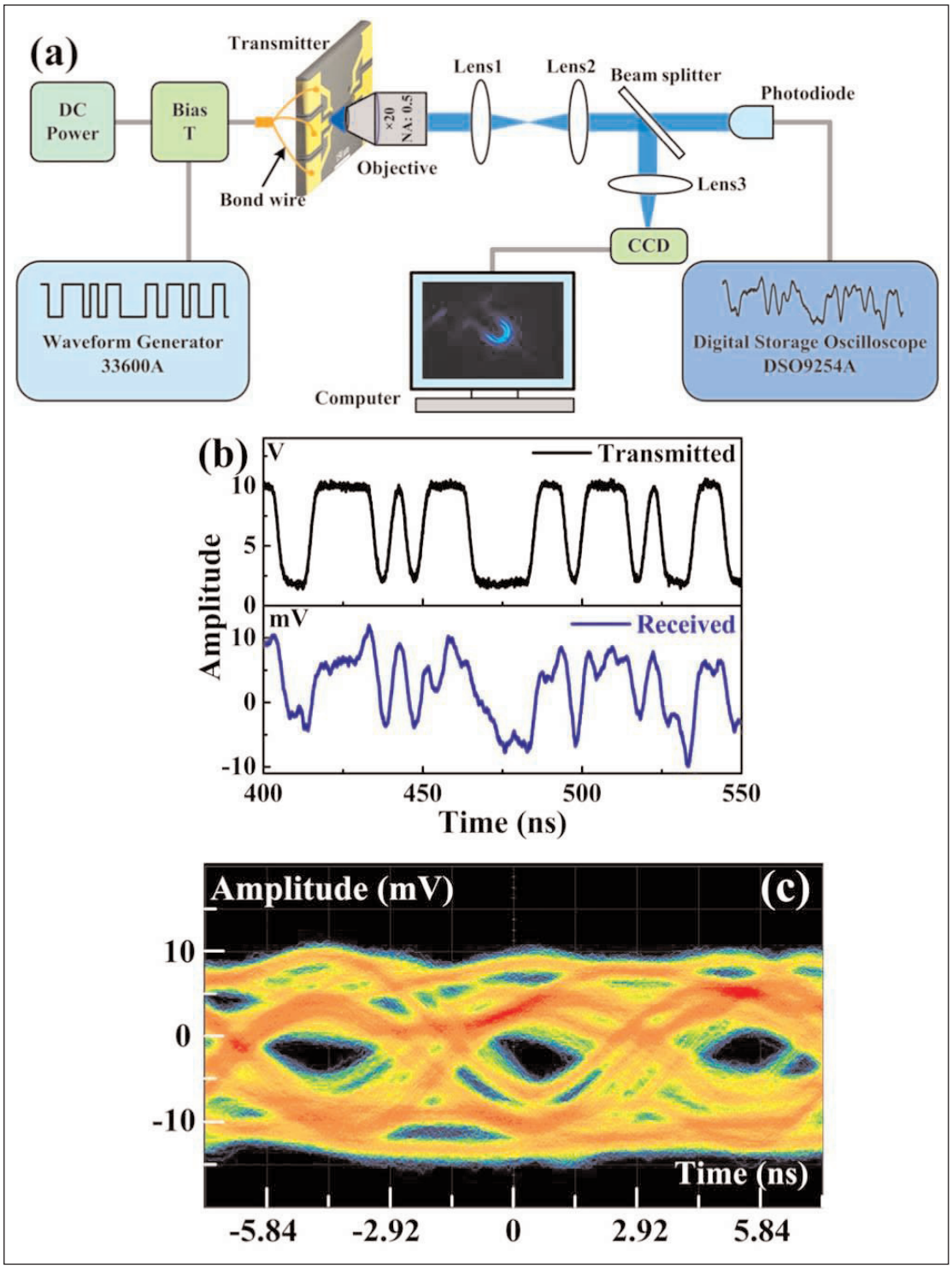

Figure 5. (a) Schematic out-of-plane visual light communication. (b) Transmitted and received PRBS data at 200Mb/s transmission rate. (c) Eye diagrams measured at 200Mb/s.

Semi-polar orienteering

Researchers based in Saudi Arabia and USA have used semi-polar InGaN quantum wells (QWs) to create a laser diode (LD) integrated with a semiconductor optical amplifier (SOA) for VLC, smart lighting, and UWOC [Chao Shen et al, Optics Express, vol26, pA219, 2018].

The team from King Abdullah University of Science and Technology (KAUST) in Saudi Arabia, University of California Santa Barbara (UCSB) in the USA, and King Abdulaziz City for Science and Technology (KACST) in Saudi Arabia, comments: "Since the on-chip integration of various photonic devices offers the advantages of small footprint, low cost and multi-functionality, it is of great interest to develop III–nitride photonic integrated circuits (PICs) at the visible wavelength."

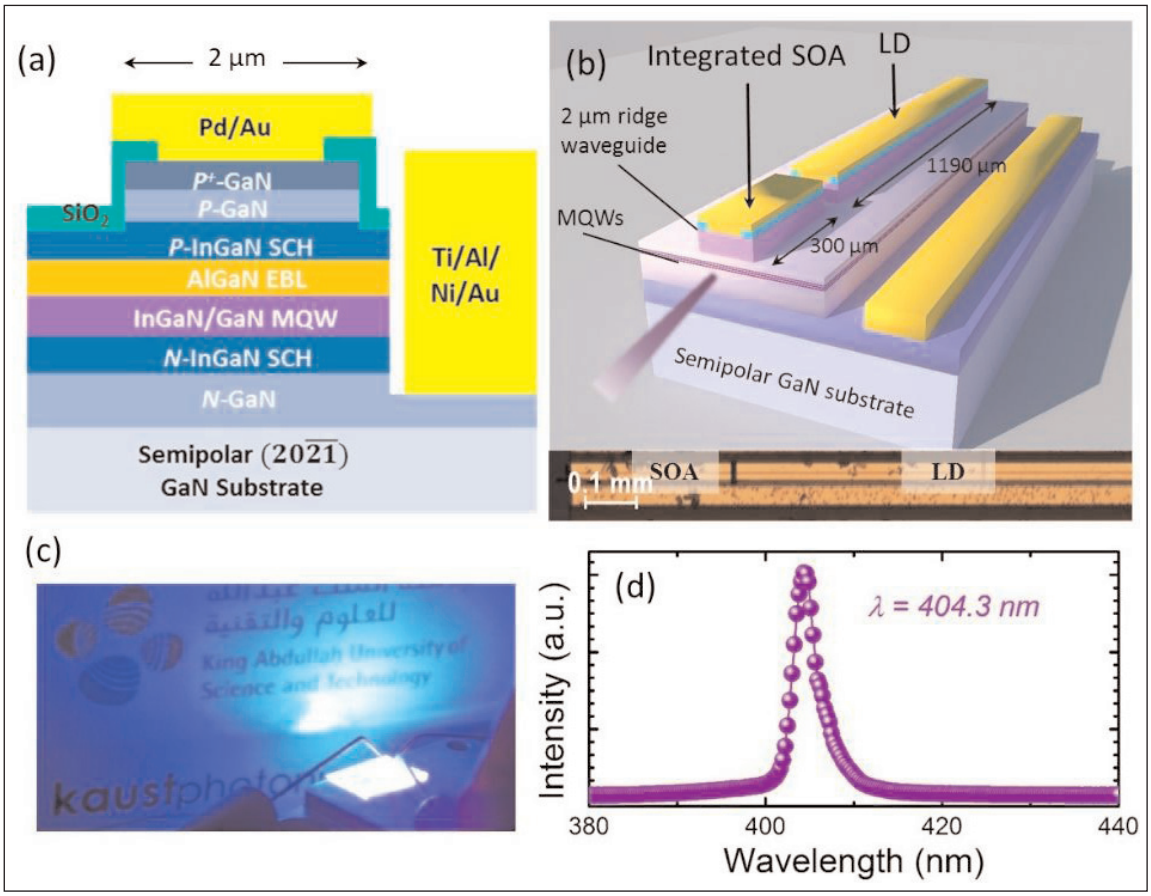

Figure 6. (a) Cross-sectional layered structure and (b) three-dimensional illustration of 405nm-emitting dual-section integrated SOA-LD on semi-polar GaN substrate. Inset: fabricated device under optical microscope. (c) Photo of device operating at room temperature. (d) Emission spectrum of device at laser gain section current of 250mA and zero SOA section driving voltage, showing peak at ~404.3nm.

The epitaxial structure for the device was grown by MOCVD on semi-polar (20$\bar{2}$1) GaN (Figure 6). The active light-emitting region was four pairs of $In_{0.1}Ga_{0.9}N$/GaN quantum wells/barriers. A 16nm $Al_{0.18}Ga_{0.82}N$ layer served as an electron-blocking layer (EBL). The separate-confinement heterostructure (SCH) waveguides consisted of 60nm/60nm p-/n-$In_{0.025}Ga_{0.975}N$. The p- and n-GaN cladding layers were 600nm and 350nm, respectively.

The p- and n-electrodes were palladium/gold (Pd/Au) and Ti/Al/Ni/Au, respectively. The structure of the separate SOA and laser diode sections were defined by patterned etching of a 2µm-wide ridge. Electrical separation of the devices was achieved by etching the p-GaN contact layer between them, while maintaining a seamless optical connection.

When the SOA was unbiased, the light output power was low due to optical losses. The light output increased as the SOA bias increased to 6.25V. In fact, beyond 5V bias, the output was greater than for a laser diode without SOA, suggesting light amplification in the SOA itself beyond 4V bias.

With a laser diode current of 250mA, the light output power increased from 8.2mW to 30.5mW as the SOA bias increased from 0V to 6.25V. Between the same

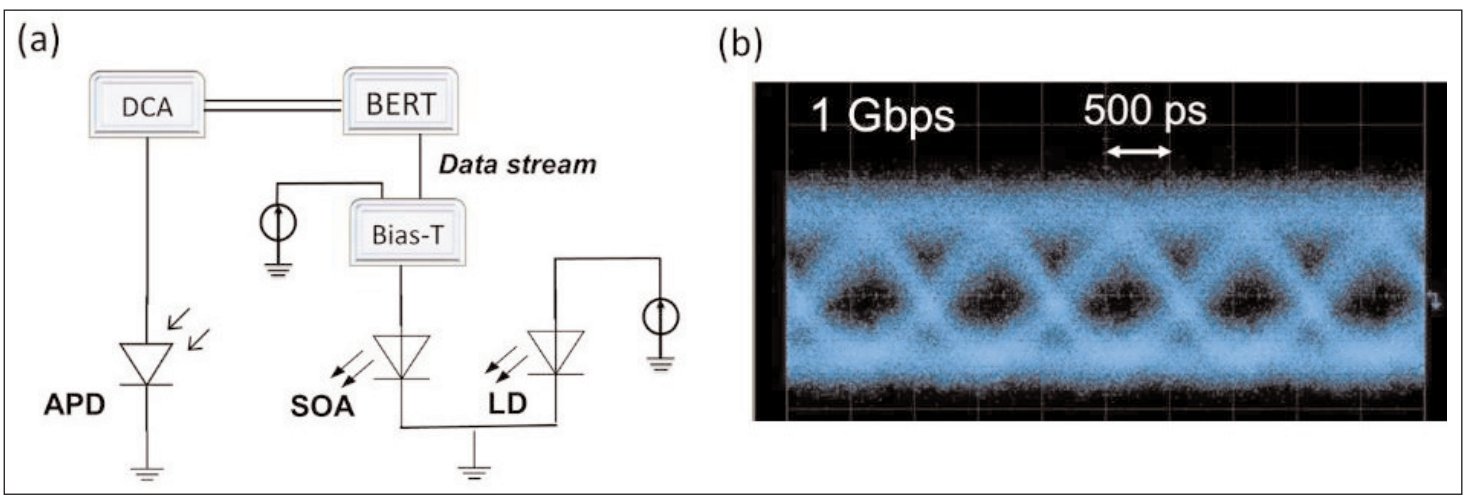

Figure 7. (a) Schematic of non-return-to-zero on-off keying modulation (NRZ-OOK) data transmission measurement using SOA-LD as transmitter and avalanche photodiode (APD) as receiver, along with bit error rate tester (BERT) and digital communication analyzer (DCA). (b) Eye diagram of 1Gbit/s data rate.

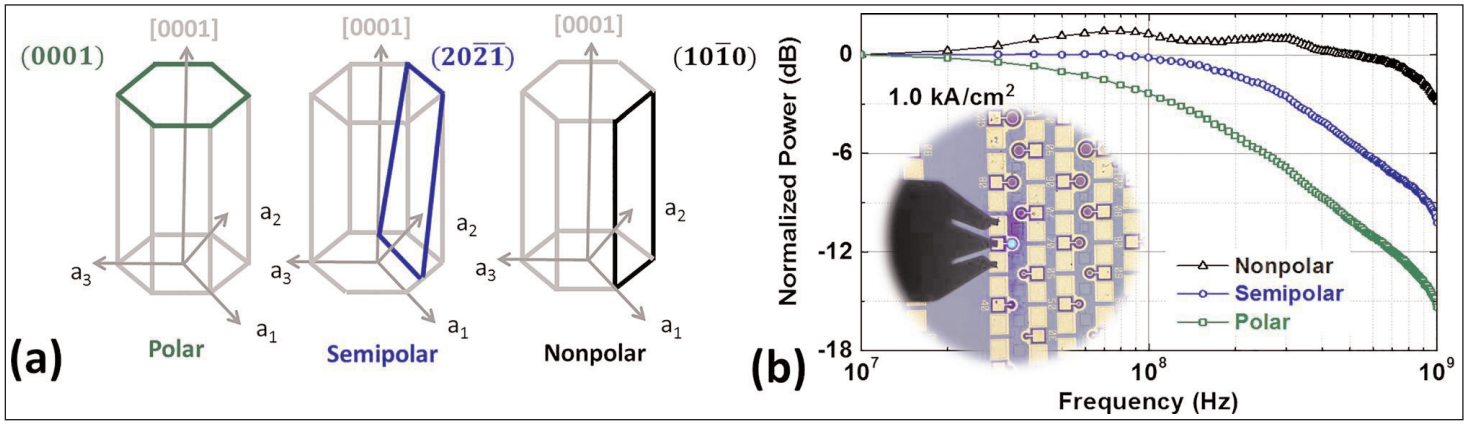

Figure 8. (a) Crystallographic planes studied and (b) normalized s-parameter (S_{21}) response of LEDs with polar (green squares), semi-polar (blue circles), and non-polar (black triangles) orientations with same device geometry operating at 1kA/cm^2. Inset: operating device probed using GSG RF electrode.

SOA biases, the laser threshold current decreased from 229mA to 135mA. With the laser diode at 250mA, the SOA current at 6V bias was 67mA, giving a total input power of 2.14W and wall-plug efficiency (WPE) of 1.3%. A separate laser diode with 317mA (250mA+67mA) current injection had a WPE of 0.54%.

The rate of increase in effective gain of the SOA as the bias increased from 4V to 6.25V was 2.36dB/V at 250mA laser diode injection. The team comments: "The high gain observed in the device is partially attributed to the large electron–hole wavefunction overlap in InGaN/GaN QWs grown on semi-polar (20$\bar{2}\bar{1}$) GaN substrate, which exhibits reduced polarization field compared to that in conventional [polar] c-plane devices." The peak amplification ratio between 0V and 6.25V SOA bias was 18.4 at 404nm wavelength and 200mA laser diode injection.

The combined device achieved 'open eye' data transmission at 1 gigabits per second (Gb/s) with SOA modulation and constant 250mA laser diode injection (Figure 7). The bit error rate was 3.4x10^{-4}, meeting the limit for forward error correction (FEC) of 3.8x10^{-3}.

University of New Mexico and UCSB in the USA have been studying the effect of crystal orientation (Figure 8) on the modulation bandwidth of InGaN light-emitting diodes [M. Monavarian et al, Appl. Phys. Lett., vol112, p041104, 2018].

In particular, the researchers sought high bandwidth at lower current injection where the efficiency of InGaN LEDs is higher, reducing 'droop' effects. The non-polar m-plane (10$\bar{1}$0) orientation was found to have the largest 3dB (half-power) bandwidth, with a value of more than 1GHz down to 500A/cm^2 injection.

The team promote LEDs over laser diodes for VLC, POF and UWOC applications: "For communication applications, advantages of LEDs compared to diode lasers include their lower cost, longer operating lifetime, lower temperature dependence, compatibility with existing lighting systems, and lower emission directionality."

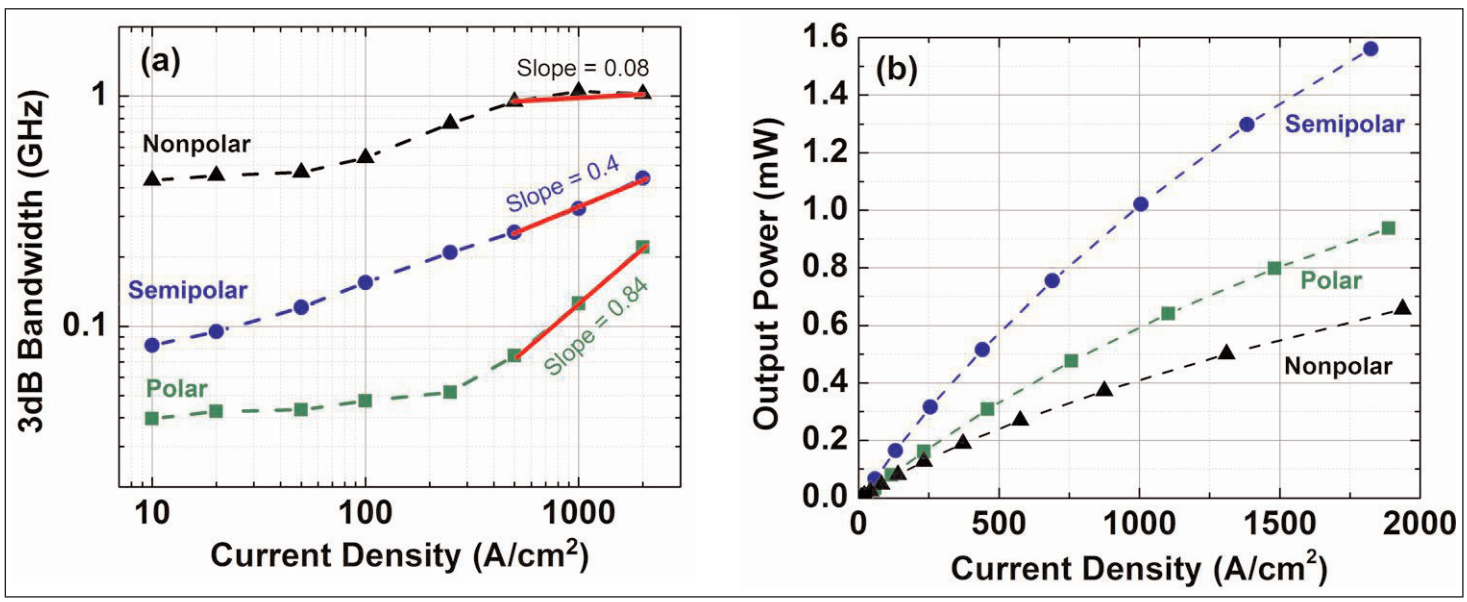

Figure 9. (a) Bandwidth and (b) optical output power versus current density for devices with polar (green squares), semi-polar (blue circles), and non-polar (black triangles) orientations.

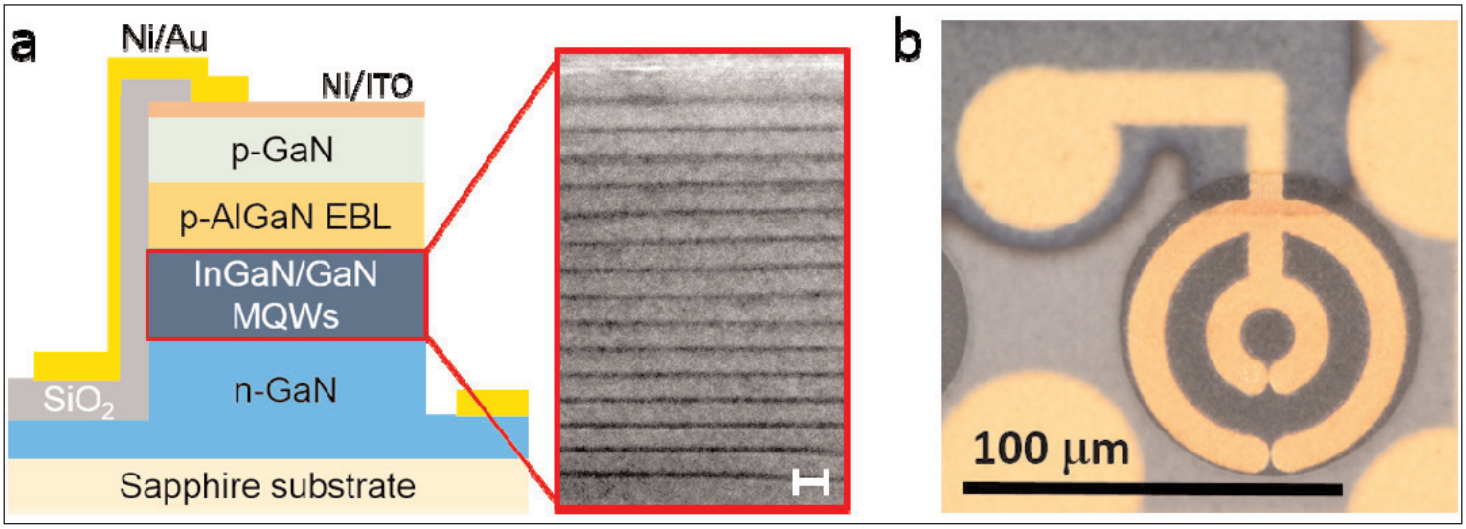

Figure 10. (a) Schematic of InGaN/GaN MQW μPD and transmission electron microscope image showing 15-pairs of 3nm InGaN/13.5nm GaN (scale bar 20nm). (b) Optical microscope image of μPD with diameter of 80μm.

The LEDs studied contained three InGaN quantum wells. The well thicknesses were chosen to maximize optical output power: 4nm for the polar c-plane (0001) and semi-polar ($20\bar{2}\bar{1}$) orientations, and 6nm for the non-polar sample. Free-standing semi-polar and non-polar GaN substrates were supplied by Mitsubishi Chemical. The polar sample was grown on c-plane sapphire.

The materials were fabricated into 60μm-diameter circular mesa LEDs with indium tin oxide (ITO) transparent conductor on the p-contact layer, Ti/Al/Ni/Au n-contact, chromium/gold contact pads, and ground-signal-ground radio frequency (GSG RF) electrodes. The micro-LED structures were designed to reduce the impact of parasitic resistance-capacitance time constant effects on modulation bandwidth.

The 3dB (half-power) bandwidths at 1kA/cm^2 current density injection were 1050MHz, 325MHz and 125MHz for the non-polar, semi-polar and polar LEDs, respectively, correcting for the frequency responses of the RF cables, bias tee and low-noise amplifier. The non-polar LED maintained its ~1GHz bandwidth down to 500A/cm^2 (Figure 9).

The researchers explain the larger bandwidth for the non-polar LED as being due to better wavefunction overlap between the electrons and holes that are desired to recombine into photons, compared with the semi-polar and completely polar orientations.

At higher current, the polar LEDs begin to benefit from coulomb screening of the charge polarization electric fields that impair performance. Hence, the bandwidth increases more rapidly above 500A/cm^2, compared with the semi-polar and non-polar orientations. In terms of raw output power, the semi-polar LED gives more than twice the intensity of the non-polar device.

The researchers used their results to assess the carrier life-times of the three devices, finding that the non-polar carriers had the shortest life-times, giving faster response to modulation. Unsurprisingly, the semi-polar structure gave a shorter life-time than the fully polar devices.

Short life-times reflect fast recombination, with the upshot of lower carrier density for a given injection current. The team sees the faster recombination of the non-polar orientation as reflecting the more complete overlap of electron and hole wavefunctions.

As the current density increases, the polar LED carrier life-time reduces and some c-plane LEDs with bandwidth of the order 1GHz have been reported at 5kA/cm^2 injection. However, high current injection means lower efficiency as a result of 'droop'.

The researchers comment: "LEDs fabricated on non-polar and semi-polar orientations are attractive for achieving higher bandwidths at lower operating currents, which is advantageous for maximizing efficiency, reducing power dissipation, and mitigating issues with thermal management."

Orthogonal-frequency division multiplexing

Finally, KAUST claims a record 3.2 gigabit per second (Gbps) data-rate performance for VLC at 405nm wavelength [Kang-Ting Ho et al, Optics Express, vol26, p3037, 2018]. The orthogonal-frequency division multiplex (OFDM) system used an InGaN multiple quantum well microphotodetector (μPD) receiver and laser diode source with quadrature amplitude modulation (QAM) coding.

The team wanted to address the bandwidth and data security challenges for future high-speed mobile internet, smart traffic, and Internet of Things (IoT). Bandgap limitations make the receiver portion of VLC systems particularly challenging.

The μPDs used a multiple quantum well with 15-period InGaN/GaN structure grown on c-plane sapphire by MOCVD (Figure 10). The p-AlGaN electron-blocking layer

was 100nm and the p-GaN was 150nm.

The μPD fabrication included annealed 5nm/250nm Ni/ITO transparent contact, 200nm SiO_2 electrical isolation, and 10nm/1μm Ni/Au contacts.

The device demonstrated wavelength selectivity with –3V reverse bias between 374nm and 408nm — a pass-band full-width at half-maximum (FWHM) of 34nm. Peak response was 70.7mA/W at 392nm wavelength. The dark current was 37.4pA. The –3V reverse bias gave the optimal performance in terms of dark current and –3dB cut-off modulation bandwidth for 405nm radiation from a laser diode (71.5MHz).

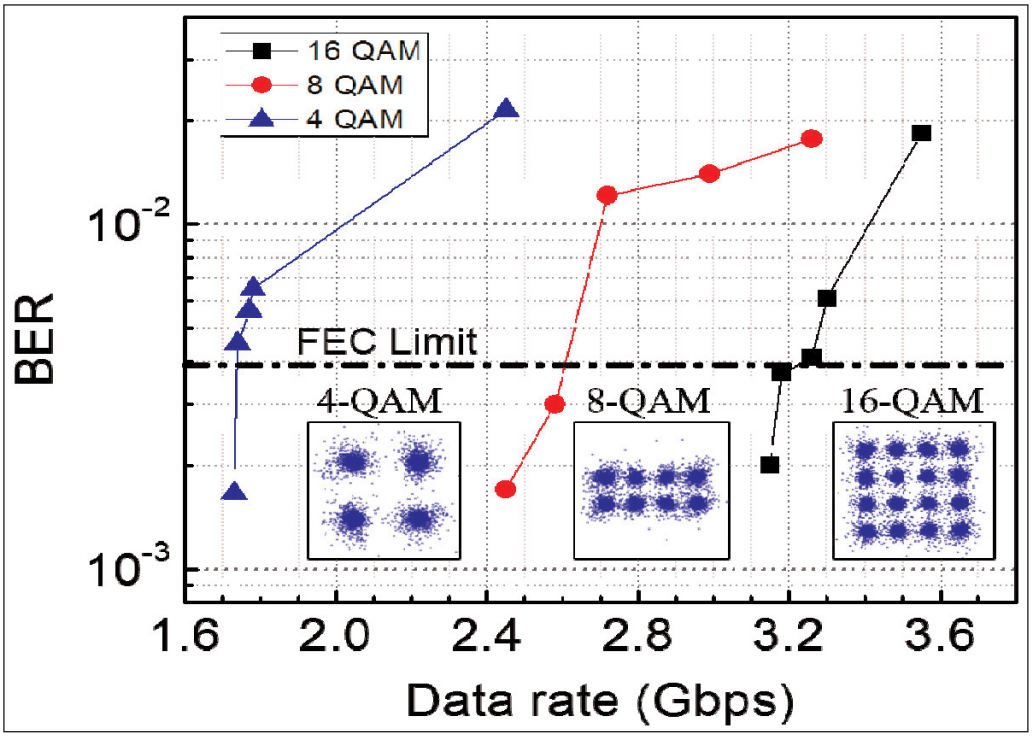

Figure 11. BER versus data rate of VLC link with different OFDM QAM order. Inset: corresponding constellation diagrams at 4-QAM, 8-QAM and 16-QAM.

An OFDM setup consisting of a 405nm laser diode and the μPD managed 16-QAM with a bit-error rate (BER) of 3.7×10^{-7} with 853MHz frequency response. This corresponds to a 3.2Gbps data-rate transmission (Figure 11). With a 7% overhead for forward-error correction, this is reduced slightly to 2.96Gbps for error-free transmission.

The researchers comment: "Our work features the record high data rate of VLC link using InGaN μPDs as receiver, which is the first demonstration of such system. In addition, compared with the prior reported results, our device was operated at lower bias voltage, and the carrier lifetime was shorter for high-speed modulation." ■

Author:
Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

Stacking III-nitride lasers with tunnel junction connections

Researchers seek high peak power for long-range light detection and ranging automotive and industrial applications.

Hamamatsu Photonics K.K. in Japan says that it has demonstrated room-temperature operation of nitride-based stacked laser diodes (LDs) with tunnel junctions for the first time [Satoru Okawara et al, Appl. Phys. Express, vol11, p012701, 2018].

The researchers hope that multiple-stack nitride-based laser diodes will lead to high-peak-power applications such as long-range light detection and ranging (LiDAR) for automotive vehicles and industry. In particular, the team points to the much higher maximum permissible exposure (MPE) for the human eye of pulsed near-ultraviolet light from III–nitride emitters, compared with the near-infrared produced by other III-V compound semiconductor systems. The stacking of laser diodes should reduce peak operating current — high-peak-current devices are difficult to pulse due to high reverse voltages from inductance effects.

The material structure was grown by metal-organic vapor phase epitaxy on free-standing GaN (Figure 1). Optically the two laser diodes were designed to 'fully confine' the ~395nm-wavelength light fields in the two guided region without crosstalk. The laser sections consisted of 1000nm n-aluminium gallium nitride $Al_{0.07}Ga_{0.93}N$ cladding, a 200nm n-GaN waveguide, a 2-period indium gallium nitride ($In_{0.06}Ga_{0.94}N$)/GaN multiple quantum well, a 200nm undoped GaN waveguide, and 400nm of p- $Al_{0.07}Ga_{0.93}N$ cladding.

The tunnel junction connecting the devices was 5nm p^{++}-InGaN and 30nm n^{++}-GaN. The researchers comment: "The thicknesses, indium composition, and doping concentrations of the tunnel junction were optimized to lower the voltage drop at the tunnel junction and to suppress the generation of hexagonal thermal pits originating from the tunnel junction layer, because the hexagonal pits generally act as current leakage paths, deteriorating the laser diode performance."

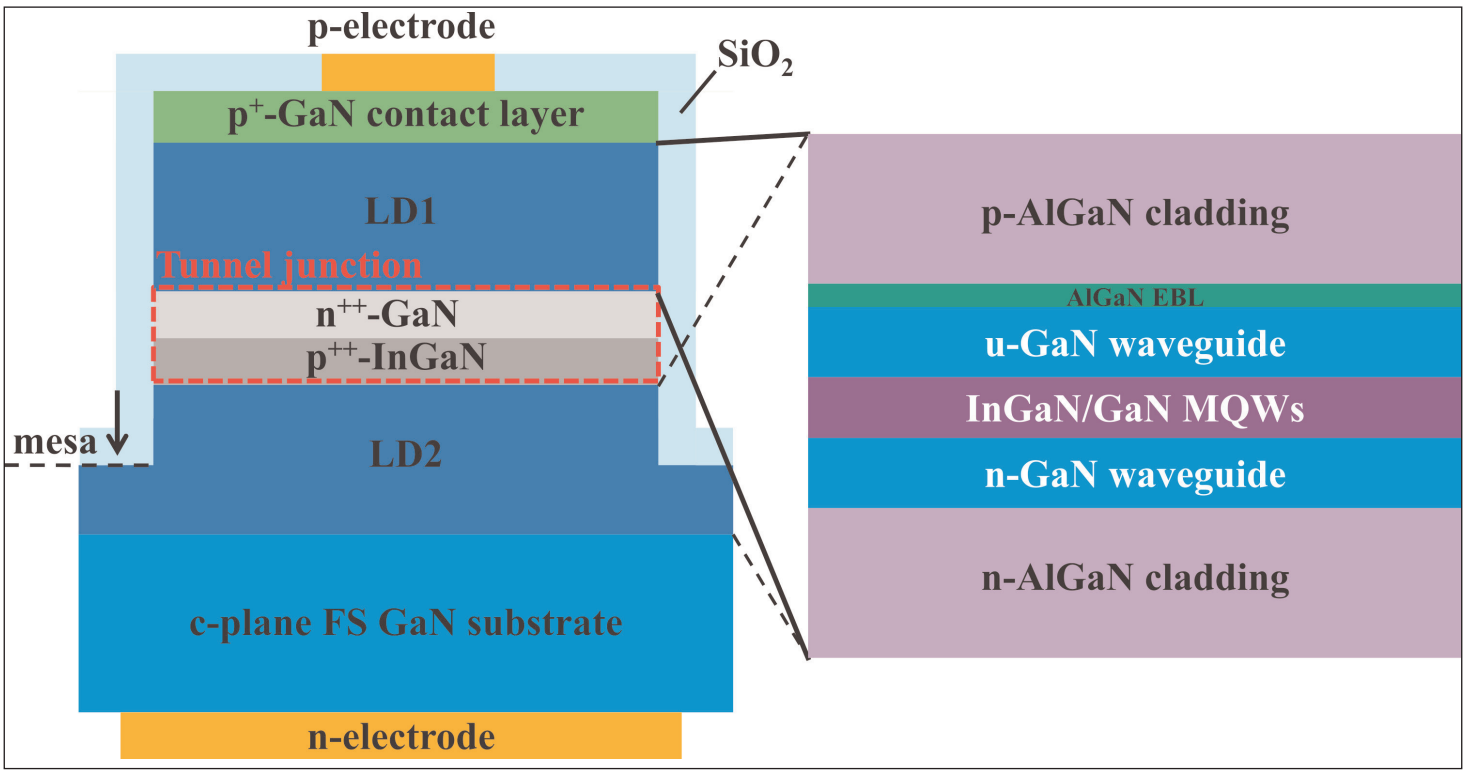

Figure 1. Schematic device structure of two-stack laser diode with tunnel junction.

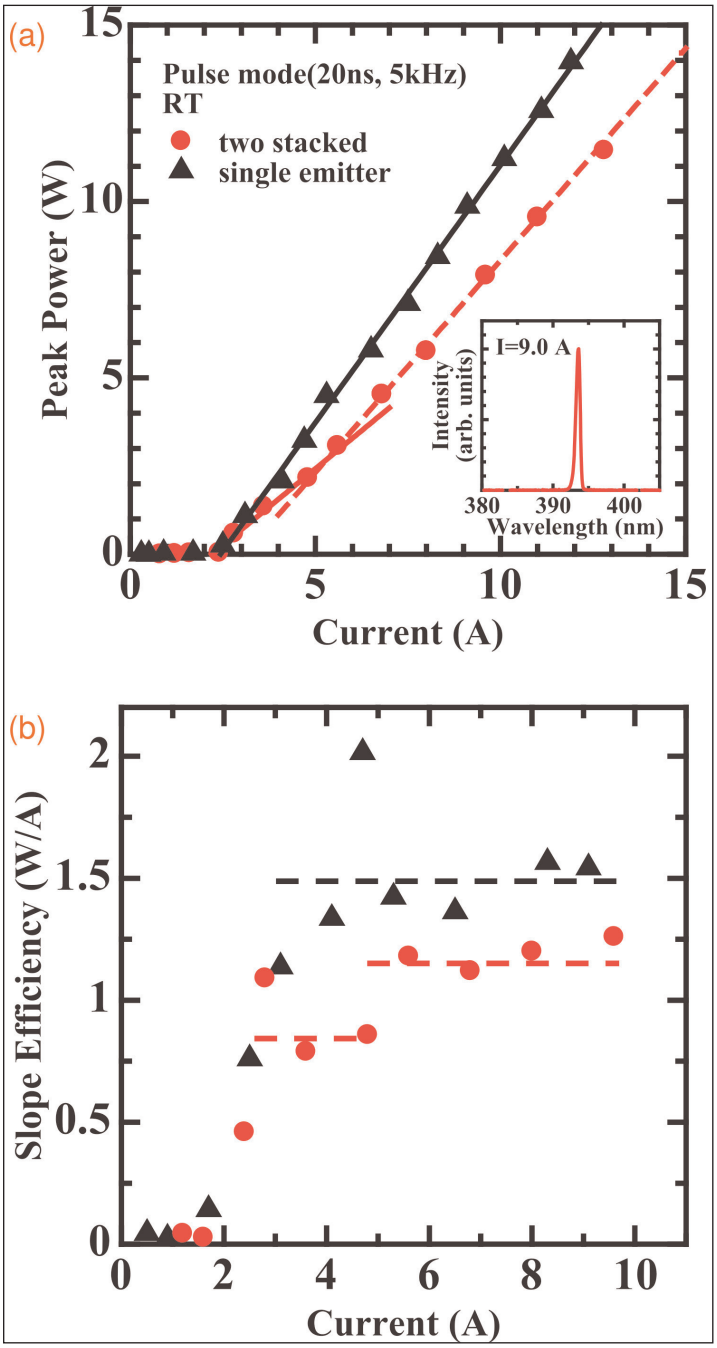

Figure 2. (a) Light output power and (b) slope efficiency versus current of two-stack (red circles) and single-emitter (black triangles) laser diodes under pulsed operation. Inset: optical spectrum of two-stack laser diode with emission wavelength of 394nm.

Twin laser devices were fabricated by etching down to the n-cladding of the lower laser diode; activation of the p-type layers; deposition of nickel/gold p-electrodes, silicon dioxide insulation and titanium/gold n-electrodes; and cleaving and passivating mirror facets. The p-activation aimed at removal of hydrogen — in the lower layers this entailed lateral diffusion. The mirror passivation was aluminium oxide. The gain-guided broad-area cavity was 70μmx1000μm. The devices were assembled p-side up into TO-9 packages.

Current-voltage studies of the double laser diode gave a series resistance of 45Ω at 50mA injection, compared with 3.5Ω for a single emitter. The corresponding turn-on voltages were 6V and 3V. The team mainly blames the high resistance on insufficient removal of hydrogen from the buried p-type layers.

In 5kHz 20ns-pulsed-mode operation (Figure 2), the stacked laser diodes output 394nm wavelength at 9A injection. The radiation from the two laser diode components could not be distinguished. The comparison single-emitter had a linear 1.5W/A laser slope up 10W output power.

For the double laser diode, there were two laser thresholds at 2.4A and 5.2A. The slope after the first threshold was 0.8W/A and, after the second, 1.1W/A. The team reports: "The slope efficiencies of the stacked laser diode were lower than that of the single-emitter laser diode because of the non-optimized mirror facet coating of the stacked laser diode." They also associate the first threshold with the upper laser diode (0.8W/A slope efficiency) and the second with the lower device (0.3W/A).

Further problems could arise from degradation of the InGaN layers in the bottom laser diode during subsequent high-temperature growth steps of the upper laser diode. "In addition, the p-dopant diffusing from the p^{++}-InGaN layer of the tunnel junction into the cladding layer of LD2 might increase the optical absorption loss for lasing," the researchers add. ■

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Author: Mike Cooke

Continuous-wave operation of semi-polar blue laser diodes

Operating voltage reduced by using thin p-type layer in combination with indium tin oxide (ITO) transparent conductor electrode as top cladding.

University of California Santa Barbara (UCSB) in the USA has improved the continuous wave (CW) performance of semi-polar blue laser diodes (LDs) on (20$\bar{2}\bar{1}$) gallium nitride (GaN) by using a thin p-type layer in combination with an indium tin oxide (ITO) transparent conductor electrode as top cladding [Shlomo Mehari et al, Optics Express, vol26, p1564, 2018]. This enabled laser output powers up to 1.1W per facet, and a wall-plug efficiency of 15%.

Although III-nitride laser diodes are already applied in projection displays and optical data storage systems, wider use is hampered by high operating voltage, poor differential efficiency, and resulting low wall-plug efficiency. To avoid self-heating reduction in efficiency, pulsed operation is used. The researchers hope that development of CW operation could open up high-intensity lighting applications such as automobile headlamps and industrial illumination.

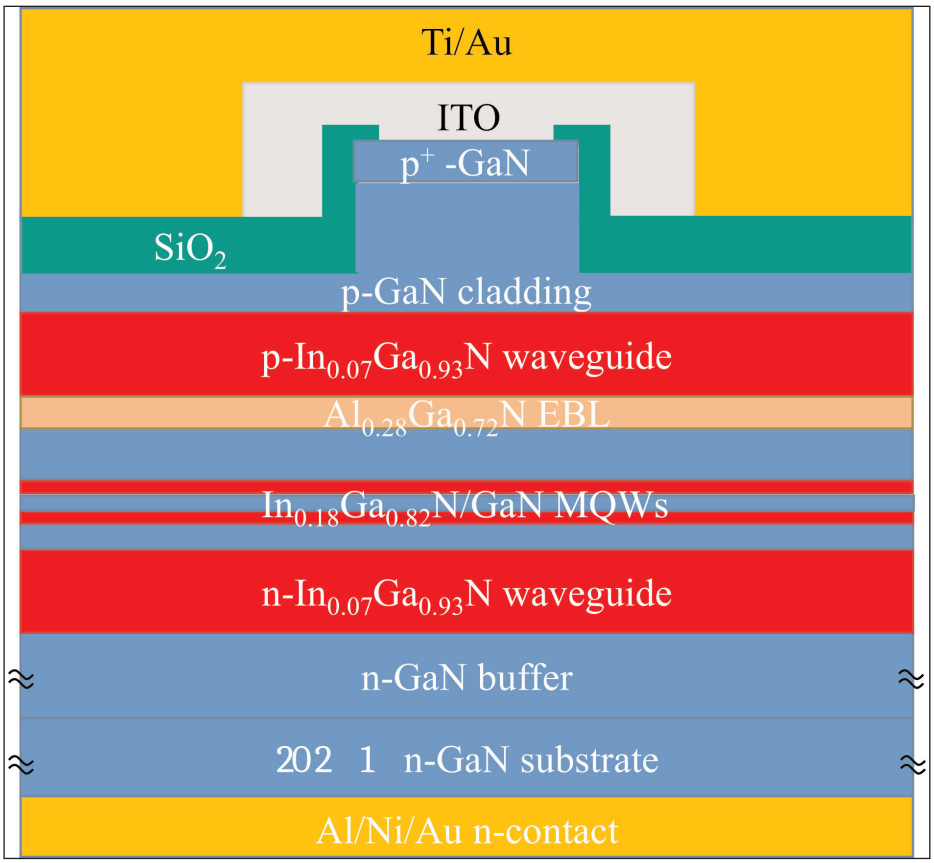

Figure 1. Schematic cross section of fabricated laser diodes with ITO p-contact layer.

Improved differential efficiency can be attained by semi-polar laser diodes, compared with the more usual polar c-plane devices, from higher indium incorporation and better electron-hole wavefunction overlap, but operating voltages remain high. The high voltage implies high power losses, which give rise to high junction temperature and further reduction in efficiency.

The UCSB team thinned the p-type GaN and used a low-refractive-index transparent conductive oxide (TCO) as cladding in the hopes of reducing the operating voltage.

The epitaxial structure for the laser diode (Figure 1) was grown on (20$\bar{2}\bar{1}$) free-standing GaN supplied by Mitsubishi Chemical. The active light-emitting region was a pair of 3.5nm quantum wells with 7nm barriers, grown by 840°C metal-organic chemical vapor deposition (MOCVD). After a 15nm top barrier, the p-type layers were grown at 1000°C.

Ridge-waveguide lasers were fabricated with 230nm sputtered silicon dioxide (SnO_2) and 150nm electron-beam evaporated indium tin oxide (ITO) and titanium/gold p-contact structure. The facets were formed by a combination of wet etching and chemically assisted ion beam etching. There was no coating on the facets. Electron-beam evaporation was also used to deposit the back n-contact. The samples were soldered to a copper block for testing.

Reducing the p-GaN thickness from 650nm to 250nm reduced the operating voltage from 7.3V to 5.35V, respectively, for 10kA/cm^2 current through the laser diode. "This low operating voltage is much lower than previously reported for blue laser diodes on semi-polar GaN substrates, and is comparable to highly optimized c-plane laser diodes," the team comments.

The voltage efficiency for photons of 430nm wavelength was 54% for 250nm p-GaN, compared with 40% for the 650nm layer. The wall-plug efficiency was 14% for 250nm p-GaN and 10.9% for 650nm.

The researchers point out that not all the improvement comes from the reduced series resistance of the thinner

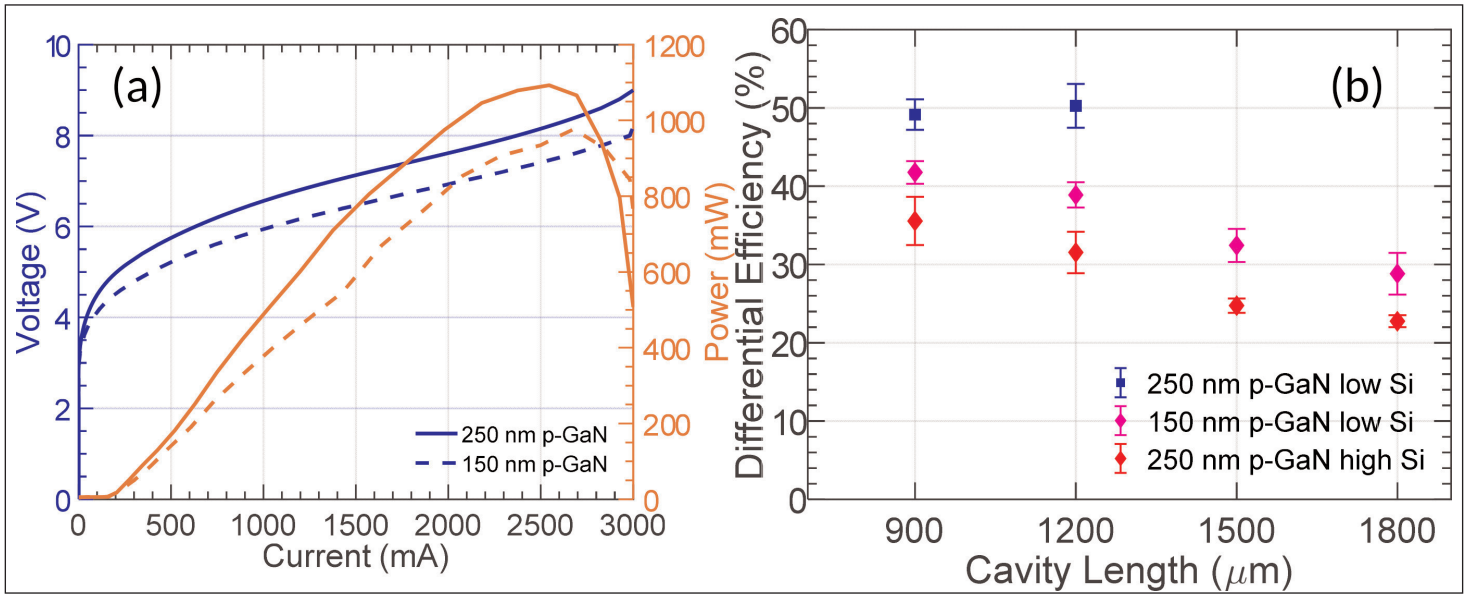

Figure 2. (a) CW light-current-voltage characteristics of 8μmx1200μm laser diodes with p-GaN thicknesses of 250nm and 150nm and lower Si doping. (b) Comparison of differential efficiencies for laser diodes with 250nm and 150nm p-GaN thicknesses and low and high Si doping levels.

250nm p-GaN layer. They suggest that at higher biases Schottky barriers may become thinner, allowing for tunneling effects to contribute to increased current flow.

The light output power performance of the devices was very similar under pulsed operation. The threshold current density was 2.2kA/cm^2. The thinner p-GaN allowed higher power under CW operation as a result of reduced heat dissipation. The peak CW light output was 0.55W for 650nm p-GaN and 0.76W for 250nm.

Infrared thermography showed a reduced average temperature in the ridge at 58°C for 250nm p-GaN for 1A current (14kA/cm^2 density), compared with 85°C for 650nm. The researchers comment: "This temperature is much lower than the previously reported peak temperature of 70°C for c-plane blue laser diodes mounted on a submount and tested at drive current of 0.1A (6.2kA/cm^2)."

The differential efficiency of the laser diodes with 650nm p-GaN was slightly higher than that of the 250nm laser diodes. The team believes that the difference suggests "some modal overlap with the ITO, which has a high material optical loss". The researchers believe that improved performance could be obtained by using a lower-absorption transparent conductive material such as zinc oxide.

Reducing the silicon doping in the n-type layers (Figure 2) allowed an increase in wall-plug efficiency to 15% at 0.96A (10kA/cm^2) and peak output power of 2.2W (1.1W from each facet, current ~2.5A). The lasing wavelength in this case was 445nm. ■

https://doi.org/10.1364/OE.26.001564

Author: Mike Cooke

Tri-anode/slant-gate GaN Schottky barrier diode on silicon

Structure reduces leakage current and increases breakdown voltage for high-performance, competitive-cost power converters.

Jun Ma and Elison Matioli of École polytechnique fédérale de Lausanne (EPFL) in Switzerland have used a hybrid tri-anode/slanted tri-gate structure to reduce leakage current and increase breakdown voltages in gallium nitride (GaN) lateral Schottky barrier diodes (SBDs) produced on silicon substrates [Appl. Phys. Lett., vol112, p052101, 2018].

Ma and Matioli comment: "The hybrid tri-anode pins the voltage drop at the Schottky junction (V_{SCH}), despite a large applied reverse bias, fixing the reverse leakage current (I_R) of the SBD." They see the devices as having potential for power converters with high performance and competitive cost.

The researchers used templates with an aluminium gallium nitride ($Al_{0.25}Ga_{0.75}N$) barrier and 5μm GaN buffer on silicon substrate. The slanted tri-gate SBD structures were etched to a depth of 180nm with inductively coupled plasma (Figure 1). The width in the

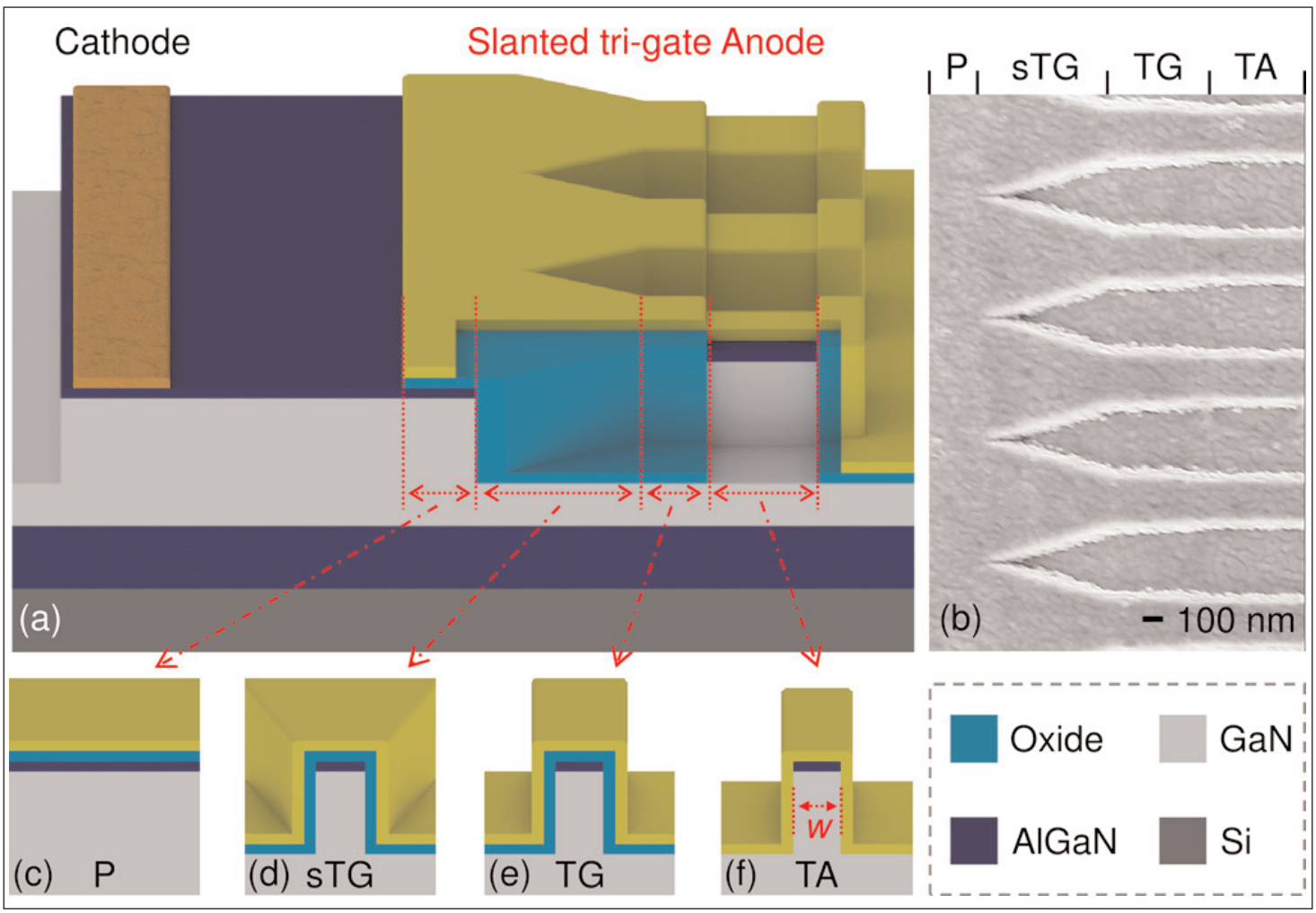

Figure 1. (a) Schematic of slanted tri-gate SBD and (b) top-view scanning electron microscopy (SEM) image of anode region. Cross-sectional schematics of (c) planar (P), (d) slanted tri-gate (sTG), (e) tri-gate (TG), and (f) tri-anode (TA) regions comprising anode.

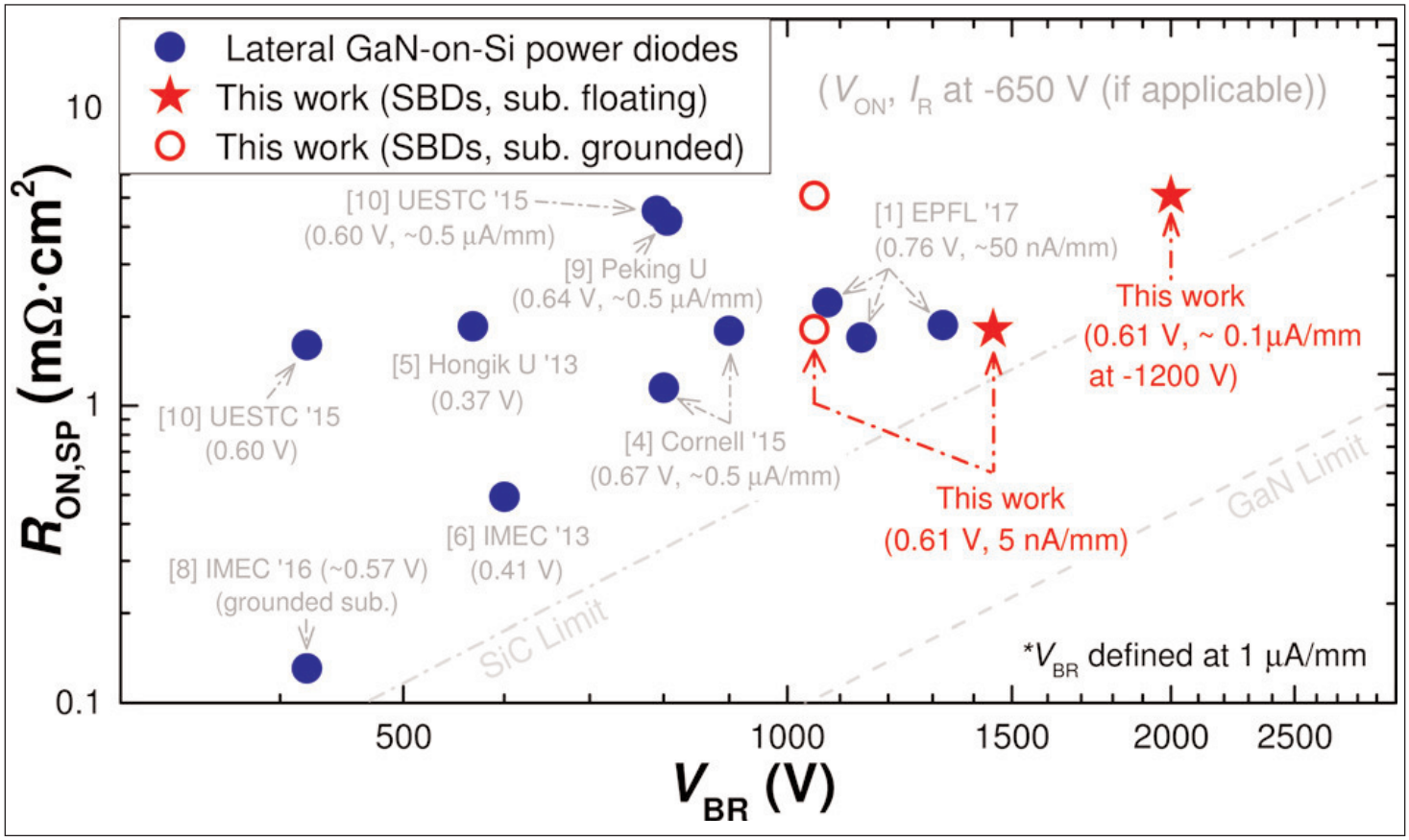

Figure 2. $R_{ON,SP}$ versus V_{BR} benchmark of slanted tri-gate SBDs against state-of-the-art lateral GaN-on-Si SBDs.

anode region was 200nm. The slanted tri-gate region increased from 200nm up to 600nm towards the cathode.

The 60μm-wide devices were isolated with mesa etching. The ohmic cathode consisted of alloyed titanium/aluminium/titanium/nickel/gold. After cathode formation, 10nm of silicon dioxide and 10nm of aluminium oxide were deposited. The oxides were removed and replaced with nickel/gold to form the 4μm-long Schottky tri-anode. The nickel/gold also formed a 1.3μm-long planar single gate, 0.7μm slanted tri-gate, and 0.5μm tri-gate leading into the anode.

The researchers modeled the devices as a tri-anode SBD connected in series with a tri-gate, a slanted tri-gate, and a planar-gate transistor. The slanted and planar gate sections also operate as field plates, designed to increase breakdown voltage.

Devices with anode-cathode distances of 15μm and 25μm demonstrated, respectively, 14Ω-mm and 22Ω-mm on-resistance at room temperature. These respective values increased to 28Ω-mm and 37Ω-mm at 150°C. The 1mA/mm on-voltage was as low as 0.61V. The ideality was 1.40 at room temperature and 1.27 at 150°C.

The performance puts the shorter device in the frame for 600V/650V applications, while the longer devices could handle 1200V ratings with ~100% safety margin

Under reverse bias, the devices pinched-off around −1.7V. Increasing the magnitude of the reverse bias to -650V did not change the ~5.5nA/mm leakage (I_R) significantly. At −830V, the leakage was still only 10nA/mm. Ma and Matioli add: "Extremely low I_R of 51±5.9nA/mm was observed at −1000V, which is significantly smaller than in any other reports of GaN-on-Si SBDs."

The leakage was increased by around 50nA/mm at 150°C. For −200V, the reverse current of 57±13nA/mm is claimed to be the smallest value among reported lateral GaN SBDs at such a high temperature.

The 1μA/mm breakdown points came at −1450V and −2000V, respectively, for the 15μm and 25μm anode–cathode devices with floating substrate bias. The corresponding hard breakdown voltages (V_{BR}) were −1500V and −2500V. The researchers estimate the critical field at 1MV/cm. Grounding the substrate gave a unified 1μA/mm breakdown of −1060V with hard failure at −1200V.

The performance puts the shorter device in the frame for 600V/650V applications, while the longer devices could handle 1200V ratings with ~100% safety margin.

The researchers compared their breakdown voltage and specific on-resistance ($R_{ON,SP}$) results with other reports (Figure 2). The team also gives a high power figure of merit of 1.16GW/cm² ($V_{BR2}/R_{ON,SP}$). ■

https://doi.org/10.1063/1.5012866

Author: Mike Cooke

Vanadium dioxide enables III-nitride phase-transition field-effect transistor

Combination gives very low leakage and sub-thermionic steep-switching.

Cornell University in the USA has demonstrated a gallium nitride (GaN) phase-transition field-effect transistor (FET) based on loading a metal-oxide-semiconductor high-electron-mobility transistor (MOS-HEMT) with a vanadium dioxide (VO_2) resistor [Amit Verma et al, IEEE Transactions on Electron Devices, vol65, p945, 2018]. The combination enabled very low leakage along with 'sub-thermionic' subthreshold steep-switching behavior.

The researchers comment: "This first demonstration of ultralow-leakage steep switching in GaN phase-FETs using integration-friendly ALD VO_2 opens the door to introducing new functionalities in nitride low-power digital devices, microwave circuits, photonic devices, and power electronics in the GaN-on-silicon platform."

Heating the VO_2 resistor above ~67°C gave an insulator to metal transition. An electrically driven transition to the metallic phase occurred above a critical field of ~27kV/cm at 60°C. The current density threshold was ~20μA/μm.

The VO_2 was grown by atomic layer deposition (ALD) using tetrakis-ethylmethylamino-vanadium (TEMAV) and ozone precursors on sapphire. The layer was 50nm thick with amorphous structure. Annealing crystallized the VO_2. The contacts on the 100μm-wide VO_2 resistors were titanium/gold.

The team comments: "Though this transition can be achieved at room temperature, an elevated temperature of 60°C was used to keep the transition voltage lower."

The resistor was connected to an aluminium gallium nitride barrier (AlGaN) MOS-HEMT on silicon (Figure 1). The GaN buffer layer was 1.3μm. The ohmic source/drain contacts were alloyed titanium/aluminium/nickel/gold. The gate stack consisted of ALD silicon nitride (SiN_x) and aluminium oxide (Al_2O_3) with nickel/gold electrode.

Without the VO_2 load resistor, the pinch-off voltage was −5V, while the on/off current ratio was 12 orders of magnitude. At 60°C, the subthreshold swing/slope (SS) was ~90mV/decade, which compares with the thermionic 'Boltzmann' limit of 66mV/decade. Good saturation gave current densities of ~0.4mA/μm.

The phase FET consisted of a 2μmx100μm VO_2 source load on a 200μm-wide GaN MOS-HEMT with 3μm gate length, and 2μm gate–source and 4.5μm gate–drain separations. The performance of the combined device

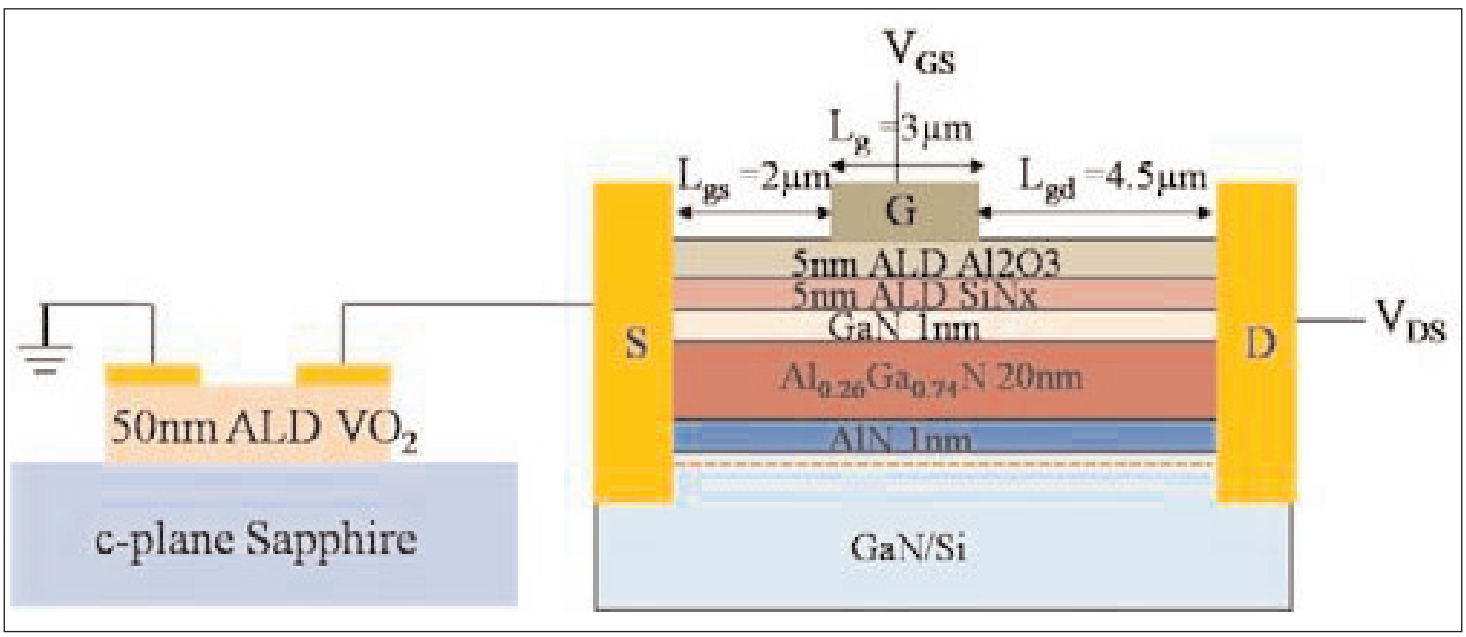

Figure 1. Schematic of phase-FET. AlGaN/GaN MOS-HEMT on Si (right) loaded at source with ALD VO_2 resistor.

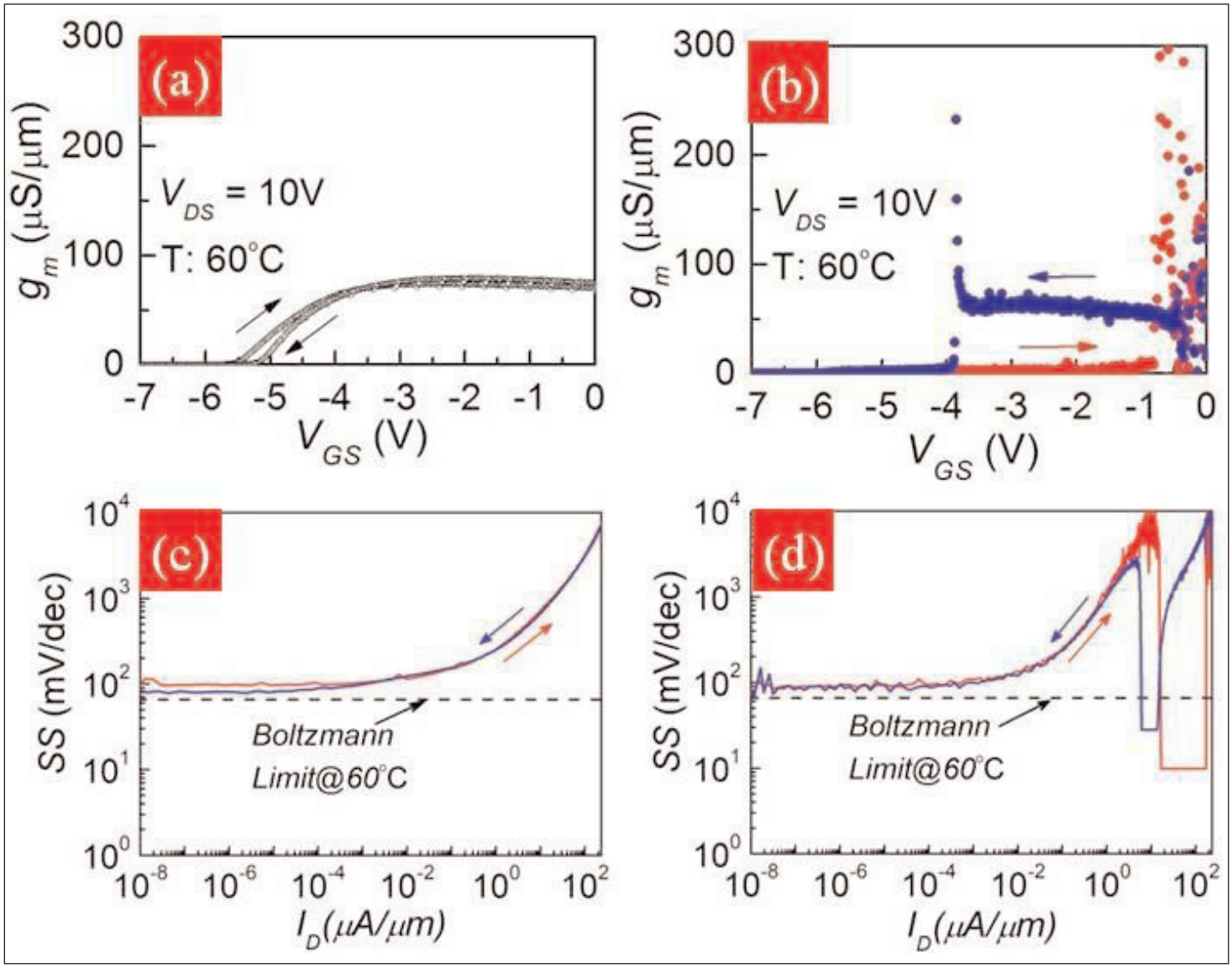

Figure 2. Measured transconductance of (a) GaN MOS-HEMT and (b) GaN phase-FET as function of gate bias. Measured SS as function of drain current for (c) GaN MOS-HEMT and (d) GaN phase-FET device at 60°C.

depended on the direction of sweep (hysteresis).

In the insulating state, the VO_2 load reduces the effective gate–source bias, suppressing the drain current. There is also an impact when the VO_2 resistor goes metallic: with the drain bias at 10V and the gate at +2V, the drain current was 337μA/μm, while in the bare MOS-HEMT the current was 427μA/μm under the same conditions. Due to the extremely low off-current, the VO_2 resistor has "no effect" in the off-state.

The transition from insulating to metallic phase for the VO_2 resistor occurred at a drain bias of about 4V in up-sweeps. The change back to insulating VO_2 was more gradual in the down sweep.

The SS behavior showed the MOS-HEMT being above the thermionic limit at all times (Figure 2).

This first demonstration of ultralow-leakage steep switching in GaN phase-FETs using integration-friendly ALD VO_2 opens the door to introducing new functionalities

However, the phase FET had values reaching down to ~9mV/decade in the up-sweep and ~29.2mV/decade in the down-sweep. At the same drain currents as these minima, the MOS-HEMT SS was ~720mV/decade.

The researchers comment: "This experimental result is an initial proof of concept to access sub-Boltzmann limit modulation using ALD VO_2. To move the steep transition gate voltages to the subthreshold regime for low-power digital switching, and potentially for memory–logic hybrids, it will be necessary to match the device geometries and the VO_2 impedance. This will also enable shaping of the hysteresis."

The team sees the next steps of the research as being on-wafer integration of the two components of the phase-FET, reducing hysteresis, reducing the VO_2 phase transition voltage at room temperature, and obtaining steep switching over a larger drain current range. ■

https://doi.org/10.1109/TED.2018.2795105

Author: Mike Cooke

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University of Nottingham, UK
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https://ukmbe.wordpress.com

15–19 April 2018
SPIE Defense + Commercial Sensing
Gaylord Palms Resort & Convention Center, Orlando, Florida, USA
E-mail: customerservice@spie.org
http://spie.org/conferences-and-exhibitions/defense--commercial-sensing

16–18 April 2018
14th International Conference on Concentrator Photovoltaics (CPV-14)
La Central Puertollano Ferial, Puertollano, Spain
E-mail: info@cpv-14.org
www.cpv-14.org

22–25 April 2018
UV LED Technologies & Applications
MELIÃ Hotel Berlin, Germany
E-mail: conference@advanced-uv.de
www.iuva.org/BerlinConference

22–26 April 2018
SPIE Photonics Europe 2018
Strasbourg Convention & Exhibition Centre, France
E-mail: info@spieeurope.org
http://spie.org/SPIE_Photonics_Europe_Conference

23–24 April 2018
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The Oxford Belfry, Milton Common, near Thame, UK
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www.armms.org/conferences

25 April 2018
Microwave and Millimeter-wave GaN – Wafer to IC Workshop
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www.csmantech.org

13–17 May 2018
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E-mail: ipec2018@jtbcom.co.jp
www.ipec2018.org

23–24 May 2018
Imec Technology Forum (ITF Belgium 2018)
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www.itf2018.com/en

5–7 June 2018
PCIM Europe (Power conversion and Intelligent Motion) 2018
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www.mesago.de/en/PCIM/main.htm

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www.vlsisymposium.org

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www.ieee-pvsc.org

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Shanghai, China
www.mesago.de/en/PCC/home.htm

9–11 July 2018
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www.intersolar.us

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