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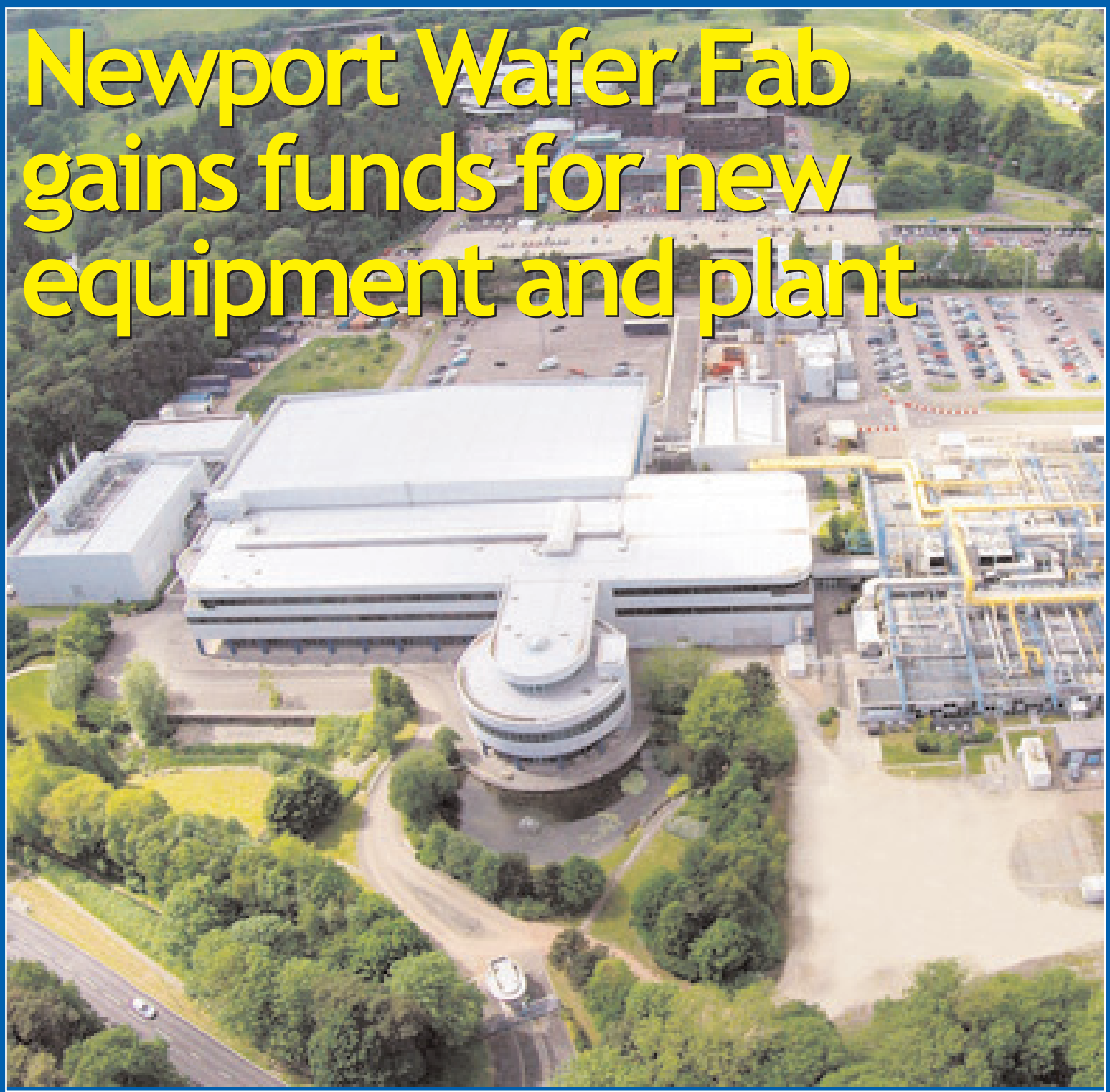

Newport Wafer Fab gains funds for new equipment and plant

Skyworks, MACOM, IQE, Cree cut guidance due to Huawei ban

EVG's €30m HQ expansion • Aixtron partners in UltimateGaN

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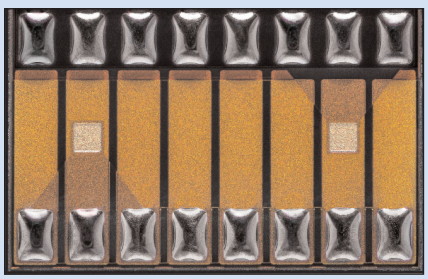
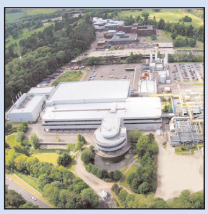
p15 United Silicon Carbide Inc has expanded its UF3C FAST series by adding the 1200V SiC FET device in a TO-247-4L 4-leaded Kelvin Sense discrete package option.

p39 EVG has begun construction on its Cleanroom V building as part of a €30m expansion.



p49 TriLumina has launched the first surface-mount flip-chip back-emitting VCSEL array without the need for a submount or bond wires.



Cover: Newport Wafer Fab, the UK's 200mm compound semiconductor wafer foundry, has a multi-million pound refinancing deal, involving a restructure of existing Welsh Government loans and a new asset finance facility from HSBC UK, funding the purchase of new equipment and plant. **p30**

editorial

Keep calm and carry on

Following NeoPhotonics, Lumentum and Qorvo in late May (reported in our April/May issue), June saw more firms cut their financial guidance, namely Skyworks, MACOM, Cree and IQE (see this issue, pages 10, 46 and 32). These are all at least partly responding to the US Department of Commerce's Bureau of Industry and Security on 15 May adding smartphone and telecom network infrastructure maker Huawei to its 'Entity List' prohibiting the sale to it of products covered by the Export Administration Regulations without obtaining an appropriate export license.

In the case of epiwafer foundry and substrate maker IQE, in late May it had said that, while expecting some delay to orders and the potential for adjustment of supplier-managed inventory levels (predominantly in its Wireless business unit) and estimating its maximum risk exposure at less than 5% of total full-year 2019 revenue, it was maintaining its guidance, since its "long-term strategy of supplying as many of the supply chains into all major OEMs as possible protects IQE's overall supply to a very significant degree" and the ban would have a "limited impact on our mid- to long-term revenue trajectory".

However, on 21 June IQE did indeed cut its 2019 revenue guidance (from £175m to £140–160m, including Wireless segment revenue down 20–25% rather than the prior guidance of just 15%) — see page 32. The firm cites a "larger impact than the previously guided risk related specifically to Huawei, due to the far-reaching impacts on other companies and supply chains that are now becoming evident… These are unprecedented times for the global semiconductor industry as geo-political conditions affect interconnected global supply chains," notes CEO Drew Nelson.

For most of the affected companies (and even those non-US firms not directly affected but still supplying to Huawei, like Germany's Infineon), stock prices have predictably been impacted accordingly. However, this was despite the fact that on 20 May the US Commerce Department created a temporary general license (until 19 August) covering export of parts for existing products, to provide time for Huawei suppliers to establish how to deal with the export restrictions.

In the meantime, the US-based Semiconductor Industry Association (SIA) lobbied the US Government, stating that it "remains concerned restrictions on our ability to sell commercial products in major markets will erode the competitiveness of the US semiconductor industry".

Now, after a meeting on 29 June with China's President Xi Jinping at the G20 Osaka Summit in Japan, US President Donald Trump (who acknowledged that "companies were not exactly happy that they couldn't sell") said that "US companies can sell their equipment to Huawei", provided that the transactions don't present a "great, national emergency problem". According to White House economic advisor Larry Kudlow, the US Commerce Department may grant some temporary licenses for US firms to resume business with Huawei, where there is no threat to national security.

However, even if semiconductor suppliers can resume some US exports to Huawei, supply chains have been disrupted and even replaced (and some Huawei product launches cancelled altogether), so a return to prior trading patterns is unlikely. Nevertheless, at least the short-term impacts (e.g. on stock prices) may be mitigated (if only until the next curve ball!).

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***Semiconductor Today* covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices** (e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers and LEDs in wireless and optical communications, etc).

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- feature articles (technology, markets, regional profiles);
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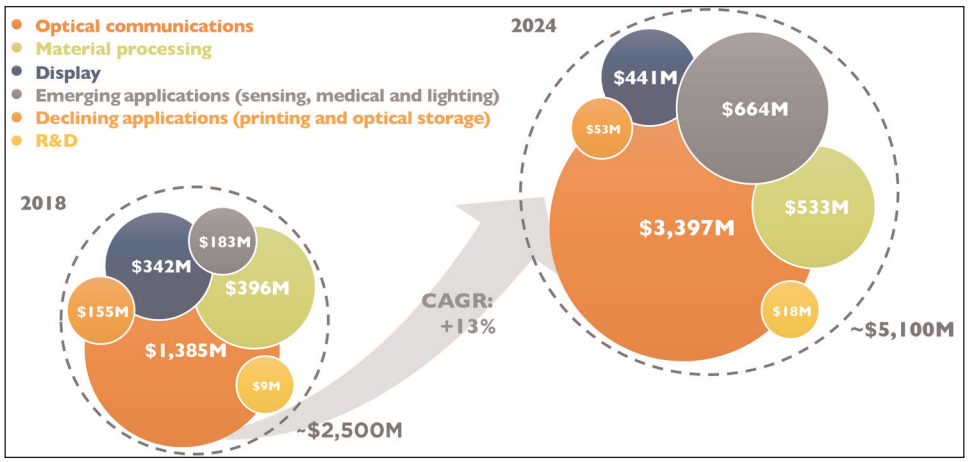
Edge-emitting laser market still driven by traditional applications, but killer applications emerging

The edge-emitting laser (EEL) market is rising at a compound annual growth rate (CAGR) of 13% from $2.5bn in 2018 to more than $5bn in 2024, according to Yole Développement's report 'Edge Emitting Laser Market & Technology Trends'. "Growth is still driven by the optical communication market segment with optical systems for datacom and telecom," says technology & market analyst Martin Vallo PhD. "It is today the largest EELs segment, with 56% of the total revenue in 2018." However, some killer applications are emerging in parallel.

Since their development in the 1960s, lasers have been used increasingly in a large number of applications, propelling the market to a trillion dollar business since the 1990s. Laser technologies are now ubiquitous in many traditional as well as emerging applications, spanning material processing, optical communications, automotive front lighting, medical surgery and 3D sensing. The laser landscape is highly fragmented, with a wide variety of laser types, including diode lasers, fiber lasers, diode-pumped solid-state lasers (DPSSLs), CO_2 lasers and excimer lasers. Traditional applications span industrial, scientific and consumer markets, but there are also many specific applications including military and biomedical markets with spectroscopic analysis.

"Edge-emitting lasers are showing different functionalities: they can be used as 'direct' lasers or coupled with optical fibers or crystals to make fibre lasers or DPSSLs," says Vallo. "As a consequence, the number of applications is impressive. Optical communication, material processing, medical, sensing, printing, display, optical storage and lighting," he adds.



Edge-emitting laser revenue forecast by market segment, 2018 versus 2024.

In addition to the optical communication market segment, the material processing and display applications are also substantial, comprising 16% and 14% of the market, respectively, in 2018. However, their market shares will decline in the future as 3D sensing in LiDAR and face/gesture recognition as well as medical and lighting applications emerge in the next five years. These might represent potential killer applications for EELs in the mid/long term, reckons Yole.

The edge-emitting laser industry clearly has a bright future, but it also represents a challenging market. "There is a large variety of applications and system and device specifications, as well as a strong competitive landscape at the technology level, between direct diodes, fiber lasers, CO_2 laser, DPSSLs and excimer lasers," comments business unit manager Pars Mukish.

The material processing and display applications are also substantial, comprising 16% and 14% of the market. Their market shares will decline as 3D sensing in LiDAR and face/gesture recognition as well as medical and lighting applications emerge in the next five years

Consequently, the edge-emitting laser industry is highly fragmented and diversified. Each application addresses a specific supply/value chain, and different positions have to be developed by industrial concerns to access different markets:

- Leading players in the material processing domain are vertically integrated, from edge-emitting laser device to laser system (for example, making laser dicers), so customers require turnkey solutions for their specific manufacturing process.
- For sensing or lighting applications, the trend is for companies to be much more specialized, as in pure EEL device manufacturers. This strategy is due to the numerous challenges at the device level concerning increasing performance, beam shaping and decreasing cost.
- Another good example is the datacom industry, which exhibits diversity of positioning along the supply chain.

www.i-micronews.com/products/edge-emitting-lasers-technology-industry-and-market-trends

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Qorvo launches power-efficient, small-cell front-end PAs & LNAs for sub-6GHz 5G wireless infrastructure

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has launched power-efficient, small-cell front-end solutions for the sub-6GHz wireless infrastructure market. The products are said to significantly boost efficiency, enabling base-station manufacturers to enhance existing 4G LTE infrastructure with greater bandwidth, coverage, throughput and capacity — particularly in high-density, high-traffic areas.

"Driven by the explosive growth of emerging 5G networks, the number of new base-station sectors deployed will double between 2018 and 2024," estimates market research firm Strategy Analytics. "5G relies on network architectures incorporating traditional macrocells and lower-power small cells in sub-6GHz and millimetre-wave frequency bands."

The new products include the Band 3 QPA9903 power amplifier (PA), the Band 8 QPA9908 power amplifier and the QPL9098 4–6GHz bypass ultra-low-noise amplifier. The PAs offer 34% power-added efficiency, enabling Power over Ethernet (PoE) small-cell architectures targeted for deployments in high-traffic areas, such as subways, train stations and stadiums or for high-quality of service (QoS) enterprise in-building applications.

The PAs are easy to linearize using digital pre-distortion (DPD) algorithms and their performance is optimized for wideband, multi-carrier signals versus a single 20MHz carrier. The highly rugged PAs can handle high levels of signal mismatch at output — up to 20:1 voltage standing wave radio (VSWR). Rugged packaging withstands the impact of a wide range of challenging environments.

"Our new small-cell products further expand Qorvo's portfolio of economical, system-level architecture solutions for wireless infrastructure," says Roger Hall, general manager of Qorvo's High Performance Solutions business. "By extending the bandwidth capacity of the existing network, customers can more cost-effectively transition to 5G and trust in Qorvo's ability to scale to high-volume manufacturing."

Qorvo says that it is paving the path to 5G by helping to define 5G standards as a delegate to the 3GPP organization and through collaboration with wireless infrastructure manufacturers, network operators, chipset providers and smartphone makers. Qorvo has helped to conduct dozens of 5G field trials, and its 28GHz products supported the Samsung 5G MIMO demonstration at the 2018 Winter Olympics.

Qorvo showcased its portfolio of RF solutions at the IEEE's International Microwave Symposium (IMS 2019) in Boston, MA, USA (4–6 June).

www.ims-ieee.org
www.qorvo.com

Qorvo launches two families of GaN PAs for mission-critical Ka-band satcom and X-band phased-array radar applications

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has launched two new gallium nitride power amplifier (PA) families for domestic and international Ka-band satcom and X-band phased-array radar applications. The solutions, which are claimed to deliver best-in-class power, linearity and efficiency in a smaller footprint, enable higher system performance while reducing costs.

The QPA2212 for Ka-band applications has what is said to be the industry's highest linearity for wideband multi-carrier systems, delivering 20W of RF power operating over the 27–31GHz frequency band. There are also 14W QPA2211D and 7W QPA2210D options. Delivering higher linear power in a single monolithic microwave integrated circuit (MMIC) PA enables cost reduction and performance enhancing opportunities, the firm states. The QPA2212D is available now in die form; packaged versions will be available in August.

Available now in both packaged and die versions, the QPA1022 for X-band phased arrays offers what is claimed to be best-in-class power-added efficiency of 45% at 4W RF power in the 8.5–11GHz range - an increase of 8% over previous products while providing 24dB large-signal gain. These capabilities translate into maximum power with minimum heat, higher reliability and lower cost of ownership, says Qorvo, adding that designers can create higher-density arrays and achieve greater range for the same power budget.

"These new amplifiers expand Qorvo's already-large portfolio of differentiated GaN products for defense applications," says Dean White, director of defense and aerospace market strategy. "Their advanced capabilities and packaging leverage our more than 30 years of expertise in designing and delivering RF solutions for this market, and also offer viable options for commercial 28GHz 5G network design."

www.qorvo.com

Qorvo GaN and GaAs amplifiers selected for Syrlinks' telemetry, tracking & control modules in LEO satellites

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) says that its amplifiers are being used in the telemetry, tracking and control modules developed by Syrlinks of Cesson-Sévigné, near Rennes, France, for low Earth orbit (LEO) satellites. The first six satellites of the constellation, designed by Airbus OneWeb Satellites, were recently launched to provide internet connectivity almost anywhere in the world. Qorvo says that the reliability and performance of its products reduce stress on the satellite power systems and ensure signal integrity in both transmit and receive modes.

Syrlinks specializes in radio communication and geolocation subsystems for space, defense and safety applications. Its NewSpace products meet the new requirements of the space industry. Syrlinks' telemetry, tracking and control modules enable remote sensing and monitoring of the Airbus OneWeb LEO satellites for internet connectivity service.

Close collaboration and flexibility across both companies' functional teams were key to the project. Syrlinks integrated the Qorvo RF front-end components into the space-qualified module and provided product definition and performance requirements for the Qorvo products. Qorvo provided product application, manufacturing and test support.

The MMIC power amplifier selected is fabricated on Qorvo's highly reliable and efficient QGaN15 0.15µm gallium nitride (GaN) process technology, which supports high-frequency applications through 40GHz. The low-noise amplifier (LNA) is fabricated on Qorvo's QPHT09 90nm gallium arsenide (GaAs) pseudomorphic high-electron-mobility transistor (pHEMT) process, which has what is claimed to be a best-in-class noise figure. Qorvo has nearly 100 commercial products (die and package options) built on these processes.

Qorvo's commercially packaged products are proving their operational readiness to meet the harsh environment of space. By combining powerful process technology with advances in packaging, Qorvo is enabling high-power devices that also achieve high reliability and are operationally rugged

"Syrlinks has been investing for three years in the NewSpace approach associated with the latest generation of components," says the firm's CEO Guy Richard. "These efforts required stronger links with manufacturers of high-performance and innovative components, such as Qorvo," he adds.

"Qorvo's commercially packaged products are proving their operational readiness to meet the harsh environment of space," says Roger Hall, general manager, Qorvo High Performance Solutions. "By combining powerful process technology with advances in packaging, Qorvo is enabling high-power devices that also achieve high reliability and are operationally rugged."

Qorvo exhibited at the IEEE's International Microwave Symposium (IMS 2019) in Boston, MA, USA (4–6 June).

www.ims-ieee.org
www.syrlinks.com
www.qorvo.com

Qorvo unveils 10W Ka-band GaN amplifier for radar and electronic warfare applications

Qorvo has unveiled a monolithic microwave integrated circuit (MMIC) power amplifier that delivers more than 10W of saturated power over the 32-38GHz band. The reliability and efficiency of the product — said to be the highest-performing MMIC on the market — enable performance objectives to be achieved in critical defense applications while reducing costs, says the firm.

Fabricated using Qorvo's gallium nitride on silicon carbide (GaN-on-SiC) technology, the 10W TGA2222 provides 16dB of large-signal gain, 25dB of small-signal gain and what is claimed to be industry-leading power-added efficiency greater than 22%. It delivers this extended RF power in a smaller die, which reduces the size (to 3.43mm x 2.65mm x 0.05mm), weight and number of components to create a simple solution for radar and electronic warfare (EW) applications.

"The increasing demand for higher data rates across all markets continues to drive the need for better-performing RF solutions," notes Roger Hall, general manager of Qorvo's High Performance Solutions business. "With the TGA2222 [available now to qualified customers], Qorvo is delivering a breakthrough MMIC with the industry's highest levels of power and bandwidth for Ka-band defense applications," he adds.

www.qorvo.com

Skyworks cuts June-quarter financial guidance due to US restrictions on exports to Huawei

Revenue guidance cut by $60m from $815–835m to $755–775m

In response to the US Department of Commerce's Bureau of Industry and Security (BIS) on 15 May adding smartphone and telecom network infrastructure maker Huawei Technologies Co Ltd and 68 of its affiliates to its 'Entity List' prohibiting the sale to Huawei of products covered by the Export Administration Regulations (EAR) without obtaining an appropriate export license, analog and mixed-signal semiconductor maker Skyworks Solutions Inc of Woburn, MA, USA has ceased all shipments to Huawei and its affiliates.

Skyworks' past shipments to Huawei and its affiliates include both mobile and wireless infrastructure solutions, contributing about 12% of the firm's total revenue during the first six months of fiscal 2019.

Hence, assuming that no further shipments to Huawei occur during Skyworks' fiscal third-quarter 2019 (ending 28 June), the firm has cut its financial guidance (provided on 2 May) for revenue from $815–835m to $755–775m and for non-GAAP diluted earnings per share (EPS) from $1.50 to $1.34.

Skyworks adds that it cannot currently predict if and when shipments to Huawei will resume.

www.skyworksinc.com

MACOM cuts June-quarter revenue guidance from $120–124m to $107–109m

In response to (1) reduced shipments to certain distribution channel partners and (2) the US Department of Commerce prohibiting exports to Huawei, for its fiscal third-quarter 2019 (to end-June) MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for RF, microwave, millimeter-wave and lightwave applications) has reduced its guidance for revenue from $120–124m to $107–109m.

Non-GAAP gross margin guidance has been reduced from 53–55% to 39–41%, which includes about $14m in inventory reserves (1300 basis points of gross margin impact) associated primarily with data-center products and products that would otherwise have been shipped to Huawei.

Guidance for adjusted earnings per share has been revised from a loss of $0.08–0.04 to a loss of $0.41–0.45 (not include restructuring- or impairment-related charges).

To save about $50m in annual expenses (once fully implemented), MACOM has implemented a restructuring plan that includes the following:

- A permanent reduction in MACOM's hourly, salaried and management workforce of about 250 (20% of the total), including personnel in R&D, Production, Sales & Marketing and General & Administrative functions. Substantially all affected staff have been notified and customary transition assistance will be provided.
- The closure of seven product development facilities, including locations in France, Japan, The Netherlands, Florida, Massachusetts, New Jersey and Rhode Island.

The firm also says it will no longer invest in the design and development of optical modules and subsystems for data-center applications. Going forward, MACOM will be a merchant supplier of integrated circuits and photonic devices and will support optical module manufacturers at the component level.

"These actions are necessary in order to strengthen our strategic plan," says president & CEO Stephen Daly.

The firm expects about $14m in restructuring charges including $7m for employee severance obligations, most of which are expected to be incurred during fiscal Q3/2019. Also, it is performing a recoverability assessment for its long-lived assets, most specifically intangible assets (which had a carrying value of $472m as of 29 March) that may be impacted. To date, MACOM has also identified about $15m of non-cash impairment charges associated with these restructuring actions.

MACOM appoints John F. Kober as chief financial officer

MACOM has appointed John F. Kober as senior VP & chief financial officer.

Kober has over 25 years of accounting and finance experience, and has been MACOM's VP & corporate controller since 2015. Prior to that, he was VP, corporate controller & treasurer at component and instrument maker CIRCOR International Inc. Kober is a certified public accountant, and holds a Bachelor of Science in Accounting and a Master of Business Administration in Finance.

www.macom.com

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pSemi offering free beta software for viewing S-parameters to assist 5G and RF measurements

Murata company pSemi Corp of San Diego, CA, USA (formerly Peregrine Semiconductor Corp) — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — says it is offering the industry sNpViewer as free beta software for in-depth graphical viewing of S-parameters. This comprehensive viewer includes Smith, polar, magnitude, phase and phase versus amplitude charting. Time-domain analysis is also available.

S-parameters (scattering parameters) describe the input-output relationships between ports in a linear RF system. Specifically, at high frequency it becomes essential to describe a given network in terms of phase and amplitude of a wave rather than voltage or current.

"As the inventors of RFSOI, we have been dealing with the challenges of S-parameters for years," says Colin Hunt, VP of sales. "In RF, it is easiest to use S-parameters for analysis because an RF signal is a complex waveform," he adds. "5G developments have massively increased the number of S-parameter files needed to be analyzed. We developed the sNpViewer to assist us with the analysis of the large number of measurements. We are now offering it as our gift to the industry."

As an example of 5G complexity, in order to select the best combination of phase and amplitude settings for a given RF channel in a multi-element array, an engineer must analyze thousands of distinct S-parameter data sets to ensure the best performance. To do this over multiple frequencies makes it even more laborious. Trying to visualize the results is complicated, says pSemi. Trying to isolate the best setting is even more demanding. The sNpViewer allows this search to be performed through thousands of S-parameter files to determine and record optimal performance.

pSemi says that this LUT feature can be especially useful for 5G beam-forming or for any other device where a phase and/or amplitude LUT is required.

www.psemi.com/snpviewer.

Arralis expanding into USA with new office in Florida

Arralis Technologies of Limerick, Ireland — which has a design center in Belfast and manufactures RF, microwave and millimeter-wave devices, modules and antennas up to and beyond 110GHz (W-band) for aerospace/satellite and security markets — is to expand into the USA with the official opening (on 1 August) of a new office at the John Mica Engineering and Aerospace Innovation Complex at Embry-Riddle Aeronautical University Research Park, Daytona Beach, FL.

"Arralis is a perfect fit for Florida's space triangle," comments university president Dr P. Barry Butler. "Their products are defining the future of global radar and wireless communications," he adds.

"We were warmly greeted by both Team Volusia and Embry-Riddle University," says Arralis' CEO Mike Gleaves. "Their help and advice, along with a high-tech manufacturing environment, large pool of highly skilled engineers and simplicity of business set-up, made our choice of location an easy decision. This expansion will allow us to bring our world-leading 94GHz products to a significant new marketplace," he reckons.

Arralis announces long-range 3D target detection with E-band automotive Corvus Radar

Arralis has launched its new E-band automotive radar system. The Corvus Radar is said to exceed what is available in the current automotive marketplace in detection range, elevation resolution and scan area, enabling multiple 3D target detection at up to 300m over a ±45° azimuth angle and ±7° elevation angle.

The system utilises Arralis' Corvus monolithic microwave integrated circuit (MMIC) portfolio and a patented analog beam-forming technique to enable detection of a 0dBm^2 target (e.g. a fast-approaching motorbike) at 300m distance. Monopulse is applied in both azimuth and elevation planes to enable resolving of targets angle within beams.

"Our extensive experience with all aspects of millimeter-wave system design, from MMICs to beam-forming, and from antenna design to system integration, has enabled us to meet a demanding specification," says Dr Peter Ludlow, principal engineer on the project. "To achieve a higher level of vehicle autonomy the detection of targets at greater distances and in unfavourable weather conditions is essential. We see the Corvus Radar as essential to enabling safe operation of autonomous vehicles in the most challenging environments."

Arralis is working with automotive OEMs and will work with customers wishing to evaluate the system.

www.arralis.com

GlobalFoundries' board gains industry veteran Dorchak as independent director to support pivot to more customer-centric and differentiated technology firm

GlobalFoundries (GF) of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with operations in Singapore, Germany and the USA) has appointed Glenda Dorchak as an independent director on its board (bringing the total number of independent directors to five).

"Glenda brings tremendous end-user market experience, and we look forward to her contributions as we pivot to a more customer-centric and differentiated technology partner to the semi industry," says chairman Ahmed Yahia Al Idrissi.

"To build the future we envision for GF, we need experienced industry leaders with the foresight and vision to guide our long-term growth strategy," says CEO Tom Caulfield. "Glenda is a strong addition to GF's board, with her proven record of executive and board leadership in semiconductor hardware and software businesses. Her extensive technical know-how in connected products and technologies will help us further position the company as a clear industry leader in differentiated foundry solutions," he believes.

Dorchak has more than 30 years of technology industry leadership experience from a broad set of management and executive roles, starting at IBM Corp and including Intel Corp, Intrinsyc Software and Spansion. She serves as an independent director for public technology companies ANSYS, Mellanox Technologies and Quantenna Communications and is an advisor to OMERS Private Equity.

www.globalfoundries.com

Pasternack receives 4-Star Supplier Excellence Award from Raytheon IDS

Pasternack Inc of Irvine, CA, USA (an Infinite Electronics brand that makes both passive and active RF, microwave and millimeter-wave products) has received the Supplier Excellence Award from Raytheon IDS for superior supplier performance.

Raytheon's Integrated Defense Systems business instituted the annual Supplier Excellence Awards program to recognize suppliers that have provided outstanding service and partnership in exceeding customer requirements. Candidates are judged on certain criteria, including overall quality and on-time delivery. Pasternack was one of 77 companies recognized by Raytheon IDS business for 4-Star honors.

"Our dedication to our customers is paramount to our mission statement, and receiving this award is a huge testament to our success in meeting our goals and our customers' expectations," says Infinite Electronics' president & CEO Penny Cotner.

www.pasternack.com

WIN releases 0.15μm GaN process for high-power mmWave PA applications and 5G infrastructure

NP15-00 technology provides 3W/mm saturated power density with high efficiency

WIN Semiconductors Corp of Taoyuan City, Taiwan — the largest pure-play compound semiconductor wafer foundry — has expanded its gallium nitride (GaN) portfolio with the commercial release of NP15-00, a 0.15μm-gate technology that supports emerging mmWave PA applications including radar, satellite communications and 5G massive MIMO infrastructure. NP15-00 supports full MMICs enabling customers to design compact, linear or saturated high-power amplifiers through 35GHz.

NP15-00 GaN employs a source-coupled field plate for improved breakdown voltage, and operates at a drain bias of 20V. This technology is fabricated on 100mm silicon carbide substrates with through-wafer vias for low-inductance grounding. In the 29GHz band, NP15-00 offers saturated output power of 3W/mm with 13dB linear gain and greater than 50% efficiency without harmonic tuning.

"The release of NP15 expands WIN's portfolio of mmWave compound semiconductor technologies for transmit power amplifiers used in 5G mmWave radio access networks (RANs), satellite communications and radar systems," says senior VP David Danzilio. "For mmWave active arrays, the higher transmit power and efficiency from NP15 affords designers greater flexibility to optimize antenna count, PA size and total array power," he adds. "Depending on where deployed, mmWave RAN infrastructure will leverage access points of various sizes, shapes and power levels, and a broad trade-space is crucial to optimize the performance and economics of mmWave active antenna systems."

NP15-00 sample kits are available and can be obtained by contacting WIN's regional sales managers.

WIN releases PIH1-10 GaAs platform

Monolithic PIN Tx/Rx switches with power and low-noise pHEMT technology enable 24–45GHz single-chip front ends for 5G handsets and mmWave access networks

WIN has announced the commercial release of its PIH1-10 high-integration millimetre-wave (mmWave) gallium arsenide (GaAs) platform.

Optimized for 5G front-ends, the PIH1-10 technology combines a 100GHz f_T enhancement-mode pseudomorphic high-electron-mobility transistor (pHEMT) with monolithic PIN and Schottky diodes to provide what is claimed to be best-in-class mmWave performance for all front-end functions. WIN reckons it is the first compound semiconductor wafer foundry to commercialize an integrated GaAs platform capable of producing single-chip front-ends for 5G handsets and mmWave radio access networks (RANs).

The core of PIH1-10 is an E-mode pHEMT that provides the gain, power density and efficiency for mmWave transmit power amplifiers and the noise performance needed in the receive low-noise amplifier (LNA). The versatile single-supply transistor can support Tx power levels of 30dBm and Rx noise figure of 2.5dB at mmWave frequencies. Furthermore, the integrated PIN diode provides mmWave Tx/Rx switch functionality with <1dB insertion loss, enabling monolithic integration of all front-end functions on a single chip. GaAs technology outperforms BiCMOS in every front-end function, and mmWave single-chip front ends realized in PIH1-10 can reduce array power consumption, simplify thermal management, and extend battery life in 5G user equipment while improving total cost of ownership for mmWave access points, says WIN.

"The commercial release of PIH-10 provides a new set of integrated GaAs solutions to improve mmWave front-end performance," says senior VP David Danzilio. "High-efficiency Ka-band GaAs power amplifiers, LNAs and low-loss switches on a compact single-chip front-end will enhance the user experience through improved battery life and better 5G mmWave coverage," he adds. "Integrated GaAs front-ends can also be used in mmWave access points, and the higher Tx power and efficiency of PIH1-10 enables smaller active antenna arrays with lower total power consumption than existing RAN hardware. Network owners expect the wireless supply chain to reduce equipment total cost of ownership and provide flexible mmWave active antenna solutions to support multiple deployment scenarios. Higher-performance integrated GaAs front-ends provide an optimum path to satisfy these diverse requirements."

www.winfoundry.com
www.ims-ieee.org

Atom Power's SiC modules achieve UL 1557 certification

Atom Power of Charlotte, NC, USA, which invented what is claimed to be the only commercial digital solid-state circuit breaker, says its SWXFT100CPM and SWXFT50CPM silicon carbide (SiC) power modules are now certified to the UL 1557 standard of Underwriters Laboratories. Atom Power's Atom Switch was recently the first of its kind listed to the UL 489I standard.

Atom Power is said to be the first company to use wide-bandgap (WBG) semiconductors in commercially available solid-state circuit breakers. Most module packages for WBG semiconductors are designed for power conversion applications (AC-to-DC or DC-to-AC), so that existing off-the-shelf WBG package designs are not conducive for circuit protection applications, notes the firm. To reduce costs and create a more manufacturable product for the future, the team needed a better implementation than was readily available.

"Our team was challenged by the limitations of off-the-shelf designs," says chief technology officer Denis Kouroussis. "To make the best product possible for our next generation of circuit breakers, we took the module manufacturing of our wide-bandgap semiconductors in-house and designed them to our specific requirements."

Atom Power says that its proprietary SiC module design allows it to vertically integrate its future circuit breaker products with the flexibility to design for all frame sizes of circuit protection in an efficient and cost-effective manner.

Atom Power's intelligent product suite currently includes a first-generation circuit breaker (Atom Switch), distribution panel (Atom Panel) and software (Atom OS) that forms what is claimed to be the fastest ever power distribution system, enabling circuit interruption capabilities up to 100,000A and reducing electrical explosion hazards to almost zero.

"Commercial and industrial buildings are long overdue for safer, smarter power distribution and circuit protection," says CEO Ryan Kennedy. "We are proud to see our mission come to fruition with our silicon carbide semiconductor modules as UL Recognized, which will enable our next generation of solid-state circuit breakers to be more easily manufactured at a reduced cost."

www.atompower.com
https://standardscatalog.ul.com/

UnitedSiC adds 4-lead Kelvin FET to UF3C FAST series

Silicon carbide (SiC) power semiconductor maker United Silicon Carbide Inc (USCi) of Monmouth Junction, NJ, USA has further expanded its UF3C FAST series by adding the 1200V high-performance SiC field-effect transistor (FET) device in a TO-247-4L 4-leaded Kelvin Sense discrete package option. The UF3C120150K4S offers a typical on-resistance ($R_{DS(on)}$) of 150mΩ, bringing the total number of 4-leaded FAST Series devices up to six and extending the on-resistance range of the entire series from 30mΩ all the way up to 150mΩ.

With a maximum operating temperature of 175°C, the UF3C120150K4S offers what is claimed to be excellent reverse recovery, low gate charge and low intrinsic capacitance. The ESD-protected, HBM class 2 TO-247-4L package offers faster switching and much cleaner gate waveforms compared with a standard 3-leaded TO-247. The 4-pin Kelvin package avoids gate ringing and false triggering which would normally require switching speeds to be limited to manage the large common source inductance of 3-leaded packages. The new device is suitable for electric vehicle (EV) charging, photovoltaic inverters, switch mode power supplies (SMPS), power factor correction (PFC) modules, motor drives and induction heating.

UnitedSiC's UF3C FAST SiC series (launched last November), which now totals 13 devices, is available in TO-247-3L and TO-247-4L packages with 1200V and 650V options. The range offers very fast-switching, high-power devices in a package capable of high power dissipation based on its efficient cascode configuration. The 4-terminal Kelvin package offers easy screw or clamp mounting with very low junction-to-case thermal resistance, taking advantage of the high-junction-temperature capabilities of SiC.

Unique to UnitedSiC's entire UJ3C and UF3C SiC FET portfolio is its true 'drop-in replacement' functionality. Designers can significantly enhance system performance, without the need to change gate drive voltage, by replacing their existing silicon IGBTs, silicon FETs, SiC MOSFETs or silicon superjunction devices with UnitedSiC's FETs.

The UF3C120150K4S is priced at $6.14 in 1000-unit quantities. Stock is available at Mouser and other local distributors.

www.mouser.com/usci
https://unitedsic.com/cascodes

Wolfspeed presents new GaN-on-SiC and LDMOS components at IMS

At the IEEE's International Microwave Symposium (IMS 2019) in Boston, MA, USA (4–6 June), Wolfspeed of Durham, NC, USA — a Cree Company that makes silicon carbide (SiC) power products and gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs) — exhibited a broad assortment of GaN-on-SiC and laterally diffused metal-oxide-semiconductor (LDMOS) devices, as well as introducing new products for aerospace/defense and communications infrastructure applications.

Wolfspeed is also giving live demonstrations each day including:

- a broadband GaN monolithic microwave integrated circuit (MMIC) power amplifier (PA) for 32V counter improvised explosive device (C-IED) applications;
- a mid-Ku-band GaN MMIC PA for satellite communications (SatCom) applications;
- a 63W average, 3.6–3.8GHz high-efficiency Doherty GaN transistor for cellular base-station transmitter amplifiers;
- a broadband GaN MMIC power amplifier for 28V X-band radar applications including military, marine and weather radars;
- a 120W multi-stage application fixture for S-band radar; and
- a troposcatter tactical radio reference design for SatCom and radio links.

The firm's components were also on display in other demos throughout IMS, including Mouser Electronics, Keysight Technologies, Maury Microwave, National Instruments, Richardson RFPD and AMCAD Engineering.

www.ims-ieee.org
www.wolfspeed.com/RF

NXP unveils RF portfolio for 5G cellular infrastructure

At the IEEE International Microwave Symposium (IMS 2019) in Boston, MA, USA (2–7 June), NXP Semiconductors N.V. of Eindhoven, The Netherlands has unveiled what it claims is one of the industry's most integrated portfolios of RF solutions for 5G cellular infrastructure, industrial and commercial markets, exceeding existing 5G RF power amplification demands for base stations — from MIMO to massive MIMO-based active antenna systems for cellular and millimeter-wave (mmWave) spectrum bands.

The firm says that its radio power solutions also simplify mMIMO deployments by enabling smaller, lighter active antenna systems, and its RF power multi-chip modules (MCMs) offer high levels of integration and performance. With solutions from sub-6GHz to 40GHz and from milliwatts to kilowatts, NXP aims to further simplify 5G infrastructure to allow partners to rapidly develop systems and join the 5G ecosystem.

"With the potential to transform entire industries and economies, 5G will be fully realized over time and NXP is uniquely positioned to facilitate its global adoption by offering one of the industry's most comprehensive cellular infrastructure portfolio focused on driving the 5G-connected world," believes Paul Hart, senior VP & general manager of NXP's Radio Power Solutions. "NXP is ahead of the demand curve as the world's top supplier of massive MIMO solutions enabling carriers to provide more bandwidth to customers," he adds.

NXP says it is enabling many of the world's first RF deployments in 5G for both sub-6GHz mMIMO and the first millimeter-wave networks. The firm adds that at the core of this is its trifecta of radio power solutions:

- Smart antenna solutions, including highly integrated analog beamforming products (operating at frequencies of 24–40GHz) that leverage NXP's silicon germanium (SiGe) technology for 5G millimeter-wave infrastructure. The solutions enable customers to build the 5G mmWave phased-array antenna systems of the future and serve consumers with substantial bandwidths in both fixed wireless access (FWA) and radio access networks (RAN) applications.
- Integrated, high-efficiency power solutions, with 5G mMIMO and IC products for base stations across all sub-6GHz cellular bands.
- Discrete high-power RF transistors for 4G and 5G MIMO-based cellular base stations, plus a full suite of gallium nitride RF and LDMOS RF power solutions for industrial, scientific & medical (ISM), broadcast, RF energy, mobile radio and aerospace & defense applications.

Claiming to be the only company delivering RF and transceiver solutions across the complete range of 5G network deployments from sub-6GHz to mmWave, NXP has established hardware and software partnerships with key multiple-system operators (MSOs) and original design manufacturers (ODMs) to quickly deliver systems for 5G hyper-connectivity to the market.

www.ims-ieee.org
www.nxp.com

EPC to provide eGaN power devices in wafer form for ease of power systems integration

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 announced the availability of its enhancement-mode GaN devices in wafer form for ease of integration. The firm's eGaN FETs and ICs are traditionally sold as singulated chip-scale devices with solder bars or solder bumps.

Chip-scale packaging is a more efficient form of packaging that reduces the resistance, inductance, size, thermal impedance and cost of power transistors. These attributes of eGaN devices enable unmatched

in-circuit performance at competitive prices, claims EPC.

Wafer-level offerings of these devices allows easier integration in customer power system sub-assemblies, further reducing device interconnect inductances and the interstitial space needed on the printed circuit board (PCB), says the firm, adding that this increases both efficiency and power density while reducing assembly costs.

"We have listened to our partners and are pleased to offer our industry-leading GaN products in wafer form that can accommodate a variety of assembly techniques and applications," says CEO & co-founder Alex Lidow.

EPC is offering eGaN power devices in wafer form either with or without solder bumps. Extra services such as wafer thinning, metallization of the wafer backside and the application of backside coating tape are also available.

www.epc-co.com/epc/Products/WaferSales.aspx

EPC & Spirit to provide lot-specific data services for eGaN FETs & ICs

EPC has partnered with Spirit Electronics of Phoenix, AZ, USA (appointed distributor for the defense & aerospace markets in May 2018) to provide an expanded range of manufacturing-lot-specific data services for its enhancement-mode gallium nitride (eGaN)-based power devices. EPC is offering a variety of data pack services for its eGaN FETs and ICs.

"Our partnership with Spirit Electronics provides the opportunity for EPC to complement Spirit's extensive history and proven successful track record in working with defense and aerospace customers," says CEO & co-founder Alex Lidow. "Offering lot-specific data services related to our eGaN power semiconductor products will enable us to bring additional value to these demanding applications," he adds.

"Our partnership with EPC has been an exciting addition to our portfolio of products, and this new offering of lot-specific data services will further help us bring the superior performance of eGaN power transistors and ICs to defense and aerospace customers, so they can design leading-edge power system solutions," states Spirit's CEO Marti McCurdy.

www.spiritelectronics.com

EPC's CEO & co-founder Alex Lidow inducted into ISPSD Hall of Fame

At the 31st IEEE International Symposium on Power Semiconductor Devices and ICs (ISPSD 2019) in Shanghai, China (19–23 May), EPC's CEO & co-founder Dr Alex Lidow was inducted into the ISPSD Hall of Fame 2019. The honor is bestowed for contributing to advancing power semiconductor technology and sustaining the success of ISPSD.

"I share this honor with Tom Herman, with whom I undertook the foundational work on the power MOSFET, and with my co-founders

at EPC, Joe Cao and Bob Beach, who had the courage to join me on our mission to develop gallium nitride power devices to crush silicon," says Lidow. "I look forward to continue working with our customers who are innovating new designs with GaN," he adds.

"Contributions to our semiconductor industry have been most important in furthering our betterment of the whole world, as well as changing the way we live," comments advisory committee chair Dr John Shen.

Northrop wins $958m US Marines contract for full-rate production of GaN-based G/ATOR radar

The US Marine Corps has awarded Northrop Grumman Corp a $958m contract for Lot 6 full-rate production of an additional 30 units of gallium nitride-based AN/TPS-80 Ground/Air Task-Oriented Radar (G/ATOR) systems. The program is managed by Program Executive Officer Land Systems.

"Northrop Grumman and the Marine Corps have successfully partnered to create a best of ground and airborne radar solution that exceeds the current threat on the modern battlefield," says Christine Harbison, VP, land and avionics C4ISR, Northrop Grumman. "G/ATOR is a crucial capability that protects our warfighters and defends against today's threat environment and the threat environment of the future," she adds. "We are excited to reach the full-rate production decision and continue providing advanced multi-mission functionality that meets our customer's mission needs, protects the warfighter in a rapidly changing threat environment, and has significant margin for capability growth."

G/ATOR replaces five legacy systems operated by the Marine Corps with a single system, providing significant improvements in performance compared with the legacy radar families in each of its modes. This results in reduced training, logistics and maintenance costs.

The AN/TPS-80 G/ATOR is an active electronically scanned array (AESA) multi-mission radar that leverages GaN to provide comprehensive real-time, full-sector, 360° situational awareness against a broad array of threats. The highly expeditionary, three-dimensional, short-to-medium-range multi-role radar system is designed to detect, identify and track cruise missiles, manned aircraft and unmanned aerial vehicles (UAVs) as well as rockets, mortars and artillery fire.

www.northropgrumman.com/Capabilities/GATOR

Integra Technologies wins US Air Force contract

Integra Technologies Inc (ITI) of El Segundo, CA, USA (which makes RF and microwave transistors and power amplifier modules for mission-critical applications) has been won a two-year contract from the US Air Force to accelerate technology and manufacturing readiness of its patented Thermally Enhanced GaN/SiC technology.

Integra says its GaN/SiC technology is suitable for high-efficiency, solid-state RF power applications including high-power radar systems requiring improved performance, increased range and reduced operating costs.

The firm has developed its Thermally Enhanced GaN/SiC for power and efficiency while operating at lower temperatures, which is a key enabler of next-generation high-performance radar platforms. Integra is leveraging its domestic R&D and manufacturing platform to optimize the GaN epiwafer, device design and package design. Also, the USAF contract will enable robust qualification of Integra's Thermally Enhanced GaN/SiC for production.

www.integratech.com

Akash hires space industry veteran Montauti

Continuing the expansion of its' core management team (assembled by co-founders Felix Ejeckam and Ty Mitchell since 2016), Akash Systems Inc of San Francisco, CA, USA — which supplies small satellites (CubeSats) and the RF power amplifiers (based on GaN-on-diamond) that power them — has appointed Fabrizio Montauti as VP of radios. Montauti has 30 years of RF communications experience through delivering radio technologies to the global space satellite communications market.

"It's one thing to design effective RF technology. It's another to deliver that technology to customers through trusted and proven partnerships," says Ejeckam, CEO and GaN-on-diamond inventor. "We're excited to leverage his expertise in conceptualizing and delivering groundbreaking space-qualified radio communications systems to our customers."

Montauti's team should deliver its first radio product, a small X/S-band transceiver, over the next few months to CubeSat and satellite customers in the Earth observation market, with a Ka/S-band transceiver shortly thereafter. GaN-on-diamond powers the company's radio products and allows for what are claimed to be record data rates at highly reduced power consumption levels.

Through his experience in radio product design, customer support, business development, sales and team leadership, Montauti is expected to further Akash's mission of extending the reach of fast, affordable information across the globe. Prior to joining Akash, he was head of Microwave Products at RUAG Space in Santa Clara, CA, where he led R&D on microwave payloads equipment. Previously, Montauti held senior management positions at numerous startups and established companies, including L3 Communications, P-Com and Siemens Telecomunicazioni.

www.AkashSystemsInc.com

Northrop Grumman demonstrates LTAMDS capability to US Army

Northrop Grumman Corp of Redondo Beach, CA, USA demonstrated its in-production solution for the US Army's Lower Tier Air and Missile Defense Sensor (LTAMDS) program during an open 'Sense Off' competition at White Sands Missile Range in New Mexico from 16 May – 1 June.

"Our mature, gallium nitride (GaN)-based design demonstrated an advanced system with our current capabilities aligned with the Army's requirements," says Christine Harbison, VP, land and avionics C4ISR division, Northrop Grumman. "Our solution supports the need for rapid deployment with an architecture that allows for significant margin of capability growth to protect our warfighters today and in the rapidly changing threat environment," she adds.

Northrop Grumman says that its LTAMDS solution demonstrated a mission-capable system with growth potential leveraging affordable, low-risk, in-production and fielded technologies from across the company's active electronically scanned array (AESA) portfolio. The system provides a 360º full-sector mission capability. Designed from the outset to meet the warfighters' current and future needs, the LTAMDS solution aligns with the Army's top requirements, including speed to field. An embedded logistics capability enables quicker and more affordable modernization and better sustainability over the lifecycle of the program.

Northrop Grumman firm will deliver its final LTAMDS proposal to the Army in the coming weeks for evaluation

Building on its decades of expertise in sea-, land-, air- and space-based military radar technology and high-performance microelectronics, the LTAMDS solution is Northrop Grumman's latest sensor product to incorporate and use GaN high-power-density radio frequency components for greater performance.

Having completed the demonstration phase, the firm will deliver its final LTAMDS proposal to the Army in the coming weeks for evaluation.

www.northropgrumman.com

Lockheed Martin demos mature, proven LTAMDS radar technology during US Army's Sense-Off

Lockheed Martin (LMT) completed a demonstration of its radar solution for the US Army's Lower Tier Air and Missile Defense Sensor (LTAMDS) program during a 'Sense-Off' at White Sands Missile Range, New Mexico.

During the two-week demonstration period, the Lockheed Martin team completed a series of exercises showcasing its radar solution and how it will meet the Army's requirements for the LTAMDS system, while providing additional deployment strategies for the air & missile defense mission.

The firm's radar will incorporate a balance of mature production radar technology in a scalable, next-generation architecture designed to evolve as mission needs change. Both Lockheed Martin and its strategic partner ELTA Systems Ltd say they are prepared to conduct the testing it takes to meet the Army's timeline.

"The LTAMDS program requires mature technology specifically designed to address the threat, which Lockheed Martin and ELTA both bring to the program. We are demonstrating and proposing an innovative approach," says Dr Rob Smith, VP & general manager of Radar and Sensor Systems at Lockheed Martin. "We will leverage technology that is production-ready and proven in the field, allowing us to meet the Army's requirements quickly and provide qualified systems within 24 months after the initial contract award," he adds. "We have a proven track record of performing on programs with aggressive development and delivery needs, such as the Q-53 radar, where both capability and schedule commitments are extremely important."

Lockheed Martin and ELTA have several recent development and production radar programs that offer active electronically scanned array (AESA) technology, which does not require modifications. Lockheed Martin has already fielded tactical operational radars with gallium nitride (GaN) technology, beginning with its delivery of a TPS-77 Multi Role Radar system to Latvia and a TPS-77 system to Romania (both in 2018). The firm is also on contract to deliver GaN in the Army's Q-53 system.

ELTA is in active production and fielding of the GaN-based ELM-2084 Multi Mission Radar that detects and tracks both aircraft and ballistic targets, while providing fire control guidance for missile interception or artillery air defense. The Army is actively procuring Iron Dome systems that include battle-proven ELM-2084 radars.

The Lockheed Martin team is built around the strength of its global organization and supply base, including strategic partnerships with ELTA and the radar systems engineering expertise of deciBel Research in Huntsville, AL.

www.lockheedmartin.com/gbas

Navitas earns Frost & Sullivan's 2019 Global Technology Innovation Award for GaNFast Power ICs

Based on its recent analysis of the global gallium nitride (GaN) integrated circuit (IC) market, Frost & Sullivan has recognized Navitas Semiconductor Inc of El Segundo, CA, USA with the 2019 Global Technology Innovation Award for its unique GaNFast power ICs.

Frost & Sullivan presents the award annually to the firm that has developed a product with innovative features and functionalities that is gaining rapid acceptance in the market. The award recognizes the quality of the solution and the customer-value enhancements it enables.

Founded in 2014, Navitas introduced what it claimed to be the first commercial GaN power ICs. The firm says that its proprietary 'AllGaN' process design kit (PDK) monolithically integrates GaN power field-effect transistors (FETs) with GaN logic and analog circuits, enabling faster charging, higher power density and greater energy savings for mobile, consumer, enterprise, eMobility and new energy markets.

The firm leverages its proprietary GaN technology to address challenges such as integration and packaging, manufacturing capability, and voltage and switching issues, which are inherent in the legacy, silicon-dominated semiconductor industry.

"Navitas' power ICs address system- and application-level concerns relating to power electronic circuits incorporated with GaN," comments senior research analyst Sushrutha Katta Sadashiva. "Instead of delivering a stand-alone discrete product, Navitas developed GaN into a system-based solution; this vision resulted in the unique GaNFast power ICs," he adds. "By leveraging its proprietary platform, Navitas achieved monolithic integration of GaN FETs with GaN drivers and other mixed-signal circuits. Navitas has embedded analog, logic and power circuits into a single package, thereby enabling the entire system to be faster, simpler, smaller and more energy efficient than existing offerings."

Through its R&D, Navitas says it has achieved the ability to cater to the technical, size and performance requirements of various power electronic systems such as mobile chargers & adapters, solar inverters, chargers for electric vehicles (EVs), and switch-mode power supplies (SMPS). Its GaNFast power ICs are fabricated on 6-inch enhancement mode (E-mode) GaN-on-silicon wafers. The firm follows a fabless model for developing its products, which encourages third-party semiconductor manufacturers to venture into the GaN domain. Through manufacturing partnerships with Taiwan Semiconductor Manufacturing Company Ltd (TSMC) and Amkor, Navitas has been able to scale to high-volume production. In addition, it has partnered with component manufacturers such as TDK and Hitachi to create miniaturized transformers that can work along with GaNFast power ICs.

Navitas reckons that its GaN power ICs will have a significant impact on consumer electronics, communication, automobiles, energy and other industries where power electronics are widely used. Leveraging the relevance of GaN in power electronic applications with voltages of 200-1200V, the firm has developed power ICs in half-bridge topologies suitable for this range. In renewable energy, GaNFast power ICs can be embedded in solar micro-inverters to reduce operating costs and increase productivity.

"GaN ICs that integrate power, analog and digital circuits are enabling dramatic improvements to next-generation power systems, and we're pleased that Navitas and this exciting technology has been recognized for its industry impact," says CEO & co-founder Gene Sheridan.

"Navitas sets the benchmark for companies planning to venture into the GaN power IC semiconductor market, and will significantly influence the growth of power-efficient and compact electronic devices in the near future," comments Frost & Sullivan's Sushrutha Katta Sadashiva. "Navitas' thought leadership will accelerate the market penetration of GaN through the company's pioneering GaNFast power ICs, which aligns with its vision to lead the high-speed revolution in power electronics."

Sanan IC adds 150mm 650V GaN-on-Si E-HEMT process to wafer foundry portfolio for power electronics

200V GaN E-HEMT process and second-gen SiC SBD process with merged PiN Schottky diode to follow later this year

Sanan Integrated Circuit Co Ltd (Sanan IC) of Xiamen City, Fujian province (China's first 6-inch pure-play compound semiconductor wafer foundry) has announced the commercial release of its 150mm gallium nitride on silicon (GaN-on-Si) wafer foundry services, intended for the latest high-voltage AC/DC and DC/AC power electronics applications.

G06P111 is a 650V enhanced-mode high-electron-mobility transistor (E-HEMT) GaN process that adds to the firm's power electronics wafer foundry portfolio of wide-bandgap (WBG) compound semiconductors, which includes 100mm and 150mm silicon carbide (SiC) for high-voltage Schottky barrier diodes (SBD). Leveraging years of high-volume GaN manufacturing experience gained by parent company Sanan Optoelectronics for the LED market, Sanan IC is able to complement its foundry services with in-house metal-organic chemical vapor deposition (MOCVD) growth capabilities of high-voltage, low-leakage GaN-on-Si epitaxial wafers with high uniformity.

"The launch of our 650V GaN E-HEMT process technology exemplifies our commitment to advanced compound semiconductor manufacturing for serving the global market," says Sanan IC's assistant general manager Jasson Chen. "We view GaN-on-silicon as a complimentary technology to silicon carbide as key wide-bandgap semiconductors of choice for today's high-voltage, high-power electronics industry," he adds. "Component suppliers and system designers are migrating to wide-bandgap semiconductors over traditional silicon for enhanced performance, efficiency and reliability in high-power analog designs. Sanan IC is well positioned for success in serving this high-growth, large-scale power electronics market," he believes.

Having passed the JEDEC standard for process reliability qualification, the G06P11 GaN-on-Si process offers device structures for 650V E-mode FETs that support a drain-to-source on-state resistance ($R_{DS(on)}$) range of 50–400mΩ. Engineered for low leakage, low gate charge, high current density and low dynamic specific on resistance (R_{sp}), it enables ultra-fast-switching compact designs for high-temperature operation.

Following later this year will be the launch of a 200V GaN E-HEMT process as well as a second-generation SiC SBD process with a merged PiN Schottky (MPS) diode structure.

Sanan IC says that GaN-on-Si as a process technology is suitable for the latest wave of consumer and server applications such as power adapters, USB-PD (power delivery), portable chargers and power factor correction (PFC) for AC/DC uninterrupted power supplies (UPS). The technology is also getting traction in other markets such as EV/HEV (hybrid/electric vehicles), LiDAR, and wireless charging. The GaN power device market is rising at a compound annual growth rate (CAGR) of 93% to $423m in 2023, according to the bull-case scenario of market research firm Yole Développement's report 'Power GaN 2018: Epitaxial, Devices, Applications, and Technology Trends report, December 2018'. Sanan IC says that it is dedicated to serving this emerging technology for these multiple market segments in the power electronics industry.

www.sanan-ic.com

GaN Systems again sponsoring China Power Supply Society's annual 'GaN Systems Cup' design competition

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) is again sponsoring the China Power Supply Society (CPSS) design competition, which is conducted this year in partnership with CPSS, the China Power Society Science Popularization Committee, and Tsinghua University.

Now underway with a record 40 engineering teams entering the competition from universities throughout China, GaN Systems recently participated in the kick-off ceremony at Tsinghua University, training the teams on the fundamentals of GaN power transistors.

The annual 'GaN Systems Cup' challenge supports worldwide innovation in the power electronics industry leveraging the benefits of GaN transistors. GaN Systems says that, as GaN technology continues to be incorporated into numerous power systems designs in the most demanding applications (including data centers, renewable energy systems, industrial, automotive and consumer electronics), the challenge gives emphasis to the importance of accelerating the development of high-performing system designs with GaN.

"Now in our fifth year and drawing the highest number of participating students to date, the GaN Systems Cup continues to bring excitement in what's possible with new design approaches," comments CEO Jim Witham. "GaN has become an important piece in addressing the power and technology challenges in areas such as data centers, computer chargers and adapters, renewable energy, wireless charging, autonomous and electric vehicles."

The contest allows students to compete for prizes and gain real-world, hands-on experience using GaN Systems' 650V power transistors from design to build. This year's challenge is to design a high-efficiency, high-power-density AC/DC power supply for data-center server power applications with a 400W-rated output power, $220V_{AC}$ input voltage range/48 DC output voltage and achieve 94% efficiency at 50% load, and greater than 3W/cm3 power density. Additional factors such as input and output power quality and total cost are also evaluated as part of overall performance.

The CPSS recently announced that 30 of the 40 teams have made it to the next phase of the competition to deliver working prototypes by early June. They will announce the finalists on 25 August and announce the winning teams at the live finals and awards ceremony on 1 November during the CPSS conference in Shenzhen, China.

www.gansystems.com

GaN Systems gives presentations and customer demonstrations at Wireless Power Week

At Wireless Power Week (WPW 2019) in London, UK (17–21 June), GaN Systems delivered presentations and displaying wireless power transfer solutions enabled by gallium nitride.

VP strategic marketing Paul Wiener gave a talk 'Moving to a World Without Wires' in a joint IEEE MTT-S Wireless Power Transfer Conference (WPTC) and IEEE PELS Workshop on Emerging Technologies: Wireless Power (WoW) session on 18 June. Also, GaN Systems' RF power and wireless power expert Tiefeng Shi gave a poster presentation on 'High Power WPT System For Through the Wall Applications'.

Customer demonstrations

GaN Systems showcased wireless charging devices and technologies from customers and partners as well as design tools and reference designs. GaN transistors are enabling higher-power-level applications from 30W up to several kilowatts — much greater than achieved with traditional silicon solutions — and opening the door for charging not just a single cell phone but several at the same time as well as laptops, drones, robots, tabletop electronics, industrial power tools, eBikes etc.

Demonstrations included:

- a multi-device charging, dual-mode solution from PowerSphyr;
- an off-the-shelf, 300W end-to-end wireless power system for aerial, mobile, marine and industrial robots from WiBotic;
- a 700W wireless power charging system for scooters from Bumblebee;
- a 150W wireless power solutions designed for industrial and consumer applications from NuCurrent; and
- a 70W, high-efficiency through-wall application enabling power from inside a home or commercial building to power devices on the outside of the building without drilling holes and routing power cords.

"We're seeing a growing number of companies using GaN to make their wireless power transfer systems more efficient and to overcome the current technical challenges in the market," says Paul Wiener, VP of strategic marketing. "Today those looking to implement wireless power now have off-the-shelf complete end-to-end solutions readily available from our partners to help them get to market quickly."

www.wpw2019.org

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Transphorm awarded $15.9m contract modification to develop US-based production of GaN epi for high-performance RF and mmW electronics

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 (HV) power conversion applications — has been awarded $15,869,322 for a modification (P00002) to a previously awarded cost-plus-fixed-price contract (N68335-19-C-0107) to exercise an option.

The option modification procures the continued services and materials necessary to conduct R&D for a US-based dedicated production source of gallium nitride (GaN) epitaxy for high-performance radio-frequency and millimeter-wave (mmW) electronics.

Work will be performed in Goleta, and is expected to be completed in June 2022. Fiscal 2019 Department of Defense funds of $10m for research, development, test and evaluation will be obligated at the time of award, none of which will expire at the end of the current fiscal year.

The Naval Air Warfare Center Aircraft Division in Lakehurst, NJ (NAWCAD Lakehurst) is the contracting activity.

www.transphormusa.com
www.navair.navy.mil/lakehurst

Transphorm adds 2nd 900V GaN FET, targeting three-phase industrial power supplies and automotive converters

Transphorm has launched its second 900V FET, the Gen III TP90H050WS (sampling now), enhancing what is claimed to be the only 900V GaN product line. The devices now enable three-phase industrial systems and higher-voltage automotive electronics to leverage GaN's speed, efficiency and power density. Further, the new FET's platform is based on Transphorm's 650V predecessor, the only JEDEC- and AEC-Q101-qualified HV GaN technology.

The TP90H050WS has a typical on-resistance of 50mΩ with a 1000V transient rating, offered in a standard TO-247 package. It can reach power levels of 8kW in a typical half bridge while maintaining greater than 99% efficiencies. Its figures of merit for $R_{on*Qoss}$ (resonant switching topologies) and R_{on*Qrr} (hard switching bridge topologies) are 2-5 times less than those of common superjunction technologies in production — indicating highly reduced switching losses. While a JEDEC-qualified version is slated for first-quarter 2020, customers can design 900V GaN power systems today.

Transphorm's first 900V device, the TP90H180PS (with a typical on-resistance of 170mΩ in a TO-220 package) is JEDEC qualified and has been available through Digi-Key since 2017. It can reach a peak efficiency of 99%, demonstrating its suitability for 3.5kW single-phase inverters.

Transphorm's Gen III TP90H050WS 900V GaN FET

"Transphorm's latest 900V GaN product represents a major milestone for commercial GaN power transistors as it reaches the 1kV mark, an industry first," claims co-founder & chief operating officer Primit Parikh. "This paves the way for GaN to be a viable choice at these higher voltage nodes," he adds. "With partial funding from ARPA-E for early risk reduction and Power America for initial product qualification, this effort represents successful public–private partnership that accelerates GaN's market adoption."

Transphorm says that its 900V platform provides higher breakdown levels for systems already targeted by its 650V FETs, such as renewables, automotive and various broad industrial applications. It is designed to be deployed in bridgeless totem-pole power factor correction (PFC), half-bridge configurations used in DC-to-DC converters and inverters. The ability to support these topologies at a higher voltage expands Transphorm's target applications to now include a broad list of three-phase industrial applications, such as uninterruptible power supplies (UPS) and automotive chargers/converters at higher battery voltage nodes.

"900V GaN power devices eliminate barriers to access applications not presently supported with GaN semiconductors," notes Victor Veliadis, deputy executive director & chief technology officer of PowerAmerica, which partially funded the project. "With innovations like this 900V platform, Transphorm is advancing the industry, creating new customer opportunities," he comments.

www.transphormusa.com/en/product/tp90h050ws-2

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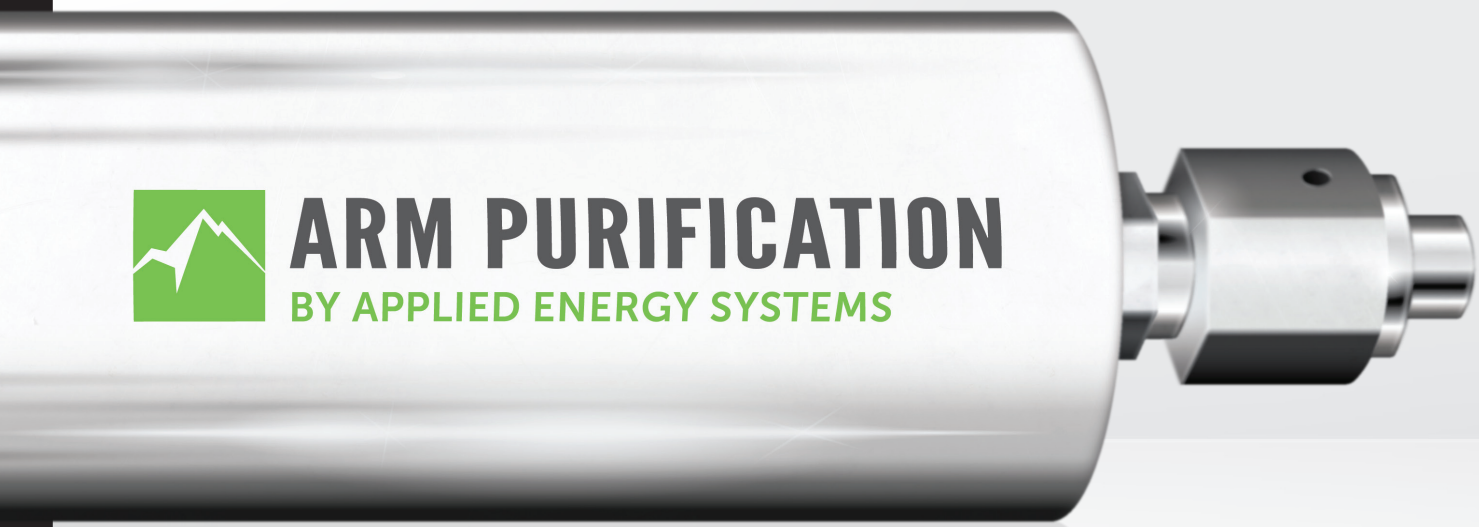

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UK's CSC-led GaNTT consortium awarded £1.3m via the Office for Low Emission Vehicles

Project targets realisation of voltage-scalable 200–600V mass-manufacturable vertical GaN trench FETs

A consortium led by the Compound Semiconductor Centre Ltd (CSC) — a joint venture founded in 2015 between Cardiff University and epi-wafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — has been awarded £1.3m in funding through 'The road to zero emission vehicles' competition sponsored by OLEV (the Office for Low Emission Vehicles). CSC leads a consortium of partners across the power electronics supply chain: SPTS Technologies Ltd of Newport, Wales; Newport Wafer Fab Ltd; Turbo Power Systems Ltd of Gateshead, UK; and the South Wales-based Compound Semiconductor Applications (CSA) Catapult, supplemented with academic expertise in power systems and devices at Swansea University and Coventry University.

The project GaNTT (Realisation of a mass-manufacturable Vertical GaN Trench FET architecture) will develop a voltage-scalable, vertical gallium nitride process platform (200-600V) suitable for electric vehicle (EV) applications and integrate the resulting device into an on-vehicle demonstrator for bi-directional battery charging. Vertical GaN architectures are a viable future technology for low- to medium-voltage and power applications, e.g. on-board charging (OBC) and DC–DC applications where higher switching speed is desirable. It also has the potential to meet the cost challenges related to existing silicon carbide (SiC) field-effect transistor (FET) technologies, although significant challenges in epitaxial material layer quality and device thermal management require de-risking.

The project will focus on the development of large-diameter substrate solutions that provide high-quality, thick GaN layers and address the challenges of lattice mismatch and wafer bow by employing novel epitaxial substrate solutions for future foundry products. Vertical GaN devices architectures enable FET operation at high electric fields and thus facilitate a significant reduction in chip area compared with lateral power devices. The breakdown voltage can be increased by increasing the thickness of the epitaxial drift region supporting the electric field, enabling the voltage to be scaled independently of chip area. The device approach also incorporates an innovative source-metal/P-body Schottky contact approach, patented by researchers at Swansea and Coventry Universities, to provide better control and stability of the channel threshold voltage.

Crucially, the project will evaluate prototype devices at the packaged device and sub-system level, with Turbo Power Systems providing a tier-1 automotive testing environment. The activity aims to establish a 'materials to system' UK supply chain in wide-bandgap materials and enhance exploitation opportunities for all partners by ensuring that device development is driven by automotive requirements. The performance benefits of the new platform technology are not limited to automotive applications, but are also suitable for use in other harsh environments (e.g. space applications, where the combination of improved power density and radiation-hardness would reduce payload and improve system reliability).

"Vertical GaN Power Technology will deliver emerging opportunities across a broad applications space, currently growing at >50% CAGR [compound annual growth rate] and forecast to be worth >$150–300m by 2023," says CSC's GaN programme manager Robert Harper. "This activity will build on UK strengths in compound semiconductor materials and device technology to energize a new supply chain in automotive power component supply," he adds.

http://compoundsemiconductorcentre.com

CSC participates in £9.8m APC-funded UK project ESCAPE

Project to develop end-to-end supply chain for silicon carbide automotive power electronics

The Compound Semiconductor Centre Ltd (CSC) — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — is a partner in a project that has been awarded £9.8m in funding through the Advanced Propulsion Centre UK Ltd (APC) at the University of Warwick.

The project ESCAPE (End-to-end Supply Chain development for Automotive Power Electronics) aims to create a complete end-to-end supply chain for next-generation silicon carbide (SiC) power electronics, which is a key component to be used in all electric vehicles (EVs), whether automotive, railway, marine or aviation.

The funding is part of the UK government's £33m investment through APC to advance the UK's low-carbon automotive capability and to develop the next generation of low-carbon vehicles, helping the automotive sector to build a prosperous low-carbon future. Led by McLaren Applied Technologies, ESCAPE is one of five projects awarded funding, ranging from the development of high-performance battery packs and electrified construction equipment to hydrogen-powered engines.

Twelve other partners will support the creation of the integrated supply chain, including other industry leaders such as AESIN, Clas-Sic Wafer Fab, the Compound Semiconductor Applications Catapult, Exawatt, Lyra Electronics, MaxPower Semiconductor, Tribus-D, Turbo Power Systems and The University of Warwick.

"The demand for silicon carbide power components is growing rapidly, and we welcome the opportunity to work with our partners to ensure the UK has a world-class future supply chain in this critical technology," comments the Compound Semiconductor Centre's director Wyn Meredith.

www.compoundsemiconductorcentre.com
www.csa.catapult.org.uk
www.apcuk.co.uk

WiBotic and GaN Systems partner on high-power wireless charging for drones and autonomous robots

Partnering with GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications), WiBotic of Seattle, WA, USA is providing off-the-shelf high-power wireless charging solutions for the rapidly growing robotics ecosystem to deliver the power levels and increased antenna range that both drones and robots demand.

The partnership aims to advance the capabilities of mobile industrial robots, freeing them from limitations imposed by existing restricted charging methods that allow for continuous operation. For mobile robots to work efficiently, flexibly and without interruption, they need to achieve autonomy with wireless charging stations rather than requiring an operator to make a physical connection, note the firms.

GaN power semiconductors enable the autonomous wireless charging that these conditions require by operating at a high switching frequency, delivering high-power capability with the spatial freedom (large air gaps) needed in the design of charging systems that require no human intervention.

WiBotic's off-the-shelf, fully automatic, intelligent wireless power system includes components that incorporate GaN Systems' technology to enable very high efficiency levels. The systems allow:

- rapid charging at hundreds of watts and greater;
- autonomous charging at multiple locations and multiple times per day without having to spend time docking;
- greater robot uptime (so fewer robots are needed to complete the same amount of work); and
- no cords and moving parts (so there is no limit on the number of charge cycles a system can deliver).

"GaN provides high reliability and, when coupled with wireless power systems from WiBotic, the technologies provide an extremely robust and reliable system that never wears out," says WiBotic's CEO & co-founder Ben Waters. "We chose GaN Systems as a strategic partner because of its unique and best-in-class GaN technology. The result of this partnership is new wireless power solutions that offer higher power delivery across a wide range of applications," he adds.

"GaN power semiconductors, operating at high frequency, are enabling several wireless charging advantages from higher power capability to significant level of spatial freedom that are needed in multiple industries," comments CEO Jim Witham.

Demonstrations of WiBotic's wireless charging solutions were given at GaN Systems' booth at PCIM Europe 2019 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (7–9 May).

www.mesago.de/en/PCIM/main.htm
www.gansystems.com
www.wibotic.com/products/high-power-dev-kit

Okmetic to double SOI wafer production capacity by second-half 2020 as part of €100m investment program

Expansion a response to rising demand for MEMS and power components

Finland-based silicon wafer maker Okmetic is investing tens of millions of euros in its plant in Vantaa during 2019–2021, targeted mainly at its core competence of silicon-on-insulator (SOI) wafers, to gradually double SOI production capacity by second-half 2020.

"SOI wafers provide an optimal substrate for the manufacture of most advanced MEMS and power components [as used in automotive and healthcare applications, smart wristbands, smartphones and tablets as well as applications related to Internet of Things (IoT) utilizing sensor-provided data in device-to-device communication]," says Anna-Riikka Vuorikari-Antikainen, senior VP, customers & markets. "We have been witnessing a growing demand for these wafers as a result of increasing amount of advanced MEMS and power components used in the electronics sector."

Okmetic's plant in Vantaa.

Okmetic has been part of the China's National Silicon Industry Group (NSIG) since 2016. The decision to increase SOI production capacity is part of Okmetic's growth and investment program for 2017–2021, worth over €100m. This is a continuation of investments made in 2017–2018, which involved a plant expansion including over 1000m2 of cleanroom space as well as new capabilities such as lithographic patterning and deep reactive-ion etching (DRIE), enabling the production of embedded structures in SOI wafers. Okmetic's net sales were €102m in 2018, and at the end of the year the firm employed 428 people.

"The latest investment decision is a response to the needs of our customers and the markets they operate in," says president Kai Seikku. "With the aid of our investment program, we are striving to ensure sufficient capacity for the next few years in order to support our customers' business."

www.okmetic.com

GlobalFoundries sign long-term agreements for high-volume supply of Soitec's 300mm SOI wafer

Demand for GF's RF-SOI, FD-SOI and silicon photonics technology growing for 5G, IoT and data-center applications

GlobalFoundries (GF) of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with operations in Singapore, Germany and the USA) and Soitec of Bernin, near Grenoble, France — which makes engineered substrates including silicon-on-insulator (SOI) wafers — have signed multiple long-term high-volume supply agreements for 300mm SOI wafers to meet the growing demand for GF's differentiated radio-frequency silicon-on-insulator (RF-SOI), fully depleted silicon-on-insulator (FD-SOI) and silicon photonics technology platforms. The firms say that the agreements build on the existing close relationship between them to ensure high-volume manufacturing for years to come.

RF-SOI solutions are used in all smartphones manufactured today and FD-SOI has become the standard technology for cost-effective, low-power devices in high-volume consumer and Internet of Things (IoT) applications as well as for mission-critical safety solutions in automotive proximity sensing. Silicon photonics technologies enable solutions to support the massive growth in communication infrastructure for data centers and next-generation 5G communication optical networks.

"GF is delivering and investing in highly differentiated industry-leading technologies required for 5G, IoT, data-center and automotive applications," says Bami Bastani, senior VP of business units at GF. "These long-term agreements with Soitec, a valued partner, represent our commitment to ensure a secure supply of ultra-lower-power, high-performance SOI solutions and supply that meet customers fast-growing needs and unprecedented demand in these attractive markets," he adds.

"GF is leading the industry in providing differentiated SOI solutions, creating more demand for Soitec's engineered substrates," comments Soitec's CEO Paul Boudre. "These agreements reflect the strength of our long-term partnership as we build the required capacity to meet this growing SOI demand."

www.globalfoundries.com

Element Six launches diamond thermal-material-grade Diafilm TM220, offering thermal conductivity over 2200W/mK

At the International Microwave Symposium (IMS 2019) in Boston, MA, USA, Luxembourg-registered synthetic diamond materials firm Element Six (E6, part of the De Beers Group) launched the diamond thermal-material-grade Diafilm TM220, which is claimed to be the first diamond thermal material engineered to offer industrial users thermal conductivity in excess of 2200W/mK.

The launch is in response to the ever-increasing demand for more content and bandwidth, which is pushing the boundaries of semiconductor thermal management. The shift to higher frequencies is creating a unique opportunity for chemical vapor deposition (CVD) diamond, and Element Six says that the launch extends its portfolio of thermal materials to even higher heat-spreading capabilities.

The new grade of CVD diamond thermal material is suitable for the thermal management of high-power-density radio frequency (RF) and application-specific integrated circuits (ASIC) devices, as well resistive components for power management at high frequencies. Diafilm TM220 also has applications in gallium nitride (GaN)-based RF, in addition to monolithic microwave integrated circuits (MMICs) for phase-array radar, space and satellite, 5G base stations and beyond. Moreover, the success of terabit rate optoelectronics networks for both metro and long-haul content delivery is predicated on high-efficiency thermal management.

As with the other material grades of Diafilm TM, TM220 is thermally isotropic, spreading heat with equal efficiency in a planar direction as well as through the material. Additional Diafilm TM220 properties include dielectric permittivity, optical clarity, electrical insulation, low density and chemical inertness, making it suitable for pushing the boundaries of advanced thermal management as either an active or passive component, says the firm.

"This new material validates the unique multi-functionality of CVD diamond and further demonstrates Element Six's leadership and innovation in CVD diamond synthesis and material characterization, where we continue to open up new areas of advancement," says Speaking at IMS, Thomas Obeloer, business development manager for Thermal Applications. "We have already had positive feedback from customers in RF device packaging, x-ray generation and the high-performance ASIC sector, who were early adopters of the TM220 grade," he adds.

Material blanks of Diafilm TM220 are available in standard thicknesses and can be made to meet specific customer requirements. To match the high performance of the diamond, the use of high-quality, sputter-deposited thin-film metallization is offered, and specifications to meet advanced needs for wire bonding or direct deposition of solder materials onto the CVD diamond can be supplied, says Element Six.

www.e6.com/thermal

StratEdge displaying thermally efficient post-fired and molded ceramic packages at IMS

At the IEEE's International Microwave Symposium (IMS 2019) in Boston, MA, USA (4–6 June), StratEdge of San Diego, CA, USA (which designs and manufactures packages and provides chip assembly & test services for microwave, millimeter-wave and high-speed digital devices) displayed its thermally efficient line of post-fired and molded ceramic semiconductor packages.

StratEdge packages operate from DC to 63+GHz and dissipate heat from compound semiconductor devices such as gallium nitride (GaN), gallium arsenide (GaAs) and

silicon carbide (SiC), enabling them to meet the critical requirements of markets such as telecom, mixed-signal, VSAT, broadband wireless, satellite, military, test & measurement, automotive, down-hole, and MEMS.

"StratEdge packages accommodate the extreme demands of compound semiconductor devices," notes president Tim Going. "We manufacture our packages to exacting specifications, using hardened or post-fired ceramics that don't shrink, substrates that dissipate heat, and electrical transition designs for exceptionally low electrical losses," he adds. "To further ensure optimized performance, StratEdge Assembly Services can package your devices in our new cleanroom, which is equipped with the latest precision wire bonding and die attach systems."

www.stratedge.com

Newport Wafer Fab completes multi-million-pound refinancing deal to fund new equipment and plant

Restructuring of Welsh Government loans and new asset financing from HSBC

Newport Wafer Fab (NWF), the UK's 200mm compound semiconductor wafer foundry, has completed a multi-million pound refinancing deal, involving a restructure of existing Welsh Government loans and a new asset finance facility from HSBC UK.

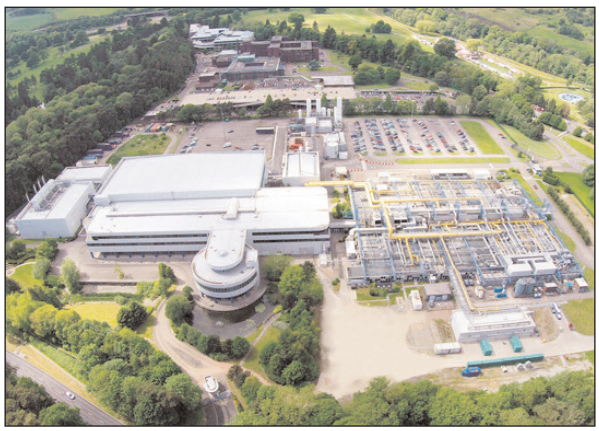
The deal includes the early settlement of deferred consideration, the purchase of specialist back-end-of-line equipment to broaden the foundry's manufacturing capabilities, and a £3m contribution to a new combined heat and power (CHP) plant designed to reduce utility costs by over £1.5m per annum.

NWF was acquired by private investors in September 2017 from Germany's Infineon Technologies AG (which acquired the fab on buying US-based International Rectifier Corp at the beginning of 2015).

NWF is a critical component of CS Connected, the world's first compound semiconductor cluster. CS Connected, which is supported by investment from the Welsh and UK governments and the Cardiff Capital Region (CCR), brings together compound semiconductor material expertise and large-scale semiconductor wafer manufacturing, combined with academic research, to deliver bespoke solutions to customer using compound semiconductor materials.

NWF provides volume manufacturing services for the cluster and any customers who have developed their own products using silicon and compound semiconductors on silicon. It is said to be pivotal to a number of significant international projects being scrutinised by companies attracted to the one-stop-shop capability of CS Connected.

CS Connected is one of 24 short-listed projects (and the only one wholly based in Wales) to receive early-stage funding from the 'Strength in Places' Fund of UK Research and Innovation (UKRI) to develop a full-stage business case submission, benefiting all regions of the UK by enabling them to tap into research and innovation capability spread across the country, aiming to yield significant economic impact, high-value job creation and regional growth.



Newport Wafer Fab semiconductor processing facility in South Wales.

NWF's CEO Dr Paul James expressed his gratitude to the involved parties for their continuing support that has strengthened the position of NWF and the wider CS Cluster.

"The Welsh Government has invested significantly in establishing Wales as a global centre for advanced compound semiconductor technologies and we were pleased to provide support for Newport Wafer Fab so that they can continue work to attract further commercial investment," says Ken Skates, the Welsh Government's Minister for Economy and Transport. "The cluster and its skilled workforce is hugely important to our economy and, with world-leading companies and technologies operating and thriving in the region, I look forward to its continued success and growth in the years ahead," he adds.

"We are delighted to be supporting a business in growth and one which is helping retain a number of jobs in South Wales," comments Warren Lewis, head of corporate banking in South Wales at HSBC UK. "The funding from HSBC UK is helping NWF grow its customer base both domestically and internationally and, as a result, is on the path to becoming the largest semiconductor foundry in Europe. We look forward to continuing our support over the coming years," he adds.

"The Cardiff Capital Region is committed to creating a complete compound semiconductor eco-system in South-East Wales to take advantage of the growing prominence of compound semiconductor technologies," says councillor Andrew Morgan, leader of Rhondda Cynon Taf County Borough Council, and chair of the Cardiff Capital Region's Regional Cabinet. "We are supporting the establishment of the world's first compound semiconductor cluster. In turn, this can place this region at the heart of a sector which is developing technology which is playing an increasingly vital role in the way we live," he adds.

"To achieve our aspiration to create the world's first compound semiconductor cluster, a robust and sustainable supply chain is critical," states councillor Debbie Wilcox, leader of Newport City Council, and a member of the Cardiff Capital Region's Regional Cabinet. "This investment will enable support of this, and in the process deliver the economic and social benefits we aspire to achieve for our local communities here in South-East Wales," she adds.

www.newportwaferfab.co.uk
http://csconnected.com
www.iqep.com

CSC, CST Global and Swansea University collaborative projects win ERDF funding

Projects to scale up novel device fabrication processes to deliver multiple new products

The Compound Semiconductor Centre Ltd (CSC) — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — has been awarded European funding support through the Avenues of Commercialisation for Nano and Micro technologies (ACNM) Operation, a 3-year, £3.3m project, part funded by the European Regional Development Fund (ERDF) through the Welsh Government.

ACNM's specific aim is to provide targeted expertise, for the East Wales region, in nano and micro technologies applied to high-value industries such as life science, healthcare, biomedical, printed functional materials, packaging, semiconductors, advanced manufacturing, high-value manufacturing and associated industries, and is being delivered by collaboration between the Centre for NanoHealth (CNH) and the Welsh Centre for Printing and Coating (WCPC) at Swansea University and the Institute of Compound Semiconductors (ICS) at Cardiff University.

The funding will support collaborative development activity at Swansea University to scale up novel compound semiconductor device fabrication processes to deliver multiple new products.

The first project builds on a collaboration between CSC, Cardiff University, III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Glasgow, Scotland, UK and Swansea University to develop a low-cost, high-specification laser chip manufacturing platform utilizing Substrate Conformal Imprint Lithography (SCIL), developed at CNH. Previous work, funded by InnovateUK, demonstrated a proof of concept of a distributed feedback (DFB) diode laser manufacturing platform that delivered a 30% cost reduction in wafer-scale manufacturing costs, without any trade-off in the laser performance.

ACNM's specific aim is to provide targeted expertise, for the East Wales region, in nano and micro technologies applied to high-value industries such as semiconductors

ACNM funding will now progress commercialization of new foundry products by increasing the on-wafer yield of the SCIL-based process and scale up from a 3" to a 4" epitaxial wafer platform. Applications for the lasers include fiber-to-the-premises (FTTP), high-capacity optical communications links in data centers, and coherent sources for trace gas sensing.

The second project aims to develop a high-volume, chip-scale packaging (CSP) concept for integration of compound semiconductor devices on flexible substrates. Printed conductive track processes developed at WCPC will be used to deliver wire-bond free, conformal interconnects to gallium arsenide (GaAs) devices. Applications for new products range from the integration of GaAs sensors into SMART Gaskets capable of monitoring high-pressure (50MPa) environments in critical pipework joints, through to the low-cost assembly of LEDs into flexible wearable products for the cosmetic and healthcare markets, and flexible, large-area LED displays.

www.compoundsemiconductorcentre.com

IQE cuts 2019 revenue guidance to £140–160m due to impact of Huawei export ban

Photonics to grow by less than 30% rather than over 50%; Wireless to shrink by 20–25% rather than 15%

In a trading update ahead, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that for first-half 2019 it now expects revenue of £65-68m (compared with the consensus of £68m).

As previously guided, first-half 2019 has been impacted by a weak smartphone handset market, particularly affecting the Wireless business unit. IQE has also experienced a reduction in indium phosphide (InP) laser revenue for the datacom market due to a customer-specific issue outside of IQE's control. This has been partially offset by new qualifications and revenue streams coming into production at the firm's Taiwan facility, where it has invested in capacity and which offer increased customer diversification.

IQE announced on 2 May that it's new Newport Mega Foundry received its first mass-production order from its leading existing vertical-cavity surface-emitting laser (VCSEL) customer. This has had a beneficial impact on Photonics revenue for May and June, in line with previous guidance.

On 24 May, in response to external geo-political uncertainties, IQE said that it may experience some delay to orders and the potential for adjustment of supplier-managed inventory levels, predominantly in its Wireless business unit.

IQE notes that it is operating in an increasingly cautious marketplace and has very recently received a reduction in forecasts from a number of chip customers, in Wireless and also in Photonics, impacting anticipated second-half 2019 revenue.

Expecting that uncertain market conditions will continue in the short-term, IQE now expects revenue of £140–160m for full-year 2019 at prevailing exchange rates (compared with the consensus of £175m). This is a larger impact than the previously guided risk related specifically to Huawei, due to the far-reaching impacts on other companies and supply chains that are now becoming evident.

Photonics

For the Photonics segment (on a constant-currency UD dollar basis), IQE has cut guidance for year-on-year revenue growth from over 50% to less than 30%.

Strong progress continues to be made at the Newport Mega Foundry for VCSEL production. Four reactors are in mass production with the first major customer, and two further customers are expected to enter mass production in second-half 2019. Sampling continues with an additional 13 customers as part of ongoing qualifications that provide breadth of exposure to global supply chains. IQE remains confident that it will continue to show strong revenue growth in the Photonics business through customer diversification in 2020 and beyond.

While the outlook for InP lasers remains challenging in the short term, IQE is engaging with several new customers who are forecasting growth, as global supply chains adapt to current conditions. The firm is in the final stages of qualification for what it says is a significant opportunity for full-service 10G distributed feedback (DFB) laser production, with revenues anticipated in fourth-quarter 2019. In addition, major progress has been made in developing next-generation 25G full-service DFBs for high-speed datacoms, hyperscale datacenters and 5G applications.

IQE may experience some delay to orders and the potential for adjustment of supplier-managed inventory levels, predominantly in its Wireless business unit.

It has very recently received a reduction in forecasts from a number of chip customers, in Wireless and also in Photonics

Wireless

For the Wireless segment, IQE now expects the year-on-year decline in revenue for full-year 2019 to be 20-25% rather than the prior guidance of just 15%.

IQE says that it is seeing significant global supply chain shifts that are affecting short-term revenues from power amplifier (PA) products, but is engaged in initial production activities with two key Asian customers who stand to benefit from significant additional volumes in the medium term, with the anticipation of second-half 2019 revenues from these customers.

IQE says that, in first-half 2019, continued strong progress has been made in R&D on the unique 5G RF filter materials portfolio based on its patented cREO (crystalline rare-earth oxide) technology, and the firm remains actively engaged with several chip customers to bring this product to market.

Infra Red

Guidance for the Infra Red segment remains unchanged, at 15% year-on-year growth. IQE says that this segment continues to perform strongly and provides a source of stability and customer diversification to its portfolio.

Adjusted Operating Profit

Given the reduction in expected revenues, IQE expects to remain profitable in 2019 but with adjusted operating profit margin significantly below the previous guidance of over 10%.

While its cost base is largely fixed in the short term, IQE is taking steps to reduce costs and avoid non-critical capital expenditure. This includes the acceleration of the assessment of strategic projects to optimize the firm's global manufacturing footprint. Active management of all cashflows will ensure that IQE remains within the limits of its current revolving credit facility in 2019.

Outlook for 2020

IQE says that it remains cautiously optimistic about growth opportunities for 2020 and, as global supply chains adjust, it expects that the significant market drivers such as 5G, connected devices and LiDAR will regain momentum. The firm reckons that it remains in a very strong position to capitaliez on this, due to its unique breadth and depth of products, global production capacity and intellectual property. IQE adds that the steps being taken to adapt and manage through this period of uncertainty will ensure that it is well placed to grow revenue and expand margins in the eventual rebound cycle.

"These are unprecedented times for the global semiconductor industry as geo-political conditions affect interconnected global supply chains," notes chief executive Dr Drew Nelson. "It is now clear that the impact of Huawei's addition to the US Bureau of Industry and Security's Entity List is having far-reaching and long-lasting impacts on global supply chains. This is a matter outside of IQE's control, but we have responded swiftly to leverage our breadth of relationships and to pursue new sales opportunities," he adds. "We are also taking prudent expenditure actions in order to manage through this period of uncertainty. IQE remains well placed to adapt to mid- to long-term share shifts at both the component (chip) and the OEM level. Indeed, we are now seeing increasing activity from customers in alternative supply chains across our business units as these supply chains respond to current market dynamics. We anticipate significant new customer qualifications during the second half of 2019 as a result. As global markets adjust and recover, we remain extremely well placed for significant future growth."

Huawei's addition to the US BIS' Entity List is having far-reaching and long-lasting impacts on global supply chains. We are taking prudent expenditure actions in order to manage through this period of uncertainty

www.iqep.com

Advanced Vacuum opens Stockholm sales & service center

Advanced Vacuum Distribution AB of Lomma, Sweden (which sells and services semiconductor and vacuum equipment) has opened a new service center in Uppsala, Sweden.

Owned by Plasma-Therm LLC of St Petersburg, FL, USA since 2011, Advanced Vacuum is the certified service agent and distributor of Edwards products in Sweden. Led by Jonas Wermenstam, the new Advanced Vacuum Distribution Service Center will provide sales and service coverage for Stockholm and surrounding regions, focusing on the distribution and service of all Edwards products.

"This new AVD facility will increase the availability of service and technical support for existing and new customers," says CEO Peter Christensen, who cites increased demand.

www.Advanced-Vacuum.com

Aixtron partners in UltimateGaN project to make power semiconductors available for broad applications at competitive cost

€48m funding from ECSEL Joint Undertaking supported by EU's Horizon 2020 program

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that it is a partner in the European research project UltimateGaN (research for GaN technologies, devices and applications to address the challenges of the futureGaN roadmap). In addition to Aixtron, 25 other companies and institutions from nine countries have come together to research the next generation of energy-saving chips based on gallium nitride (GaN) over the next three years. The aim is to make these power semiconductors available for a wide range of applications at globally competitive costs.

UltimateGaN is one of the largest existing European research projects in semiconductor development. The €48m in funding consists of investment by industry, subsidies from the individual participating countries and the Electronic Components and Systems for European Leadership (ECSEL) Joint Undertaking (JU).

Efficient use of energy for climate protection

"By developing intelligent technologies, we are making a key contribution to the global challenge of climate change," says Aixtron president Dr Felix Grawert. "New materials and efficient chip solutions play a key role here. With this research project, we are creating the conditions for making innovative energy-saving chips available for many future-oriented everyday applications," Grawert adds.

"Gallium nitride semiconductor devices are revolutionizing energy use on many levels," says professor Michael Heuken, Aixtron's VP Research & Development. "The research project opens up an enormous global market potential," he adds. "It enables better performance and efficiency in a wide range of applications and significantly improves user comfort. Efficient operation of servers and data centers, fast and wireless charging of smartphones, data exchange between machines in real time, or lightning-fast video streaming become reality."

UltimateGaN — smaller, energy-efficient chips at marketable costs

UltimateGaN's objective is to develop innovative power and high-frequency electronics from GaN. Aixtron is contributing its expertise as a supplier to the semiconductor industry and in the production of GaN to the research project: The production of high-quality wafers using metal-organic chemical vapor deposition (MOCVD) technology is carried out on Aixtron equipment at the Infineon plant in Villach, Austria.

UltimateGaN is one of the largest existing European research projects in semiconductor development

In terms of materials and processes, research is now going one step further to develop the next generation of these highly efficient energy-saving chips for the mass market: The focus is on further miniaturization and provision of the chips in high quality and at globally competitive costs. The unique material structure of GaN enables higher current densities to be achieved, which allows smaller and lighter designs that switch the current much more efficiently and can transmit higher data rates more quickly. The result is a significant reduction in energy consumption: current losses are reduced by up to 50%. ►

UltimateGaN project partners

UltimateGaN's 26 partners from nine countries include: Austria Technologie & Systemtechnik AG, Infineon Technologies Austria AG, Fronius International GmbH, CTR Carinthian Tech Research AG, and Graz University of Technology (of Austria); IMEC (in Belgium); Aixtron SE, Infineon Technologies AG, Siltronic AG, Max-Planck-Institut für Eisenforschung GmbH, Fraunhofer Society for the Promotion of Applied Research e.V., Chemnitz University of Technology and NaMLab GmbH (of Germany); Università degli studi di Padova, Infineon Technologies Italia, and Universita di Milano Bicocca (of Italy); Eltek AS (in Norway); Slovak University of Technology in Bratislava, and Nano Design SRO (of Slovakia); Ecole Polytechnique Fédérale de Lausanne (EPFL) and Attolight SA (of Switzerland); IKERLAN, For Optimal Renewable Energy, and LEAR (of Spain); and RISE Research Institutes of Sweden AB and SweGaN AB (of Sweden).

The project has received funding from the ECSEL Joint Undertaking (JU) under grant agreement No 826392. The JU receives support from the European Union's Horizon 2020 research and innovation program and Austria, Belgium, Germany, Italy, Slovakia, Spain, Sweden, Norway, Switzerland.

Profit from renewable energy, e-mobility and faster data transfer

Many applications in which low energy consumption, compact designs and faster data exchange are key will benefit from the use of the chips. The energy efficiency of high-performance servers and other IT infrastructure devices will gain a further boost with the research project: power dissipation can be significantly reduced by the higher switching efficiency of GaN power devices. The new 5G mobile communication standard and ultra-fast video loading are also supported, for example, as is real-time traffic flow control for autonomous driving or, in the context of Industry 4.0, easy communication between machines.

Research focuses along the entire value chain

When seeking to miniaturize GaN chips, the small and compact design as well as the complex technology required for the connections and packaging present special challenges. High current densities, the effect of electrical fields, and material stresses and stabilities must be taken into account. As a result, the research will take a holistic approach with the entire value chain in focus — from process development, design, assembly and packaging technologies to integrated system solutions. The consortium of partners from academia and business is therefore equally broadly based.

www.aixtron.com
www.ultimategan.eu

Lake Shore's all-in-one instrument offers complete Hall measurement and analysis

Lake Shore Cryotronics Inc of Westerville, near Columbus, OH, USA (which makes scientific sensors, instruments and systems for measurement and control under low-temperature and magnetic field conditions) claims that, for researchers studying semiconductor materials, its new MeasureReady M91 FastHall measurement controller delivers significantly higher levels of accuracy, speed and convenience compared with traditional Hall-effect measurement solutions.

Combining all the necessary Hall measurement system functions into a single instrument, the M91 automatically executes measurements, collecting the data and calculating the final Hall and mobility parameters, outputting 'answers' not just data. By automatically optimizing the excitation and measurement range, the instrument eliminates manual trial-and-error steps and ensures that measurements are always made under optimal conditions for the sample.

LakeShore's M91 FastHall controller.

The instrument is said to also provide better measurements faster – especially with low-mobility materials. Most commonly measured materials can be analyzed in a few seconds. Its speed is due to Lake Shore's patented FastHall technology, which eliminates the need to reverse the magnetic field during the measurement. This is particularly beneficial when using superconducting magnets, which are relatively slow at completing field reversals.

The firm also says that the M91 is easy to use, can be integrated easily with existing lab systems, and provides a cost-effective way for researchers to build a new Hall system or upgrade an existing one.

www.lakeshore.com

Riber licenses LAAS-CNRS' reflective surface defect and curvature measurement technology

EZ-Curve in-situ control device unveiled for vacuum thin-film deposition

Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has signed an operational licensing agreement with Toulouse Tech Transfer (TTT, a regional operator for creating value and transferring technology from public research to businesses in France's Occitanie region) for the exclusive marketing of a reflective surface defect and curvature measurement technology, developed by the Laboratory for Analysis and Architecture of Systems (LAAS-CNRS), one of the largest in-house units of the French National Centre for Scientific Research (CNRS).

Dedicated high-precision metrology technology for semiconductor manufacturing

Research engineer Alexandre Arnoult and post-doctoral researcher Jonathan Colin of LAAS-CNRS have developed an optical device that is easy to implement and helps to improve control over operations to deposit thin films. The device can be used in any type of environment.

This makes is possible to measure curvature and defects on all types of surfaces in real time and over significant production times. For example, it helps to avoid dislocations, produce perfectly even wafers or control deposit consistency. The device will also be equipped with machine learning algorithms that will be specially developed to optimize analysis and control for the materials growth process.

EZ-Curve: new technological component for Riber's strategic development

The know-how based on this research — marketed under the new EZ-Curve brand — will enable Riber to extend its range of solutions and services, providing research laboratories and semiconductor manufacturers with added value in line with their needs, the firm says.

Alexandre Arnoult together with the demonstration unit at the Laboratory for Analysis and Architecture of Systems (LAAS-

For industrial users, ensuring the traceability and reliability of their measurements is key to effectively managing their manufacturing processes and guarantee product quality and performance, Riber adds. For researchers, analyzing and understanding materials growth-related behavior makes it possible to expand fundamental knowledge.

In addition to controlling the epitaxial growth process with high-precision 3D reflectance metrics, EZ-Curve also offers wider possibilities by supporting the implementation of automated advanced control processes and, over the longer term, the development of smart MBE systems.

"EZ-Curve is a significant technological innovation compared with the measurement instruments currently available on the market," reckons Riber's CEO Philippe Ley. "Our ambition is to provide our clients with the very precise levers needed to considerably improve their processes and the results of their developments, whether they are academic or industrial," he adds. "This new technological component and its industrialization will make it possible to further strengthen MBE performance capabilities".

The new device is said to offer a range of benefits: being non-invasive, cost-effective, portable, lightweight, easy to install and use, EZ-Curve is adapted for in-situ epitaxial process analysis.

"Monitoring a wafer's deformations during the vacuum growth or processing of a thin film represents an unrivalled source of information on the atomistic processes involved, and quality control for industrial processes," says Arnoult. "Until now, this monitoring was reserved for specialists using tools that were complex to master," he adds. "Our new technology successfully makes it possible to achieve this combination of increased sensitivity with outstanding robustness and simple implementation, which enables [the user] to deploy it across a large number of advanced and/or production systems. For example, we can now continuously monitor molecular beam epitaxy growth for complex semiconductor structures with low constraints, opening up possibilities for in-situ feedback control during processes, and therefore optimization and automation of processes."

Following maturation and market release phases, Riber, LAAS-CNRS and TTT intend to continue sharing their knowledge in order to support the product's development worldwide.

www.riber.com
www.laas.fr
www.toulouse-tech-transfer.com

OIPT launches Atomfab high-volume ALD for GaN power device passivation

UK-based plasma etch and deposition processing system maker Oxford Instruments Plasma Technology (OIPT) has launched a plasma atomic layer deposition (ALD) high-volume manufacturing (HVM) solution delivering what is said to be a step change needed to address fundamental challenges in the gallium nitride power device industry.

Gallium nitride devices are enabling the next generation of efficient power electronic devices for applications such as compact consumer power supplies, 5G networks, electric vehicles (EVs) and renewable energy conversion. Although GaN devices are more efficient and higher performance than existing technologies, there are manufacturing yield and scalability challenges that need to be addressed to deliver reliable devices at a competitive cost.

A key challenge is a consistently high-quality gate passivation. OIPT says that Atomfab delivers this with high throughput and low cost of ownership (CoO), highlighting the following aspects:

- passivation and dielectric properties enable the demanding device performance critical for key applications;
- remote plasma delivers a reproducible GaN interface — Atomfab precisely controls the plasma to protect the underlying sensitive GaN substrate;
- high throughput delivered by a high-deposition-rate process on a high-uptime HVM platform specifically developed for GaN power applications.

OIPT says that the significantly reduced cost per wafer that Atomfab delivers is enabled by numerous technical innovations including a patent-pending fast remote plasma source.

The firm adds that Atomfab fulfils the customer needs on a single wafer platform with SEMI-standard cluster configurations and improved process controls for the latest compound semiconductor solutions.

"Atomfab provides many key benefits to our GaN device manufacturing customers including significant CoO reduction, increased yield and excellent film quality and device performance," claims strategic business development director Klaas Wisniewski, adding that OIPT has now applied its compound semiconductor plasma processing expertise to a HVM platform.

"We've been highly commended for our unique plasma ALD solutions and have listened to our HVM customers to take these solutions to the next level," says managing director Mike Gansser-Potts. "Atomfab provides these HVM solutions to our customers".

www.oxford-instruments.com/plasma

EVG launches HERCULES NIL 300mm fully integrated lithography track system

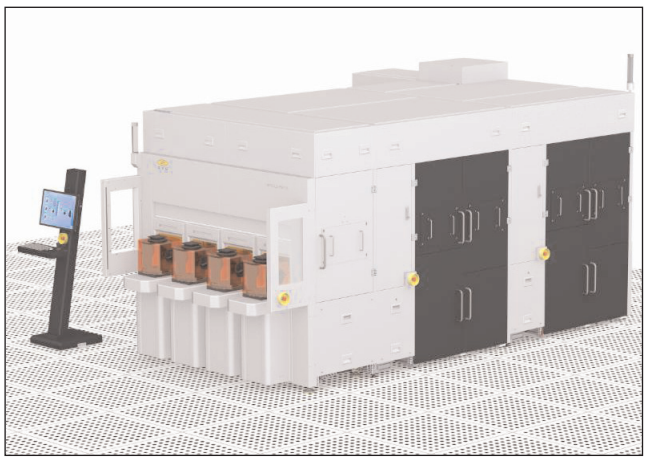
EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — has unveiled the HERCULES NIL 300mm — a fully integrated track system that combines cleaning, resist coating and baking pre-processing steps with EVG's proprietary SmartNIL wafer-level nanoimprint lithography (NIL) process in a single platform for wafers up to 300mm in diameter.

The HERCULES NIL 300mm is a highly versatile platform designed for companies targeting high-volume manufacturing (HVM). It is the first NIL system based on EVG's fully modular equipment platforms with swappable modules to give users maximum freedom to configure their systems to best meet their production needs, including bridge capabilities for 200mm and 300mm wafers. EVG's SmartNIL technology has also been improved and modularized for the HERCULES NIL 300mm, providing what are claimed to be the most advanced nanoimprint capabilities on the market with low-force and conformal imprinting, fast high-power exposure and smooth stamp detachment.

The HERCULES NIL 300mm supports the production of a variety of devices and applications, including optical devices for augmented/virtual reality (AR/VR) headsets, 3D sensors, bio-medical devices, nanophotonics and plasmonics. Demonstrations of the new system are now available at EVG's NILPhotonics Competence Center. The firm has already received multiple orders for the new system.

Fulfilling potential of nanoimprint lithography

NIL has proven to be a highly efficient method to fabricate micro- and nanopatterns on large areas, to replicate complex structures and to directly pattern functional layers for a wide range of structure sizes and shapes, says EVG. As a result, NIL is increasingly becoming a key enabling technology to support the production of new devices and applications across a wide range of markets, particularly in photonics and biotechnology. As demand for NIL-enabled devices and applications continues to grow, NIL solutions must be capable of scaling up to higher levels of productivity while maintaining low cost of ownership, adds the firm. SmartNIL technology is the result of years of research, development and field experience to address nanopatterning requirements that cannot be supported by conventional lithography, and has been field proven to be easily scalable from die-level sample sizes all the way up to large-area substrates.



HERCULES NIL 300mm fully modular and integrated SmartNIL UV-NIL system.

"The HERCULES NIL 300mm represents a major leap forward in bringing SmartNIL to high-volume, wafer-level manufacturing," believes executive technology director Paul Lindner. "The platform has literally been built from the ground up for high productivity and to provide customers with a high degree of flexibility to support their evolving production needs. For more than 20 years, EV Group has pioneered NIL technology, and today we have the dominant market share worldwide," he adds. "We work in close collaboration with our customers to ensure their success in implementing NIL in their manufacturing strategy and to provide them with the best possible solution to meet their needs. An example of this is our NILPhotonics Competence Center, which reduces the entry barrier for nanoimprinting and gives easy access to a world-class infrastructure and nanoimprint experts."

Key attributes of the HERCULES NIL 300mm include:

- fully automated UV-NIL imprinting and low-force detachment;
- processing substrates up to 300mm in diameter;
- fully modular platform that can accommodate up to eight swappable process modules (imprinting and pre-processing), for higher tool productivity;
- 200mm/300mm bridge-tool capability (providing greater flexibility and longer tool lifetime);
- full-area imprint coverage (which avoids pattern stitching errors associated with step-and-repeat lithography systems due to limited field size);
- volume manufacturing of structures down to 40nm and smaller;
- supports a wide range of structure sizes and shapes (including 3D);
- can be used on high-topography (rough) surfaces;
- ability to replicate multiple-use soft stamps to extend the lifetime of master imprint templates; and
- equipped with front-end module with up to four load ports (300mm FOUPs/200mm open cassettes) for continuous operation.

www.evgroup.com/en/products/lithography/nanoimprint_systems

EVG investing €30m to expand capacity at HQ

Construction of 620m² cleanroom creates extra development, demonstration and pilot production capacity

EV Group — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — has begun construction on another building project at its corporate headquarters in St. Florian am Inn, Austria. With an investment of €30m, the new Cleanroom V building will create additional capacity for product and process development, equipment demonstrations for existing and potential customers, feasibility studies as well as prototyping and pilot production.

The groundwork for the new building was recently finished and includes footings up to 14m deep into the ground. After the new cleanroom is completed, it will host equipment such as EVG's lithography systems, wafer bonders and metrology systems-(operating at micro- and nanometer accuracies). EVG says that the contaminant-free conditions of its cleanrooms at its headquarters, as well as its subsidiaries in America and Asia, are comparable to those in the fabs of customers worldwide.

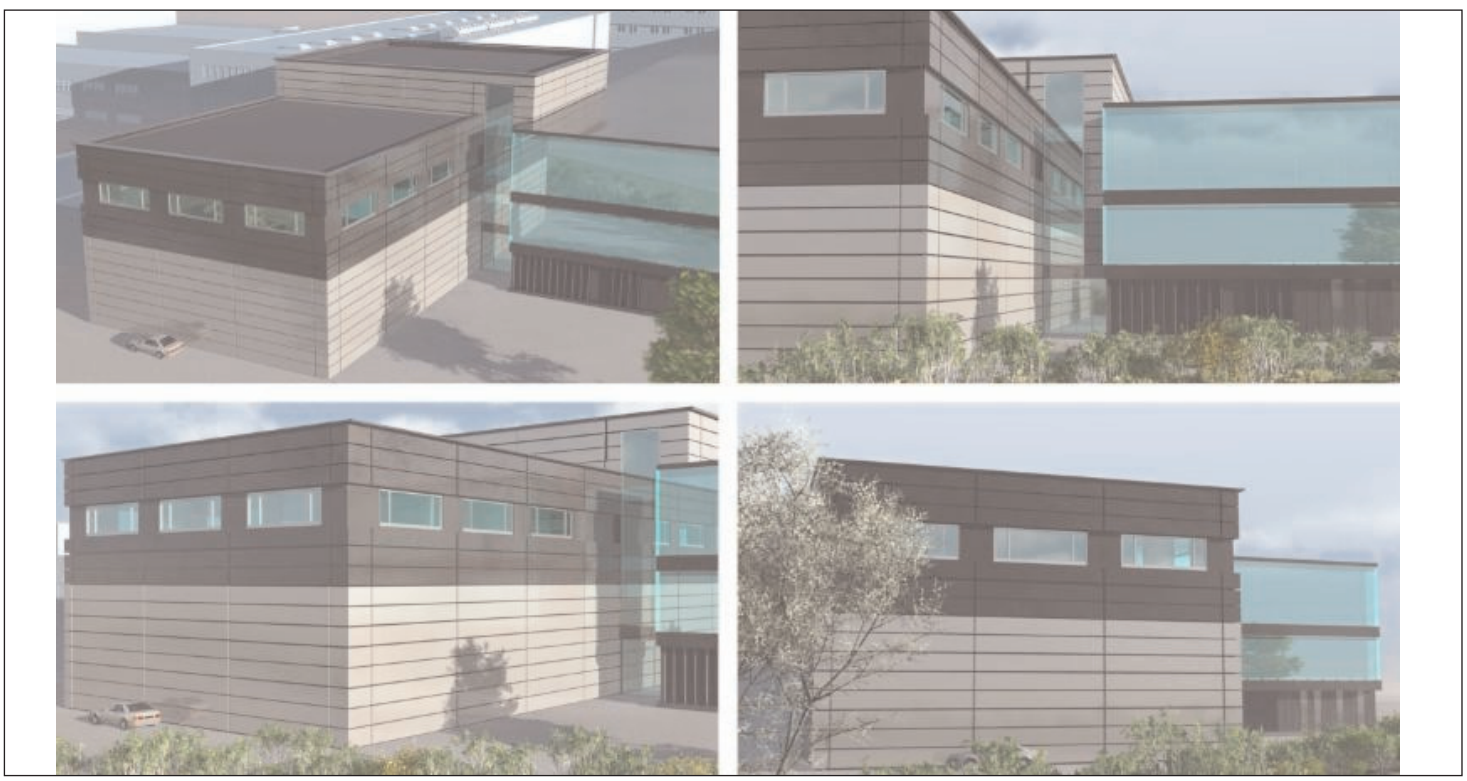
"Just this past April, EV Group celebrated the opening of our new Manufacturing III facility with our employees, which itself provides 1800m^2 of additional production floor space for the final assembly of our equipment," notes executive operations & financial director Dr Werner Thallner. "Meantime, the construction crews already started to work at the other end of our campus on this new building, which will add even more capacity to support our business growth. With the investment in expanding our cleanroom capacity, we continue to demonstrate our local commitment to Austria, as well as our global commitment to our worldwide customers," he adds.

"Our engineers develop and optimize wafer processes for our equipment to fulfill individual production requirements, often in close cooperation with our customers," says corporate technology development & IP director Markus Wimplinger. "This new building will open completely new opportunities to the EVG technology teams," he believes.

The new Cleanroom V building will provide about 620m2 of additional cleanroom floor space — nearly doubling cleanroom capacity at EVG's headquarters. In total, the new building will encompass a floor space of about 4400m^2. Construction work is due to be completed by the middle of 2020.

EVG says that, in the last 10 years alone, investment at its headquarters (where worldwide development and production are centralized) amounted to nearly €100m. During this period, EVG expanded its manufacturing capacity, machining center, cleanrooms and application labs in several stages and built a new R&D center and training center. Also, in addition to the new reception and office building with its continuous glass front, a large company restaurant as well as a day-care facility for EVG staff were created.

www.EVGroup.com



3D rendering of new building adjacent to existing reception and office building.

Palomar partners with UK's Electronics and Photonics Innovation Centre

Investing $1m in equipment for demo lab for photonics packaging

Photonics and microelectronic device assembly & packaging equipment maker Palomar Technologies Inc of Carlsbad, CA, USA is partnering with the Electronics and Photonics Innovation Centre (EPIC) to establish a Palomar Demonstration Laboratory. As part of the partnership, Palomar is investing $1m in equipment, including a fully loaded 3880 die bonder and an 8000i ball/bump wire bonder for use by customers at the EPIC facility in Paignton, Torbay (the heart of an electronics and photonics cluster in the UK).

As a center of excellence supporting technological innovation and promoting collaborative activity between businesses and research institutions, EPIC (which is managed by TDA, a trading name of Torbay Economic Development Co Ltd) focuses on supporting start-up and spin-off companies and encourages foreign direct investment to Torbay and its microelectronics and photonics sector.

Palomar's 3880 die bonder.

Palomar's equipment will support many key businesses in Torbay's photonics and microelectronics cluster, says Josef Schmidl, Palomar's managing director EMEA. "Our focus is to enable our customers to realize the high-growth-potential opportunities that are available in these exciting, rapidly evolving industry sectors."

"Palomar is one of many businesses who are seeing the opportunities that EPIC brings," says EPIC director Wayne Loschi. "This type of collaboration will drive innovation and the emergence of new technologies in a thriving sector."

Targeting European photonics companies, the Palomar Demonstration Laboratory provides the opportunity to learn more about the firm's techniques driving the photonics market and also to take advantage of prototyping and process development services utilizing its decades of experience in the photonics market. In December, Palomar opened a full-service Innovation Center in Singapore to complement its existing Innovation Center in Carlsbad, and this latest demonstration laboratory further reaches out to photonics companies to make its solutions more readily available.

www.palomartechnologies.com
www.epic-centre.co.uk

DISCO completes construction of new US head office in Silicon Valley

Relocation from Santa Clara to San Jose to be completed in early July

Tokyo-based equipment maker DISCO Corp — which makes semiconductor manufacturing equipment including chemical mechanical polishing (CMP) systems and laser-based ingot slicing equipment and processes for silicon carbide (SiC) — says DISCO HI-TEC America Inc has completed construction of its new head office/sales & service office in Silicon Valley for the purpose of strengthening the organization's ability to respond to customer requirements. The new office building at 5921 Optical Court in San Jose, CA 95138, USA has a floor area about three times larger than the existing building in Santa Clara, CA (6200m^2, rather than 2000m^2) and processing space about 3.5 times larger (including a cleanroom). Construction costs (site, building acquisition, renovation) totaled $21m.

Artist's impression of new DISCO HI-TEC America HQ.

DISCO says that, with advances in Internet of Things (IoT), medical, communications and self-driving technology, the development needs for semiconductors and electronic components is increasing, causing the number of requests from manufacturers for processing verification and contracted processing in the device development stages to increase. Thus, it was essential for DISCO to further enhance its services.

DISCO HI-TEC America Inc provides sales and maintenance of precision processing equipment, precision processing tools and related equipment, applications support, and contracted processing services.

Relocation to the new office building should be completed in early July.

www.disco.co.jp

Nanometrics and Rudolph agree merger

Process control metrology and software analytics provider Nanometrics Inc of Milpitas, CA, USA and Rudolph Technologies Inc of Wilmington, MA, USA (which makes lithography equipment, process control systems and process control software for semiconductor and advanced packaging device makers) have agreed to combine in an all-stock merger, forming an end-to-end metrology, inspection, process control software and lithography equipment provider for the semiconductor industry and other advanced markets.

As unanimously approved by the boards of directors of both firms, Rudolph stockholders will receive 0.8042 shares of Nanometrics common stock for each Rudolph share. Post-merger, current Nanometrics and Rudolph stockholders will each own 50% of the combined firm.

Rudolph's CEO Michael Plisinski will be CEO and chief financial officer Steven Roth will be CFO of the firm, alongside a team consisting of executives from both companies. The board will be led by Nanometrics' director Christopher Seams and will have 12 directors, (six from each existing board). The firm will be based in Wilmington but maintain a strong presence at Nanometrics' headquarters in Milpitas.

"Nanometrics has a long history of innovation in the field of optical metrology, pioneering the use of scatterometry for semiconductor process control," says its president & CEO Pierre-Yves Lesaicherre. "In recent years, we have established a strong position in optical critical dimension metrology, enabling the ramp of advanced technology nodes by each of the major semiconductor manufacturers worldwide." The merger marks "the culmination of our respective businesses' growth, diversification and increased scale," he adds. "The combined global support organizations, technology development teams and product portfolio will create a unique, end-to-end solution provider across the entire semiconductor fabrication process. The combined firm will be able to provide improved device yield at reduced manufacturing cycle time, supporting the accelerated product life cycles in the semiconductor and other advanced markets," he believes.

"This strategic transaction brings together two successful and complementary teams and product portfolios," says Plisinski. "Nanometrics' metrology portfolio is a strong strategic fit with Rudolph's current diversified product lines including software, inspection, metrology and lithography. Our current set of products has already created integrated solutions for the advanced packaging market, and we expect to develop new integrated solutions for customers as we are able to draw from an even larger set of products in the future," he adds. "Our customers are consolidating and rapidly innovating across the complete value chain from front-end fabrication to packaging. Bringing these two successful and complementary teams together enables us to solve our customers' high-value problems in the years ahead."

Merging two highly complementary inspection and metrology companies is expected to yield the following:

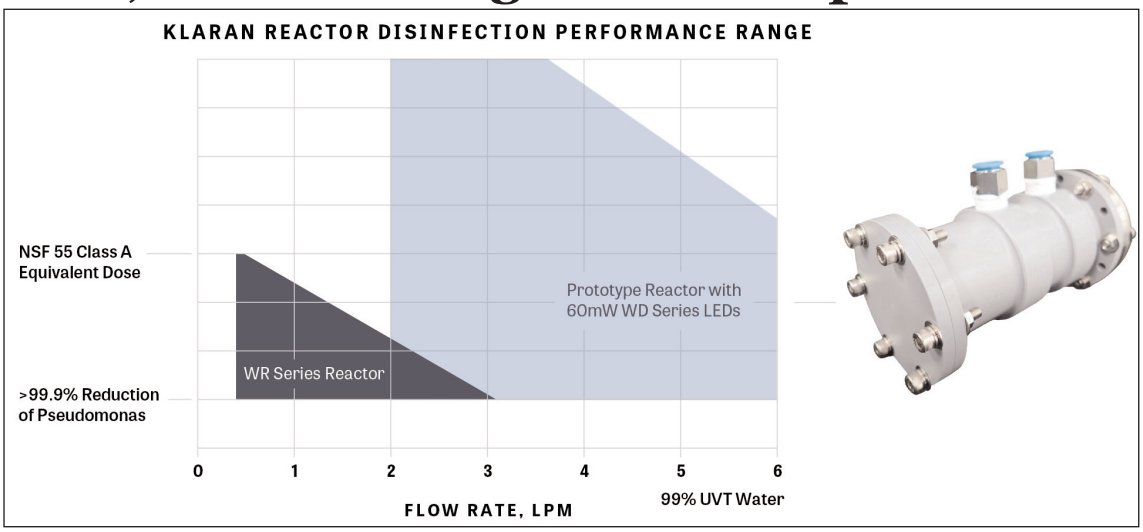
- Complementary products: By bringing together front-end metrology with inspection solutions, it is believed that the new firm will have the opportunity to offer more comprehensive process control solutions. These served markets are also complementary, as the combined product portfolio provides tools and software to those producing advanced nodes and specialty devices in the front-end along with advanced packaging in the back-end. As customers continue to invest in more advanced process control solutions, the combined technology portfolio and established channels to these markets is expected to accelerate the ability to serve both front-end and back-end markets.
- Enlarged served markets: Each firm currently has a semiconductor industry SAM of at least $1bn, with additional SAM (serviceable addressable market) expansion opportunities of $400–500m per company. The combination is expected to expand this to about $3bn. With each firm's capabilities in their respective served markets, the merger should strengthen the combined team's opportunity to grow their share of the combined SAM and invest in expansions.
- Global scale: The combined firm's broader, global scale (with locations and facilities across the USA, China, Europe, Japan, South Korea, Singapore and Taiwan) is expected to enable it to better invest, compete and provide innovative services to the customer base. Nanometrics and Rudolph together had $600m in revenue and $118m in operating income (for 2018). Also, at the end of Q1/2019, they had $319m in combined cash and marketable securities, $526m working capital and no debt.
- Strong cash generation: In 2017 and 2018 the firms generated a collective $223m in cash flows from operating activities. The combination is expected to enhance free cash flow generation of the merged enterprise, resulting in a stronger cash position to enable strategic capital deployment.
- Increased shareholder value: The combined firm is expected to drive long-term shareholder value through cost synergies and revenue growth opportunities. Annual cost synergies of at least $20m are expected, primarily from elimination of duplicate public company costs, elimination of redundant facility leases, and other general administration areas. The firms expect extra potential upside from revenue synergies via cross-selling and software modules.

The transaction is expected to close in second-half 2019.

www.nanometrics.com
www.rudolphtech.com

Klaran launches 60mW UVC LED & reactor prototype for water disinfection, demonstrating NSF Class A performance

Crystal IS Inc of Green Island, NY, USA, an Asahi Kasei company that makes proprietary ultraviolet light-emitting diodes (UVC LEDs), says that its Klaran product line has gained a new 60mW UVC LED in its water disinfection (WD) series.



In an advanced prototype reactor, the 60mW LED has demonstrated effective and affordable water treatment at flow rates up to three liters per minute, with disinfection rates comparable to NSF/ANSI 55 Class 'A', says the firm. Klaran's existing WD series LEDs and water treatment reactors are used to treat point-of-use (PoU) water at flow rates up to two liters per minute and at disinfection rates comparable with NSF/ANSI Class 'B'.

The new reactor, which is expected to be ready for market in early 2020, incorporates a user-replaceable LED 'engine' to address both the different market performance requirements and alternate business revenue models of the commercial water industry. Similar to Klaran's other WD series devices, the new LED is priced at under 25 cents per mW. "The introduction of our new 60mW LED marks another milestone in proving that UVC LEDs can affordably deliver the performance needs of the commercial and consumer point-of-use markets," says Eoin Connolly, VP for Klaran.

Klaran's expanding portfolio of products enable manufacturers and distributors of point-of-use water products to reduce their total cost of ownership by addressing maintenance issues, such as annual replacement and unplanned service, related to traditional UVC technologies, says the firm. "An unplanned UV lamp failure can quickly cost hundreds of dollars to a service provider, making a serious impact on profit margins," notes Connolly. "Our rigorous testing of thousands of Klaran devices and ISO 9001 quality system provide the data-driven proof in the reliability and performance of our Klaran products," he adds.

www.cisuvc.com/products/klaran

AquiSense's PearlAqua Micro UV LED system validated to US-EPA protocols across all five models

Nikkiso Group company AquiSense Technologies LLC of Erlanger, KY, USA (which designs and makes water, air and surface disinfection systems based on UV-C LEDs) says that it has become the first UV LED supplier to be tested against US-EPA protocols. Its PearlAqua Micro range was verified by Hull Consulting LLC in compliance with US-EPA microbiological performance protocols.

The PearlAqua Micro is claimed to be the world's smallest UV system. With thousands of installations this year alone, the range offers benefits through LED current sensing and UV intensity monitoring as well as a variety of other design benefits specific only to AquiSense. The PearlAqua Micro is designed to be integrated at the point of use for disinfection applications.

PearlAqua Micro is validated to US-EPA protocols to meet microbiological performance with flow rates of 0.1–10.0LPM. This validation provides reduction equivalent dose (RED) allowing AquiSense to support customers selecting the appropriate configuration for their application, flow rate, microbiological performance, and UV dose. The firm offers five models in the PearlAqua Micro range, all of which comply with required UV dose standards set by the US-EPA.

"Validating our product line has been a key strategy for us to offer customers the most reliable and trusted information on the performance of our products," says chief technology officer Jennifer Pagan. "We take validation and certification very seriously, as the claims we make affect the health and safety of our customers," she adds. "Being third-party tested according to standards set by the US-EPA is a prime example of our willingness to offer trusted performance."

www.aquisense.com

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Seoul Semiconductor files patent lawsuit against second Philips TV display distributor for infringement of LCD backlight system technology

South Korean LED maker Seoul Semiconductor Co Ltd has filed a patent infringement lawsuit in the United States District Court for the Central District of California against The Factory Depot Advantages Inc, a distributor of Philips TV displays.

Seoul asserts that a Philips LED TV display being sold by this distributor infringes 10 patents regarding manufacturing of LED backlighting units. In particular, the patented technologies encompass an LED TV backlight unit system for enhancing the color gamut of LCD displays, and LED lenses for providing uniform illumination to LCD displays.

Seoul says that it has made significant R&D efforts since the beginning of the LED backlight technology, and has established thousands of LED chip/package patents, 150 optical lens patents, and 200 high-color phosphor application patents.

This is the second patent infringement lawsuit that Seoul has filed against a Philips TV product distributor, after filing a lawsuit last year for infringement of 19 patents against Fry's Electronics (a US big-box retailer that sold allegedly infringing TV products). That litigation is also currently ongoing in the US District Court for the Eastern District of Texas.

"To protect our LED backlight system technology, we have demanded a cease of infringement against global TV companies, TV ODM/OEM manufacturers, and LCD display manufacturers operating in the US, Europe and Asia," says Sam Ryu, Seoul's VP of IT business. "To establish fair market competition culture, wrong practice — attempting unfair competition by using low-cost components that infringe hard-earned patents — should be eliminated."

www.seoulsemicon.com

Seoul Semiconductor files patent suit against European distributor of MEGAMAN Lighting Products

Seoul Semiconductor has filed a lawsuit in Germany in the District Court of Düsseldorf asserting that European LED lighting distributor Leuchtstark Vertriebs GmbH is selling a 'MEGAMAN' brand lighting product that infringes two of its LED patents. MEGAMAN is an Asian-based LED lamp brand. Seoul is currently investigating Leuchstark's OEM/ODM manufacturers as well as other distributors.

The asserted patents relate to one of Seoul's LED light extraction patent portfolios. In December, Seoul successfully enforced a patent in the field of LED light extraction technology, and the District Court of Düsseldorf ordered an injunction against sales of the accused Everlight products as well as a recall of any such products sold after 13 July 2012.

Seoul holds rights to more than 14,000 LED patents, and has notified 90 companies regarding TVs, cell phones, lighting and automobiles of patent infringements in the past year. Seoul has successfully enforced 62 patents in eight countries in the past five years.

"Respecting intellectual property is essential to establish a fair competition business culture," says Nam Ki-bum, executive VP of the Lighting Department at Seoul Semiconductor. "We will take all necessary legal actions against companies that have suspicions of infringing our patents or of unlawful access to our trade secret by luring employees, as we have done against Everlight," he adds.

www.SeoulSemicon.com

Plessey's GaN-on-Si micro-LED emissive display wins two Electronics Industry Awards

At the 2019 Electronics Industry Awards at London's Tower Hotel, UK-based Plessey received the Display Product of the Year and the Embedded Solution Product of the Year for its micro-LED Emissive Display.

Plessey provides full-field emissive micro-LED displays combine very high-density RGB pixel arrays with high-performance CMOS back-planes to produce high-brightness, low-power and high-frame-rate image sources for head-mounted displays (HMDs) and augmented reality (AR) and virtual reality (VR) systems. The firm has 150mm and 200mm wafer processing facilities (to undertake design, test and assembly of LED products) as well as a suite of photonic characterization and applications laboratories.

"As demand for micro-LED displays is accelerating, Plessey's GaN-on-silicon is recognized as the only technology platform capable of addressing all of the challenges involved with manufacturing micro-LED displays in high volumes cost-effectively," comments Niamh Marriot, editor of CIE magazine. "It

is also one of the only viable solutions that can enable products that are not only compact enough to be worn without restricting the overall experience for AR [augmented reality] applications and in HUDs [head-up displays], but also provide the size, weight, power and luminance needed… With its integrated components and excellent thermal performance, it is a stand-out display," she adds.

"As the only provider of GaN-on-silicon monolithic micro-LEDs, Plessey is disrupting the display market with a technology that delivers a tangibly better consumer experience," says Mike Lee, Plessey's president of corporate & business development.

www.plesseysemiconductors.com/products/microleds

www.electronicsindustryawards.co.uk/winners-2019

Luminus launches Pico-COB LEDs with 3.5mm or 4.5mm light-emitting surface and 675lm or 1255lm output

Luminus Devices Inc of Sunnyvale, CA, USA — which designs and manufactures LEDs and solid-state technology (SST) light sources for global illumination markets — is expanding its Gen4 LED chip-on-board (COB) portfolio with two new Pico-COBs with high output and very small light-emitting surfaces (LES) that enable spot lights with compact form factors, narrow beam angles, and high center-beam candle power.

Small, 6mm LES COBs are typically limited to about 9° viewing angles. Luminus' new Pico-COBs enable fixtures with viewing angles as narrow as 3–5° and produce high flux density (punch) that is important for high quality-of-light directional lighting applications such as retail, museum, residential and hospitality lighting.

The CXM-3 has an LES of 3.5mm and produces up to 675 lumens of at least 90-CRI (color rendering index) warm 3000K light, making it a suitable replacement for a 50W halogen spot. The CXM-4 has an LES of 4.5mm and generates up to 1255 lumens.

As with all Luminus COBs, they are specified and 100% factory tested at a junction temperature of 85°C to ensure performance and consistency that meets the users' expectations in real-world application conditions.

The higher maximum case temperatures and maximum drive currents of Luminus' Pico-COBs with Gen4 technology can be leveraged to create innovative designs with smaller form factors, says Tom Jory, VP of illumination marketing. "This means lighting designers can specify luminaires with our Pico-COBs and create unique dramatic effects with longer throws and narrower beams produced by tiny fixtures incorporating sleek designs that are hidden in the architecture," he adds.

www.luminus.com

Cree cuts June-quarter revenue guidance from $263–271m to $245–252m

Soft demand for LED Products plus Huawei export ban also cut EPS guidance from $0.12–0.16 to $0.08–0.12

Cree Inc of Durham, NC, USA says that — in response to (1) softer-than-expected demand for LED Products (as global trade uncertainties persist) and (2) the US Department of Commerce's Bureau of Industry and Security (BIS) on 15 May adding Huawei Technologies Co Ltd and 68 of its affiliates to its 'Entity List' prohibiting the sale to Huawei of products covered by the Export Administration Regulations (EAR) without obtaining an appropriate export license — it has updated its financial guidance (provided on 1 May) for fiscal fourth-quarter 2019 (ending 30 June).

Revenue for products and materials associated with Huawei's wireless infrastructure build-out were expected to be up to $15m in fiscal Q4/2019.

Pending any further guidance from BIS, Cree does not expect to ship any additional products in fiscal Q4 for the Huawei build-out and cannot predict when it will be able to resume such shipments.

For fiscal fourth-quarter 2019 for continuing operations, Cree has reduced its guidance for revenue from $263–271m to $245–252m (including $132–135m for its Wolfspeed silicon carbide materials, power and gallium nitride RF device business and $113–117m for its LED Products business) and for non-GAAP net income from $12–17m ($0.12–0.16 per diluted share) to $8–13m ($0.08–0.12 per diluted share).

Cree says that it will continue to monitor and provide updates for the impact of the BIS action on its business, including its ability to apply for and obtain licenses from BIS to allow it to ship products to Huawei going forward.

Cree completes sale of Cree Lighting to Ideal Industries

Cree has completed the sale (announced on 15 March) of its Lighting Products business unit (Cree Lighting, including the LED lighting fixtures, lamps and corporate lighting solutions business for commercial, industrial and consumer applications) to Ideal Industries Inc of Sycamore, IL, USA.

"This represents a pivotal chapter for Cree as we sharpen our focus to become a semiconductor powerhouse in silicon carbide (SiC) and gallium nitride (GaN) technologies," says CEO Gregg Lowe."Cree's technologies are helping to power major transitions in our economy, whether it's the automotive industry's transition to electric vehicles or the telecommunications sector's move to faster 5G networks," he adds. "Our leadership in SiC and GaN positions us well to help customers improve performance and realize greater efficiencies."

Cree will use the proceeds from the sale to accelerate the growth of Wolfspeed, its Power & RF business, and expand its semiconductor operations. The firm recently unveiled plans to invest up to $1bn in expanding its silicon carbide capacity to meet the growing demand for SiC and GaN-on-SiC technologies. The expansion includes the development of an automated 200mm silicon carbide fabrication facility and a materials mega factory at its US campus in Durham.

www.idealindustries.com
www.cree.com

Lumileds issues its first sustainability report

Lumileds LLC of San Jose, CA, USA has released its 2018 Sustainability Report, which details its progress in supporting the transition to a worldwide low-carbon economy. The report highlights how Lumileds' lighting solutions are contributing to positive changes in energy usage, safety, and health and wellness.

The firm says it follows a formalized sustainability agenda that identifies specific priorities and tracks progress. For example, in its global LED and automotive lighting operations, it recently surpassed its 2020 operational goals relative to 2015 including:

- 41% reduction in emissions (20% goal);
- 25% reduction in energy consumption (20% goal); and
- 25% reduction in water usage (20% goal).

The sustainability objectives are based on creating value for customers through sustainable innovations, reducing the environmental footprint of the firm's operations, driving improvements in the supply chain toward compliance with the Responsible Business Alliance (RBA) and preventing injuries. Lumileds has aligned its sustainability efforts with external frameworks such as the United Nations Sustainable Development Goals (SDGs), and identified four SDGs to which it can make the most significant contribution: climate action, good health and well-being, affordable and clean energy, and responsible consumption and production.

Lumileds says that its development of energy-efficient, low-carbon LED lighting technologies supports the urgent action to combat climate change. A 2017 market analysis by IHS Markit estimated that Lumileds LEDs reduced total CO2 equivalent emissions of lighting globally by 39 million metric tons (equivalent to shutting down 11 coal fired power plants in the USA). In addition to the 41% reduction in carbon dioxide emissions, three sustainability programs at the Singapore facility reduced the impact of perfluorinated compounds on the environment by 90%.

"Lumileds' commitment to and strong performance in occupational health and safety is demonstrated by our low injury rates, as shown in the report," says Jan van Rompay, director of sustainability. "In the area of hazardous substances, we are on track to phase out in our consumer products the use of all polyvinylchloride (PVC) and non-regulated bromide flame retardants (BFR), substances that are implicated in detrimental effects on human health, by 2023. As of 2018, 87% of Lumileds consumer products are PVC and BFR free."

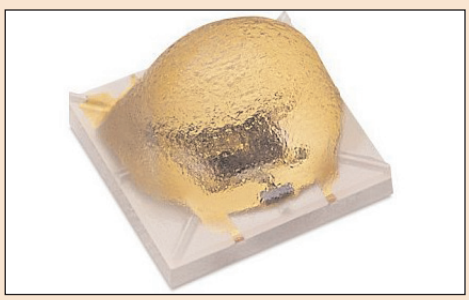
By the end of this year, all Lumileds facilities worldwide will be ISO 14001:2015 and OHSAS 18001:2007 certified. The firm also certified against the International Automotive Quality Management Systems standards (IATF16949:2016), which outlines the requirements on designing, developing, manufacturing, installing and servicing automotive products.

www.lumileds.com/company/sustainability?showReport=1

Lumileds' LUXEON IR Domed Asymmetric emitter matches field-of-view to surveillance camera sensors

Lumileds has announced the latest addition to its LUXEON IR Family, the LUXEON IR Domed Asymmetric, that matches the field-of-view (FoV) aspect ratio of typical cameras used in surveillance, machine vision and time-of-flight systems. The 95 x 58° design is said to dramatically improve image uniformity.

"The asymmetric dome targets long-range applications such as professional surveillance and machine vision systems as well as time-of-flight applications that rely on image uniformity across an entire field," says Wouter Schrama, senior product manager IR Products. "By matching the sensor's aspect ratio, we get the highest utilization of light by uniformly matching the FoV of the camera. This increases system efficiency and offers a path to lower system cost and better performance."



LUXEON IR Domed Asymmetric emitters combine radiant power of 1450mW with an asymmetric dome that improves image uniformity on infrared surveillance cameras.

The LUXEON IR Domed Asymmetric delivers 'state-of-the-art' radiant power of 1350mW at 850nm and 1450mW at 940nm. The emitters are offered in a 3.7mm x 3.7mm package with standard 3-pad configuration for direct upgrade of existing circuit board designs. Component quality is ensured by use of the highest-quality silicone dome, gold-finished solder pads and gold-based bond wires for corrosion resistance. The ceramic package utilizes what is claimed to be the industry's lowest-thermal-resistance substrate (2.5°C/W) for rapid removal of heat, smaller optics and more compact camera designs.

Lumileds has lifetime information including L70 data available for its LUXEON IR Family.

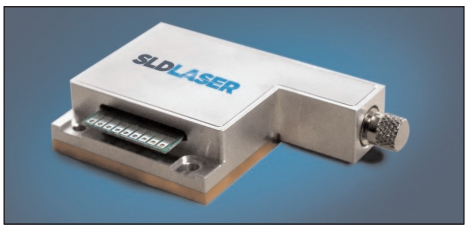
www.lumileds.com/products/infrared-emitters/luxeon-ir-domed-line

SLD Laser demonstrates high-power blue laser modules for materials processing applications

SLD Laser of Goleta, CA, USA (a spin-off from LED lighting firm Soraa Inc that is commercializing visible laser-based light sources and blue laser products for automotive, industrial, specialty lighting and display applications as well as sensing and LiFi communications) has demonstrated compact, high-power, high-brightness, fiber-coupled blue laser modules for materials processing applications including copper welding for battery production for electric vehicles (EVs) and consumer electronic devices, as well as 3D printing. At Laser World of Photonics 2019 in Munich, Germany (24–27 June), the firm debuted the blue laser module technology, and also demonstrating its UL and IEC safety-certified high-luminance LaserLight-SMD and LaserLight-Fiber products.

"SLD's blue laser light modules feature up to 12 times the absorption, processing quality and speed compared to infrared laser technology," reckons says president, chief operating officer & co-founder Dr James Raring. "This technology produces superior results in copper, aluminum, stainless steel, as well as other metals such as nickel, gold, titanium and silver that are commonly used for plating, other thin metal processes and 3D printing," he adds.

SLD's blue laser light output is also highly absorptive in non-metals and organics, and therefore is suitable for marking, engraving and cutting of these materials. Moreover, for biomedical applications, it exhibits more than ten times absorption in blood hemoglobin and melanin in skin than infrared lasers, enabling next-generation solutions in dermatology and surgery.



SLD's new blue laser module.

SLD says that its blue laser module is ultra-compact (with a form factor roughly the size of a credit card) and delivers over 20W from a 100μm transport fiber. The technology is modular and can be power scaled and aggregated with optical fibers into higher-power systems to deliver hundreds of watts from high-brightness delivery fibers less than 600μm diameter. The modules feature the firm's proprietary and patented Semipolar GaN laser diode technology, with highly efficient and reliable operation to enable system integrators and application development teams to configure solutions for a wide variety of applications, and to get to market quickly.

Also at Laser World of Photonics, SLD is showcasing its LaserLight product line. The firm has recently initiated production of the UL and IEC safety-certified LaserLight-SMD and LaserLight-Fiber products, including the recently demonstrated fiber-coupled SMD and SkyBeam (the first 12,000 lumen LaserLight spotlight for outdoor lighting applications based on the SMD). LaserLight products won the Technical Innovation Award at May's LightFair International trade fair in Philadelphia, PA.

"We have recently entered production for our two first LaserLight product lines into the automotive and specialty lighting markets, delivering up to 10 times higher visibility and safety than can be achieved with LEDs, and replacing older legacy lighting that contains mercury," says chief marketing officer & co-founder Dr Paul Rudy. "LaserLight products serve a myriad of applications such as automotive headlights, portable handheld flashlights, drones, off-road light bars, and professional applications in search and rescue, marine, avionics, architecture, and entertainment," he adds. "We are thrilled to now take the next step, and introduce the blue laser module technology for emerging industrial materials processing and biomedical applications."

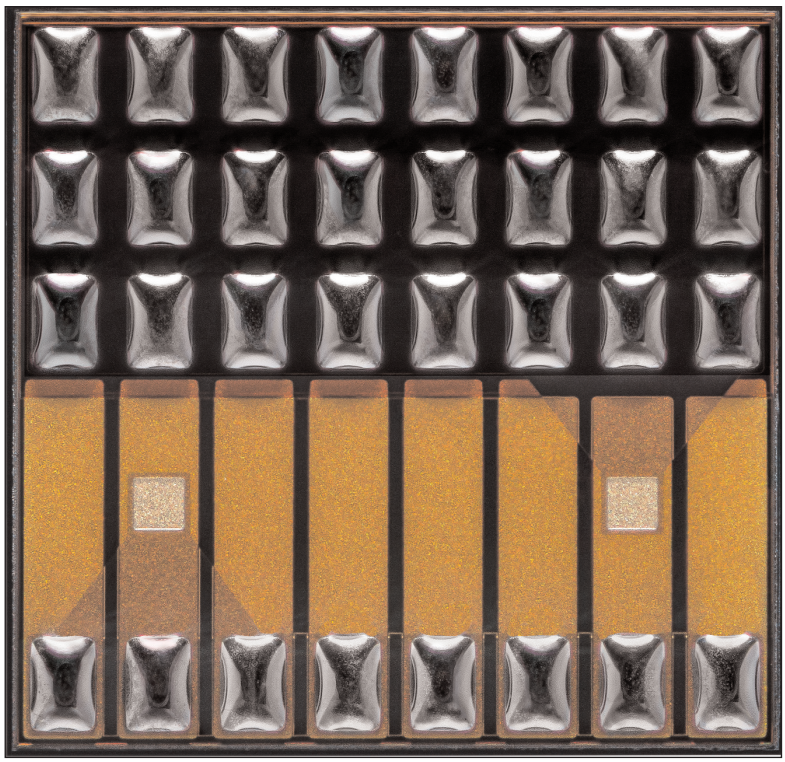
www.SLDLaser.com

TriLumina launches first surface-mount flip-chip back-emitting VCSEL array without need for submount

TriLumina Corp of Albuquerque, NM, USA, which manufactures and integrates flip-chip vertical-cavity surface-emitting laser (VCSEL) array light sources for 3D sensing LiDAR (light detection and ranging) and interior illumination products, has launched the first surface-mount flip-chip back-emitting VCSEL array without the need for a submount or bond wires, allowing lower costs and higher performance than existing designs using near-infrared (NIR) light-emitting laser diodes for 3D sensing.

"For the first time, engineers can create extremely small, low-cost, high-performance products utilizing a NIR surface-mount back-emitting VCSEL array, without the need for a large and costly submount," says chief marketing officer Luke Smithwick.

Conventional VCSEL arrays are mounted on a submount and use bond wires for electrical connections. TriLumina's unique, patented flip-chip, back-emitting VCSEL technology has been flip-chip packaged and used in automotive long-range LiDAR prototypes, for low-power mobile, and in-cabin 3D sensing applications. The new 4W chip-on-board (CoB) SMT (surface-mount technology) VCSEL device is a compact, surface-mountable design, consisting of a single VCSEL array die, that is mountable on a printed circuit board (PCB) without the need for a submount carrier for the VCSEL die. This small, very low-cost illumination technology presents a solution for numerous 3D sensing applications, as well as providing innovative NIR illumination options for replacing existing LEDs in applications such as NIR camera systems, mobile cameras, in-cabin occupant monitoring and AR/VR systems. TriLumina's integrated back-side etched micro-lenses enable integrated optics, which further reduces device height compared with conventional VCSELs with separate optical lenses and can result in lower battery drain with multi-zone operation. It is claimed to have the smallest footprint with the lowest-cost implementation in its class, making it suitable for use in mobile devices.



The TriLumina 4 W chip-on-board SMT VCSEL array.

The TriLumina 4 W CoB SMT VCSEL array has the smallest footprint with the lowest cost implementation in its class, making it suitable for use in mobile devices.

"TriLumina has led VCSEL illumination for 3D sensing with our innovative flip-chip back-emitting multi-chip illumination modules for long-range LiDAR applications," claims president & CEO Brian Wong. "Now, we've innovated once again, by eliminating the need for a package for low-power mobile and automotive in-cabin applications."

TriLumina claims that the new architecture has excellent thermal properties with a very compact form factor. The VCSEL has integrated solder balls and mounts directly to a PCB using standard surface-mount technology (SMT), with built-in hermeticity. The CoB SMT VCSEL array eliminates the need for wire bonds or other expensive packaging technology found on standard top-emitting VCSELs. Although the device is designed for efficient operation in indirect time-of-flight (ToF) applications, the lack of wire bonds also has inherently low parasitic inductance, making the emitter compatible with ultra-high-resolution, fast rise-time, short pulse-width direct ToF applications.

www.trilumina.com

II-VI's June-quarter guidance unchanged by US restrictions on exports to Huawei

After a detailed analysis, engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has concluded that there will be minimal effects on its sales and prospects from the US Department of Commerce on 16 May adding Huawei Technologies Co Ltd and 68 of its affiliates to its 'Entity List' prohibiting the sale to Huawei of products covered by the Export Administration Regulations (EAR) without obtaining an appropriate export license. As a result, II-VI is reaffirming its prior guidance for fiscal fourth-quarter 2019 (to end-June).

The firm says that it will continue to monitor any updates to this directive to assess any changes that may be required and will be fully compliant.

II-VI currently does not expect these developments to affect the merits of the merger with fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA, which is still expected to complete mid calendar year 2019.

II-VI Inc wins 2019 Supplier Excellence Award from Fujitsu

II-VI Inc has received the 2019 Supplier Excellence Award from Fujitsu Network Communications Inc (a provider of business, information technology and communications solutions) at its annual Supplier Day event in Allen, Texas.

"II-VI is proud to receive this recognition from Fujitsu and would like to thank our operations teams for their relentless efforts which made it possible," says Richard Smart, general manager, II-VI Network Solutions Division. "The award is a testament to our ability to leverage our vertical integration and global supply chain management excellence in order to provide outstanding logistics support to key customers such as Fujitsu," he adds.

www.ii-vi.com

II-VI showcases innovations at Laser World of Photonics

At Laser World of Photonics 2019 in Munich, Germany (24–27 June), engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA showcased the following new products and solutions:

High-power collimated laser bars and collimated semi-framed stacks: II-VI now combines its high-power laser bars and new simplified semi-framed stack structures with fully automated optical alignment processes to deliver highly reliable modular assemblies at optimal cost for direct-diode and diode-pumped solid-state (DPSS) lasers.

120W pump laser modules with wavelength-stabilized output power: II-VI's pump laser modules achieve 120W of output power while precisely maintaining a wavelength of 976nm over a wide operating temperature range. The precise wavelength stability lowers the warm-up time and maintenance of laser systems, improving productivity.

The exhibit showcased what is claimed to be one of the broadest portfolios of merchant products for all laser technology platforms employed in high-power or precision materials processing. From ultraviolet to the far-infrared, II-VI's laser optics are on display along with new products for direct-diode, solid-state and fiber lasers, as well as laser heads and beam delivery solutions.

II-VI also showcased its wide-diameter epitaxial wafers that enable a broad range of photonics and wireless applications.

www.ii-vi.com

II-VI launches 120W pump laser modules with wavelength-stabilized output for ultrafast fiber lasers

II-VI Inc of Saxonburg, PA, USA has launched 976nm pump laser modules with up to 120W of wavelength-stabilized output power.

Wavelength-stabilized pump laser modules enable ultrafast fiber lasers to operate with very short pulses for high-precision drilling and marking. II-VI's pump laser modules achieve 120W of output power while precisely maintaining a wavelength of 976nm over a wide operating temperature range. Their high power enables fiber lasers to be designed with fewer pump laser modules, lowering laser system cost. Their precise wavelength stability lowers the warm-up time and maintenance of laser systems, improving productivity, says the firm.

"This wavelength-stabilized module achieves 50% more output power than that which we introduced only four months ago, demonstrating our rapid technology advances," says Chris Koeppen, VP of II-VI Industrial Laser Group. "Our vertically integrated modules leverage both the reliability of our gallium arsenide semiconductor laser platform and our state-of-the-art spatial beam combining technology to achieve high efficiency and wavelength-stabilized output powers over an industry-leading operating temperature range of 20–45°C," he adds.

II-VI's wavelength-stabilized pump laser modules are available over a wide range of power levels of 15–120W coupled to industry-standard 106.5µm core fiber. II-VI's broad portfolio of components for fiber lasers includes seed lasers, acousto-optic modulators, pump and fiber-laser combiners, as well as micro-optics for high-power isolators.

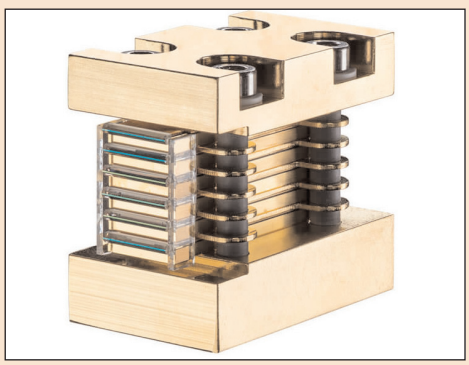
At Laser World of Photonics 2019 in Munich, Germany (24–27 June), II-VI exhibited its portfolio of merchant products for all laser technology platforms employed in high-power or precision materials processing. From ultraviolet to the far-infrared, II-VI's laser optics are on display along with new products for fiber lasers as well as laser heads and beam delivery solutions. In the life sciences area, II-VI's display consists of spectroscopy optics, flow cells and precision temperature-controlled modules to support advances such as in DNA sequencing. II-VI also showed products from epitaxial wafers to semiconductor lasers that can enable new features such as 3D sensing in the next generation of consumer electronics.

www.world-of-photonics.com
www.ii-vi.com/material-processing

II-VI launches high-power collimated laser bars and collimated semi-framed stacks for direct-diode and DPSS lasers

II-VI Inc has launched its high-power laser bars and semi-framed stacks mounted with micro-optic collimator lenses, offering cost-effective modular assemblies that have high performance and reliability and can be easily integrated into direct-diode lasers and diode-pumped solid-state (DPSS) lasers.

Direct-diode and DPSS lasers are increasingly the tools of choice for a wide range of materials processing, biomedical and defense applications, due to their compact form factor, high-power short-pulsed operation and availability over a broad range of wavelengths from near-infrared to ultraviolet. The performance, quality, reliability and cost of these systems are highly dependent on those of their semiconductor laser sub-assemblies. II-VI now combines its high power laser bars and new simplified semi-framed stack structures



II-VI's collimated semi-framed stacks.

with fully automated optical alignment processes to deliver modular assemblies at optimal cost.

"Our laser bars feature a proprietary hard solder technology that withstands high-power pulsed operation with field-proven reliability," says Chris Koeppen, VP of II-VI Industrial Laser Group. "We now efficiently deliver optimal custom designs by leveraging the automated assembly processes in our direct-diode manufacturing lines. These processes enable a variety of micro-optics, such as collimator lenses and volume Bragg gratings, to be cost-effectively mounted and precisely aligned to a broad range of customer-defined stack geometries."

At Laser World of Photonics in Munich, Germany (24–27 June), II-VI exhibited its portfolio of merchant products for all laser technology platforms employed in high-power or precision materials processing. From ultraviolet to the far-infrared, II-VI's laser optics are on display along with new products for fiber lasers and laser heads and beam delivery solutions. II-VI is also showing products from epitaxial wafers to semiconductor lasers that will enable new features such as 3D sensing in the next generation of consumer electronics.

www.ii-vi.com/multimode-pump-

Finisar's quarterly revenue falls 5.3% due to drop in sales of 40G-and-lower transceivers and VCSEL arrays for 3D applications

For full-year fiscal 2019 (ended 28 April), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of $1280.5m, down 2.7% on fiscal 2018's $1316.5m. In particular, Datacom product sales fell by $102.3m (9.9%), as a result of a decline in sales of 40G transceivers (due to customers switching their technology infrastructure to higher-speed transceivers) as well as lower 100G transceiver revenue (due to a decrease in the average selling prices for products). In contrast, Telecom product sales rose by $66.2m (23%), due mainly to an increase in sales of wavelength-selective switches (WSS) products.

Fiscal fourth-quarter 2019 revenue was $310.1m, down 5.3% on $327.6m last quarter but level with a year ago. Datacom product sales were down by $12.8m (5.5%) on last quarter, due mainly to a decline in sales of 40G-and-lower transceivers as well as vertical-cavity surface-emitting laser (VCSEL) arrays for 3D applications. Telecom product sales were down by $4.8m (5%) on last quarter, due mainly to a decline in sales of 10G tunable transceivers.

On a non-GAAP basis, full-year gross margin fell from 29.7% to 29.2%. However, quarterly gross margin of 30.8% is up on 30.2% last quarter and 24.7% a year ago.

Full-year operating expenses were cut from $292.2m (22.2% of revenue) to $260.2m. Fiscal Q4 operating expenses were $64.6m, up slightly from $63.6m (19.5% of revenue) last quarter but cut from $72m a year ago.

Net income was hence down from $34.2m ($0.29 per diluted share) last quarter to $33m ($0.27 per diluted share) but this was up from just $5.8m ($0.05 per diluted share) a year ago. Full-year net income has correspondingly risen from $100.4m ($0.86 per diluted share) to $119m ($1.00 per diluted share).

www.finisar.com

POET cuts losses as revenue grows 17% in Q1

For first-quarter 2019, POET Technologies Inc of Toronto, Canada and San Jose, CA, USA — a designer and manufacturer of optoelectronic devices, including light sources, passive waveguides and photonic integrated circuits (PIC) for the sensing and datacom markets — has reported revenue of US$1.8m, up 17% on US$1.6m last quarter and 2.7 times the US$0.7m a year ago, due primarily to the recognition of higher non-recurring engineering (NRE) revenue.

Results include DenseLight Semiconductor as a discontinued operation (effective 1 January), after the firm on 3 February signed a letter of intent (LOI) to sell the Singapore-based subsidiary. All financial data hence represent the combined results from both continuing and discontinued operations.

Gross margin has risen further, from 60% a year ago and 67% last quarter to 80%.

Net loss was US$2.7m ($0.01 per share), cut from a net loss before taxes of US$3.6m ($0.01 per share) last quarter and US$3.2m ($0.01 per share) a year ago. Until the time of the sale of DenseLight, the firm intends to continue to report revenue within the DenseLight operation since the bulk of its R&D, production and sales activities are conducted there. The operation of the firm as a single integrated unit also ensures that DenseLight's activities will continue to be directed by POET toward the completion of remaining developments connected to POET's Optical Interposer technology. After the sale, DenseLight is expected to remain a development resource, key supplier and strategic partner in the expansion of applications and product sales for POET. POET intends to remain focused throughout the sale process on gaining customer interest, NRE support, qualification and product sales to customers for Optical Interposer-based solutions.

Additionally, after the end of Q1/2019, on 3 May POET completed the second tranche of its private placement of convertible debentures for gross proceeds of US$1.1m (C$1.5m), for which the firm paid about US$57,200 (C$76,600) in brokerage fees related to the closing. This brings the total capital raised to about US$2.5m (C$3.4m). Proceeds from the second tranche of convertible debentures are expected to be used to fund operations pending completion of the sale of DenseLight. Definitive agreements for DenseLight's sale are being drafted and are expected to be completed by 30 June. Key terms (including the identity of the buyer) will be disclosed in the Notice to Shareholders for the Annual and Special Meeting to be held in Toronto on or before 15 August.

POET expects to continue to solicit interest from potential subscribers for additional tranches of convertible debentures over the coming months. Any subsequent tranches will be subject to approval by the TSX Venture Exchange.

www.denselight.com

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Emcore appoints Bruce Grooms to board

Emcore Corp of Alhambra, CA, USA — which provides indium phosphide (InP)-based optical chips, components, subsystems and systems for the broadband and specialty fiber-optics markets — has appointed Bruce Grooms to its board of directors.

Grooms has extensive senior management and executive experience in both the private sector and the US Navy. From 2015 until 1 June 2019, Grooms served as Raytheon's VP of US business development Navy and Marine Corps Programs, where he was responsible for identifying and pursuing US Navy and Marine Corps business growth opportunities for Raytheon and was one of its primary contacts with Navy customers, pursuing opportunities in the evolving cyber area, undersea growth and next-generation strike weapons.

Prior to joining Raytheon, Grooms served in the US Navy, retiring as a Vice Admiral following a 35-year US Navy career. His US Navy service included the positions of Deputy Chief of Staff for Capability Development at the NATO Allied Command Transformation, Joint Staff Director and Assistant Deputy for Operations, Plans and Strategy for the Chief of Naval Operations' staff, and Deputy Director and subsequently Director of the Submarine Warfare Division. He also served as Senior Inspector for the Nuclear Propulsion Examining Board, Senior Military Assistant to the Under Secretary of Defense for Policy, and Company Officer and Commandment of Midshipmen at the US Naval Academy.

Grooms holds a B.S. degree in Aerospace Engineering from the US Naval Academy and earned a master's degree in national security and strategic studies from the Naval War College, graduating with distinction, and later attended Stanford University as a National Security Fellow.

"Grooms' significant leadership experience, including the US Navy and with one of Emcore's largest customers, positions him well to make valuable contributions to Emcore and our board of directors," comments chairman Dr Gerald Fine.

www.emcore.com

Emcore introducing 1.8GHz-bandwidth cable broadband transmission capability at ANGACOM

At the ANGACOM 2019 Exhibition & Congress for Broadband, Cable and Satellite in Cologne, Germany (4–6 June), Emcore introduced 1.8GHz-bandwidth plans for linear fiber-optic HFC (hybrid fiber coaxial) networks.

Emcore says that 1.8GHz builds on the foundation of its ongoing advancements in 1.2GHz systems where its forward-path CATV transmitters utilizing linear externally modulated laser (L-EML) technology can now achieve 46dB MER (modulation error ratio) with full quadrature amplitude modulation (QAM) loading up to 40km. Emcore says that its L-EML-based transmitters continue to receive wide acceptance with major cable broadband service providers and are available in a rack-mountable 1RU form factor, or a PCBA (printed circuit board assembly) mini-transmitter subassembly enabling systems designers to quickly integrate the L-EML device technology into a variety of CATV transmitter platforms.

"With 1.8GHz capability, Emcore continues its leadership in advancing the network performance cable broadband service providers can deliver to their customers," says senior product director Grant Olecko. "Cable service providers can future-proof their systems with up to a 50% increase in network capacity with no change to existing architecture," he adds.

At ANGACOM, Emcore also showcased its MEDALLION series portfolio of end-to-end CATV rackmount transmission systems featuring the 8100 DOCSIS 3.1, L-EML 1550nm CATV transmitter along with MEDALLION 7100 and 7110 high-power CATV fiber amplifiers and MEDALLION 2100 optical A/B switch. In addition, Emcore is displaying the new Model 3644 mini-Tx 1.2GHz, 1550nm L-EML CATV transmitter subassembly designed for a range of CATV applications to 40km and beyond.

www.angacom.de

Infinite Electronics acquires Integra Optics

Infinite Electronics Inc of Irvine, CA, USA, a supplier of electronic components through a family of brands, has acquired carrier-grade optical transceiver maker Integra Optics of Latham, NY, USA.

Founded in 2007, Integra is one of the fastest-growing telecoms companies on the Inc 5000 list, with locations across the USA, Canada and South America.

Continuing to operate as an independent brand within the overall Infinite family, Integra's president Jim Pascarell will join the Infinite executive team and will continue to lead Integra's day-to-day operations. Founder David Prescott is leaving Integra and his current role as CEO and CTO, but will remain as a consultant to the Infinite team for a period of time. The merger will "broaden the products, technologies and services Integra Optics can offer to current customers, while also continuing to break ground to significantly increase network reliability and availability across an even wider customer base," Prescott says.

This merger opens up a whole new level of experts and resources within Infinite to help us drive the continued growth and expansion of our business

"This merger opens up a whole new level of experts and resources within Infinite to help us drive the continued growth and expansion of our business," says Pascarell.

"We see an incredible opportunity to expand our technical reach to more engineers with this critical need in the market for high-quality optical transceiver products and solutions," says Infinite Electronics' CEO Penny Cotner. "With the combined leadership of the Infinite Electronics and Integra Optics teams, we see great opportunities ahead."

www.infiniteelectronics.com

Sofradir and ULIS merge as Lynred

Combined cooled and uncooled IR detector firm aims to shorten time-to-market for new products

France's Sofradir of Palaiseau (near Paris), which makes infrared detectors for military, space, scientific and industrial applications, and its subsidiary ULIS of Veurey-Voroize (near Grenoble) have merged under the new name Lynred to present an all-inclusive IR product offering to the global aerospace, defense, industrial and consumer markets. In response to increasing market requirements, the firm says it has attained a critical mass geared to shortening the time-to-market process of new products. Its US entity remains a subsidiary and has been renamed Lynred USA.

Sofradir makes cooled IR detectors based on mercury cadmium telluride (MCT/HgCdTe), indium antimonide (InSb), quantum-well infrared photodetector (QWIP) and indium gallium arsenide (InGaAs) technology. ULIS makes uncooled IR sensors based on amorphous silicon.

Lynred is the new identity under which its 1000 staff will provide what is claimed to be the widest range of IR technologies to global markets, assure a long-term and reliable product supply, and accompany client projects with IR design and equipment integration support.

"Lynred will enter the market with a new vision for the future in an increasingly competitive market, which has seen the number of players double over the last five years," says chairman Jean-François Delepau. "We are the established European leader in infrared technologies," he claims. "Now, Lynred gives us more punching weight in R&D and increased visibility within the IR ecosystem. Thanks to the commitment of our employees in forming Lynred and increased support from our partners, we will be able to offer new attractive solutions to our customers."

According to the report 'The world market for military infrared imaging detectors and systems' by market research firm Maxtech International, the market is estimated to be growing from $8.5bn (about €7.6bn) in 2018 to $14bn (€12.5bn) in 2023. Also, according to the report 'Uncooled Infrared Imagers and Detectors 2019' by Yole Développement, extrapolated market data indicates that the market for cameras for industrial and consumer applications could rise from $2.9 (€2.6bn) to $4.1bn (€3.7bn). This translates to a potential global annual market growth rate of about 10% at camera and system level.

Lynred is advancing its development of next-generation IR detectors via the €150m ($167.4m) investment it is making in the Nano2022 project over the next five years. These IR devices will be designed to address trends in autonomous systems for smart buildings (workspace management, energy savings), road safety and in-cabin comfort of vehicles.

Developments also include the very large-dimension IR detectors needed for space and astronomy observation as well as compact and lightweight IR detectors for use in portable devices and on drones.

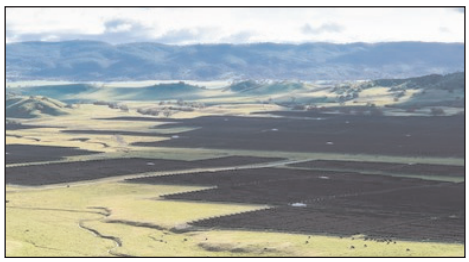
Lynred says it will continue enlarging its product catalog, strengthening its R&D investments and hiring in support of activities.

www.lynred.com

First Solar and Capital Dynamics announce commissioning of 280MW California Flats Solar Project

Independent global private asset management firm Capital Dynamics and cadmium telluride thin-film photovoltaic module First Solar Inc of Tempe, AZ, USA have announced completion and commercial operation of the 280MW$_{AC}$ California Flats Solar Project, located on 2900 acres within the Jack Ranch owned by Hearst, near the borders of San Luis Obispo and Monterey County.

The project partners emphasized co-locating the project with one of the largest working cattle ranches in the USA while minimizing and mitigating the environmental impact. Ranch employees worked in tandem with the construction and operation teams, with input from stakeholders, to assess and plan the development. The facility hence has a low visual impact and cannot be seen from any public roads. The project supports and complements the sustainable cattle operation of the ranch.



"The California Flats Solar Project helped us meet our goal of finding a sustainable solution to keep the 73,000-acre Jack Ranch intact as a historic working cattle ranch," says Steve Hearst, VP & general manager of Hearst Western Properties.

Covering about 3% of the area of the ranch, the project was built in two phases and is fully contracted under two long-term power purchase agreements (PPAs) serving both utility and corporate renewable customers. First Solar completed development and constructed the project after acquiring it in 2015. Capital Dynamics acquired it from First Solar in August 2017.

"The California Flats Solar Project is the first to feature our innovative Series 6 PV module technology," says Troy Lauterbach, senior VP of EPC & Energy Services at First Solar. Series 6 modules are claimed to have about half the carbon footprint of conventional crystalline silicon PV panels, delivering the smallest environmental footprint and the fastest energy payback time of any PV technology.

Construction of the project took about three years, creating about 2.1 million work hours, and had a peak construction workforce of over 1100. The facility will generate energy equivalent to the needs of about 116,000 average California households per year, displacing over 109,000 metric tons of CO_2 annually based on the PG&E grid (equivalent to taking about 22,000 cars off the road).

www.firstsolar.com
www.capdyn.com

Cove Mountain 2 plant to power Facebook data center in Utah

First Solar says its Cove Mountain 2 solar power plant will support Facebook's Eagle Mountain Data Center in Utah, through a power purchase agreement (PPA) with Rocky Mountain Power (a division of PacifiCorp and part of Berkshire Hathaway Energy).

The 122MW$_{AC}$ facility will be built near the town of Enterprise in Iron County, Utah, and also near the 58MW$_{AC}$ Cove Mountain power plant (announced in 2018, also to supply energy for Facebook's operations). Due to begin operation in 2020, Cove Mountain 2 will supply energy to Facebook under the Schedule 34 Renewable Energy Tariff, which enables customers to work with Rocky Mountain Power to meet their renewable energy goals by facilitating construction and contracting of new renewable energy projects.

"This project is an important part of our commitment to support all of our data centers and offices with 100% renewable energy in 2020," says Paul Clements, Facebook's director of energy & infrastructure. "Working with First Solar and Rocky Mountain Power allows us to ensure that our data center will be supported by new renewable energy resources — like this solar power plant — in the same electrical grid as our data center," he adds.

Powered by Series 6 modules, Cove Mountain 2 will generate electricity equivalent to the needs of 36,000 average Utah homes, while displacing 235,000 metric tons of CO_2 annually (equal to removing 46,000 cars from the road). It will also save 800 million liters of water annually, based on Utah averages.

"Cove Mountain 2 demonstrates the ability of utility-scale solar to power corporate renewable energy ambitions effectively," says Karl Brutsaert, First Solar's senior director of corporate renewables. "Combining the commercial and environmental efficiencies of utility-scale solar with a green tariff PPA model allows companies like Facebook to meet their decarbonization commitments," he adds.

First Solar expects to begin construction in late 2019. Cove Mountain and Cove Mountain 2 will generate about 450 construction jobs on average, and up to 1100 jobs at the peak of activity.

"Cove Mountain and Cove Mountain 2 demonstrate Utah's ability to attract new long-term business partners to the State through Rocky Mountain Power's green tariff initiative," says Kathryn Arbeit, VP of project development for First Solar.

Alta's co-founder Atwater wins William Cherry Award

At the 46th annual IEEE Photovoltaic Specialists Conference (PVSC 2019) in Chicago (24-28 June), professor Harry Atwater, the Howard Hughes Professor of Applied Physics and Materials Science at the California Institute of Technology (Caltech), will receive the 2019 IEEE William Cherry Award for major innovations in the progress and future of photovoltaic science and technology.

The IEEE PVSC organizing committee established the award in memory of one of the founders of the photovoltaic field, William R. Cherry, to recognize individuals who have made "outstanding contributions to the advancement of photovoltaic science and technology". The award selection is made by the William R. Cherry Committee, composed of all past general chairmen of the specialist's conferences and all past recipients of the award.

Atwater has shown "unique insight into photovoltaics research from his first paper in 1982", and has since contributed to more than 450 publications in the field. "The passion and creativity of professor Harry Atwater to improve photovoltaic technologies are widely recognized," comments award committee chair Dr Pierre Verlinden.

During his career Atwater has focused on two main scientific research themes: photovoltaic solar energy conversion and light-matter interactions in materials. He has created new high-efficiency solar cell designs and has pioneered principles for light management in solar cells. Atwater is the co-founder of Alta Devices of Sunnyvale, CA, USA, which holds the record for single-junction solar cell efficiency.

"Professor Atwater's vision for the potential of highly efficient, flexible solar technology has dramatically contributed to the progress of our whole industry," comments Alta Devices' CEO Jian Ding.

Atwater currently serves as director of the DOE (Department of Energy) Joint Center for Artificial Photosynthesis, and as strategic director for the QESST ERC program. Atwater received his B.S., M.S. and Ph.D. degrees from the Massachusetts Institute of Technology in 1981, 1983 and 1987, respectively. He held the IBM Postdoctoral Fellowship at Harvard University from 1987 to 1988 and has been a member of the Caltech faculty since 1988.

www.altadevices.com

InGaN platelets for green and red LEDs

Reduced strain should enable more efficient recombination of the electrons and holes into photons.

Lund University and RISE Research Institutes in Sweden have developed indium gallium nitride (InGaN) platelet arrays as a basis for green and red light-emitting diodes (LEDs) [Zhaoxia Bi et al, Nano Lett. (2019) vol19, no5, p2832]. The researchers used the platelets to achieve quantum well (QW) regions with higher indium content with less compressive strain from lattice mismatching. "The large strain has a direct impact on the crystal quality of the QWs, potentially introducing plastic crystal deformation during growth and then leading to a dislocation formation," the team explains.

High strain in InGaN heterostructures also leads to large piezoelectric fields, which reduce the efficiency of the electron–hole recombination processes that are needed for photon emission — a mechanism called the 'quantum-confined Stark effect' (QCSE).

Strain effects severely reduce the performance of red and green InGaN-based LEDs, relative to blue devices that can reach 80% external quantum efficiency. By using the InGaN platelets, lower strain in InGaN QWs with high indium content should be achieved due to the smaller lattice mismatch. Higher indium content narrows the bandgap, increasing the wavelength.

The platelet growth technique combined selective-area metal-organic vapor phase epitaxy (MOVPE) and reformation to convert InGaN pyramid structures into c-plane oriented platelets. The selective-area epitaxy was on (0001) GaN-on-silicon templates, using silicon nitride masking with 100nm-diameter holes at 1μm pitch. The platelets are 100–200nm high and extend laterally a few hundred nanometers.

The reformation process consisted of 1070°C annealing in ammonia (NH_3) and InGaN regrowth to create a smooth top surface. The annealing did not affect the $\{10\bar{1}1\}$ pyramid side facets, which remained smooth after the thermal processing.

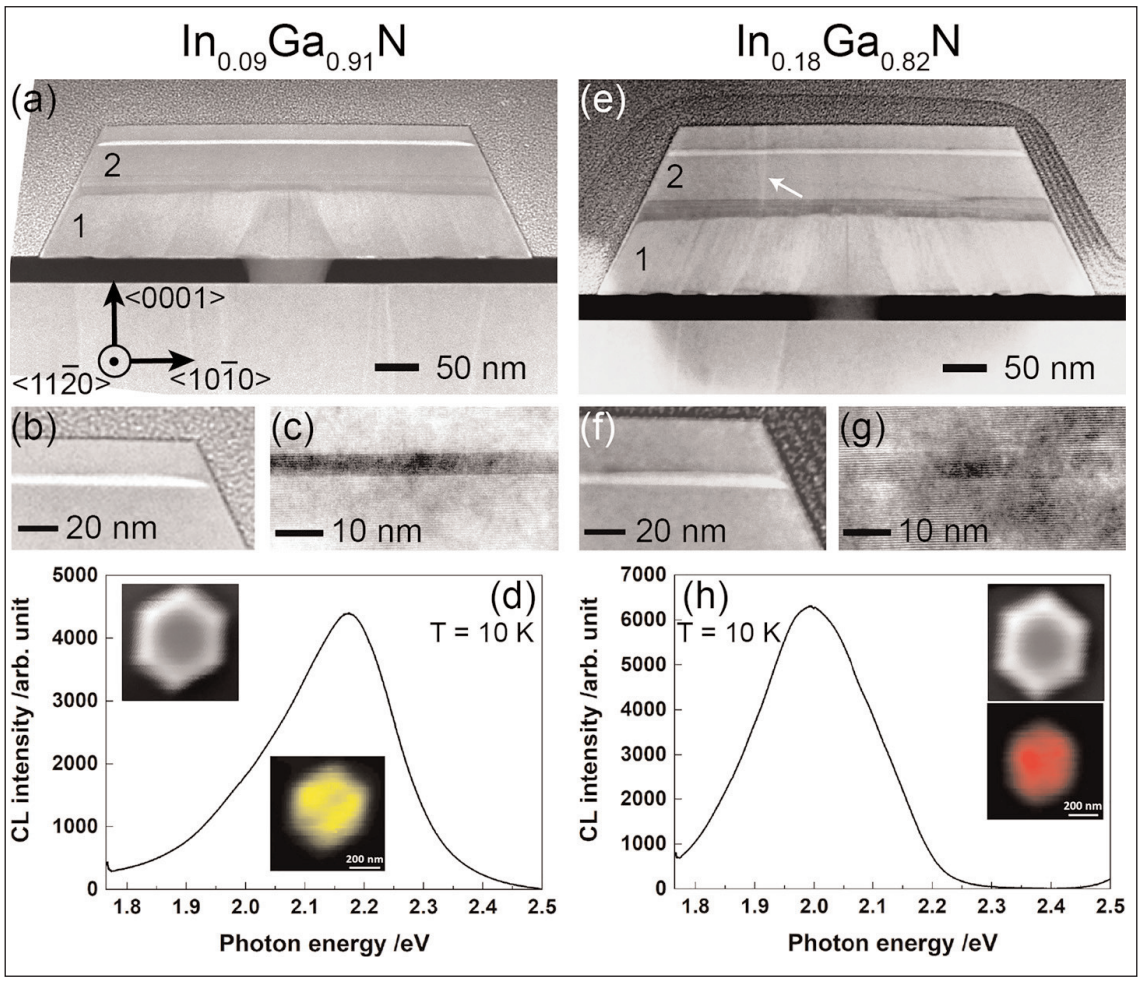


Figure 1. (a, e) Cross-sectional high-angle annular dark-field scanning transmission electron microscope (HAADF-STEM) images of single QW samples. The white arrow in panel e indicates dislocation. (b, f) Magnified HAADF-STEM images close to periphery and (c, g) high-resolution TEM images in middle of QWs. (d, h) CL spectra measured at 10K. Inset: SEM images and corresponding monochromatic CL images with QW emission. CL images recorded in energy windows of (d) 1.80–2.50eV and (h) 1.85–2.35eV.

The researchers explain: "The surfaces of {10$\bar{1}$1} planes are N-terminated. N atoms at the surface are supposed to bond with H atoms cracked from NH_3, which can be a reason for the stable {10$\bar{1}$1} planes during the annealing."

The regrowth included an intermediate InGaN layer with a low V/III ratio of 700 (close to the limit for In/Ga droplet formation). The aim of the intermediate layer was to reduce pit formation in the c-plane surface. The researchers suggest that the metal-rich conditions on the growth plane gives a longer adatom diffusion length, flattening the initially rough surface.

The indium content of the intermediate layer was estimated to be less than 5%.

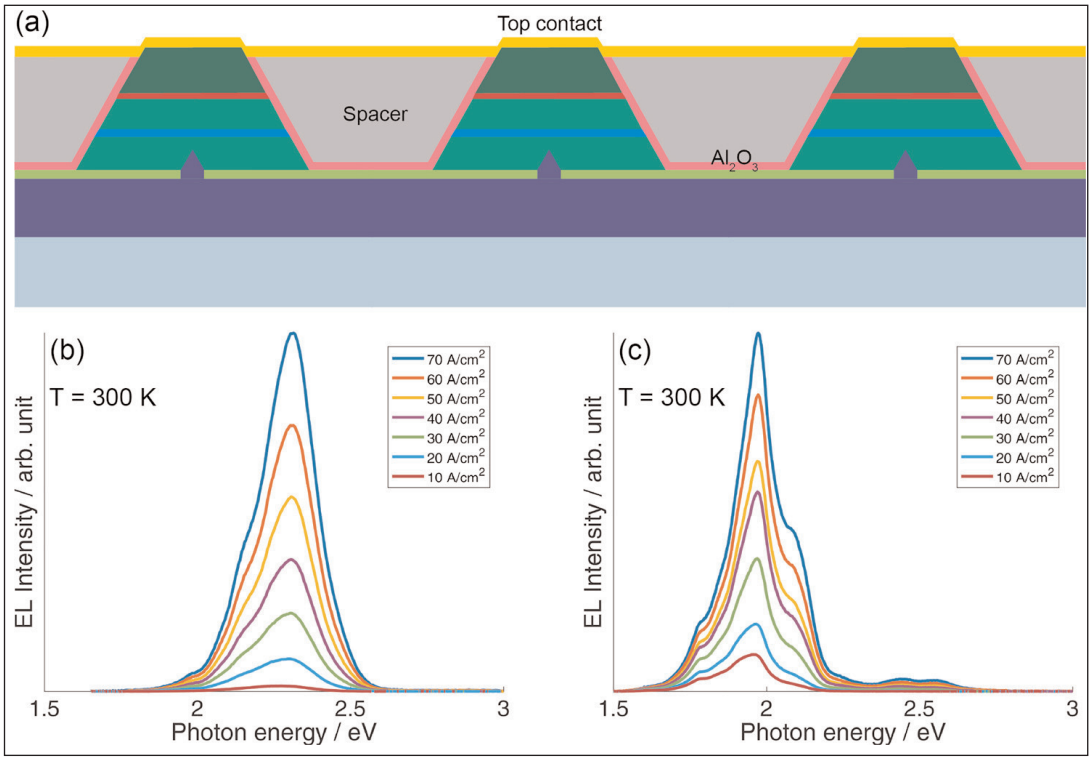


Figure 2. (a) Schematic of InGaN platelet LEDs. (b, c) EL spectra at different current injection levels for green and red LEDs on $In_{0.09}Ga_{0.91}N$ and $In_{0.18}Ga_{0.82}N$ platelets, respectively. Current density normalized to QW rather than contact area.

The technique was successful in removing pits from $In_{0.09}Ga_{0.91}N$ platelets, but there remained some pits in $In_{0.18}Ga_{0.82}N$ structures. This residual pitting was attributed to the larger lattice mismatch with the intermediate layer. The top InGaN layer was 40–50nm thick.

Comparison of photoluminescence and energy-dispersive x-ray analysis suggested that the InGaN below the intermediate layer had higher indium content fluctuations compared with the InGaN above. Photoluminescence analysis tends to overestimate indium content when there are large fluctuations.

The researchers found that growth of InGaN quantum wells on the InGaN platelets had enhanced indium incorporation, probably due to reduced compressive strain relative to wells grown on pure GaN.

The InGaN platelets had narrow PL peaks: 107meV and 151meV full-widths at half-maximum (FWHMs) for $In_{0.09}Ga_{0.91}N$ and $In_{0.18}Ga_{0.82}N$, respectively. These platelets were used for green and red LEDs, respectively.

Cathodoluminescence (CL) spectra under electron-beam excitation showed a QW peak in the emission at 2.17eV (in the yellow range) for the $In_{0.09}Ga_{0.91}N$ platelet and 1.95eV (red) for $In_{0.18}Ga_{0.82}N$ (Figure 1). The researchers report that the QW was slightly thicker on an $In_{0.18}Ga_{0.82}N$ platelet: 5.8nm, compared with 4.5nm. The team suggests the thicker well increases the quantum-confined Stark effect, red-shifting the emission.

The indium content of the well could also be higher on the higher-indium-concentration platelet, narrowing the bandgap. The higher indium content could be the result of reduced 'indium pulling' compared with the lower-indium-concentration platelet.

For LEDs, a ~200nm p-InGaN contact layer was added to platelets with quantum wells (Figure 2). The n-contact was through the n-GaN buffer. Electrical isolation was achieved with 30nm atomic layer deposition (ALD) aluminium oxide (Al_2O_3) passivation and spin-coated/planarized polymer spacer material. The spacer was also used as an etch mask for removal of the Al_2O_3 from the top of the p-GaN contact. The contact metal was circular in form with 360μm diameter, covering around $1.2x10^5$ platelets.

Electroluminescence (EL) from the LEDs gave green (2.30eV) and red (1.98eV) peaks for $In_{0.09}Ga_{0.91}N$ and $In_{0.18}Ga_{0.82}N$ platelet structures, respectively. The corresponding FWHM linewidths were 210meV and 150meV.

Funding for the work came from various projects: the European Union's 'NWs4LIGHT', the Swedish Foundation for Strategic Research's 'Energy-efficient LED-lighting Based on Nanowires', the Swedish Energy Agency's 'Nanowire-based Light Emitting Diodes with Multiple Wavelengths in the Visible Range', and the EELYS' 'Ultra-efficient RGB-lighting Based on Nanowire Technology'. Some money for the work also came from the Swedish Research Council, the Knut and Alice Wallenberg Foundation, and VINNOVA, the Swedish government's 'innovation agency'. ■

www.sp.se/en

http://doi.org/10.1021/acs.nanolett.8b04781

Author: Mike Cooke

Boosting near-UV and deep-UV performance of light-emitting diodes

Mike Cooke reports on recent research to improve photon extraction and material quality in deep-ultraviolet light-emitting diodes.

Although ultraviolet (UV) is not visible, it has many uses, and light-emitting diodes (LEDs) producing such light from 'near' ultraviolet (400–300nm) to 'deep' ultraviolet (300–200nm) wavelengths are the subjects of much research.

UV-LEDs are seen as being useful for spectroscopy, photopolymer curing, water/air purification, medical and biological disinfection, biochemical detection, non-line-of-sight communication, and special lighting. Also, some schemes for white light using phosphors are powered by near-UV in LED or laser diode systems.

Some of these applications need deep ultraviolet (DUV) wavelengths. In the DUV range, competing mercury-lamp systems have drawbacks such as fragility and bulk, along with short lifetime and low efficiency. And, of course, mercury is highly toxic. Shorter wavelengths are more effective in damaging or killing biological systems — for example, ~250nm is needed to break up DNA.

As wavelengths push into the DUV 200–300nm wavelength range, efficiency becomes particularly low, of the order a few percent. Sapphire is the preferred substrate, but suffers from lattice mismatch and thermal expansion mismatch with the active light-emitting aluminium gallium nitride (AlGaN) semiconductor material that introduces strain/stress, generating efficiency-killing defects.

Here we look at recent reports attempting to improve the performance of near-UV and deep-UV LEDs.

Reflecting on chromium/aluminium n-electrode

Researchers in China have been applying reflective n-type electrode metal structures to boost light extraction in 280nm-wavelength DUV-LEDs [Yang Gao et al, IEEE Transactions on Electron Devices, published online 21 May 2019].

The work by Huazhong University of Science and Technology and University of Science and Technology of China used a chromium/aluminium (Cr/Al) combination to enhance reflection of the electrodes on the n-type AlGaN contact layer of the LEDs. While the chromium absorbs DUV radiation, aluminium is highly reflective.

The researchers explain the need for chromium in the electrode: "If we only adopt the Al layer as the n-type electrode, it is almost impossible to form an ohmic contact with the Al-rich n-AlGaN. Therefore, a Cr metal layer must be introduced before the deposition of the

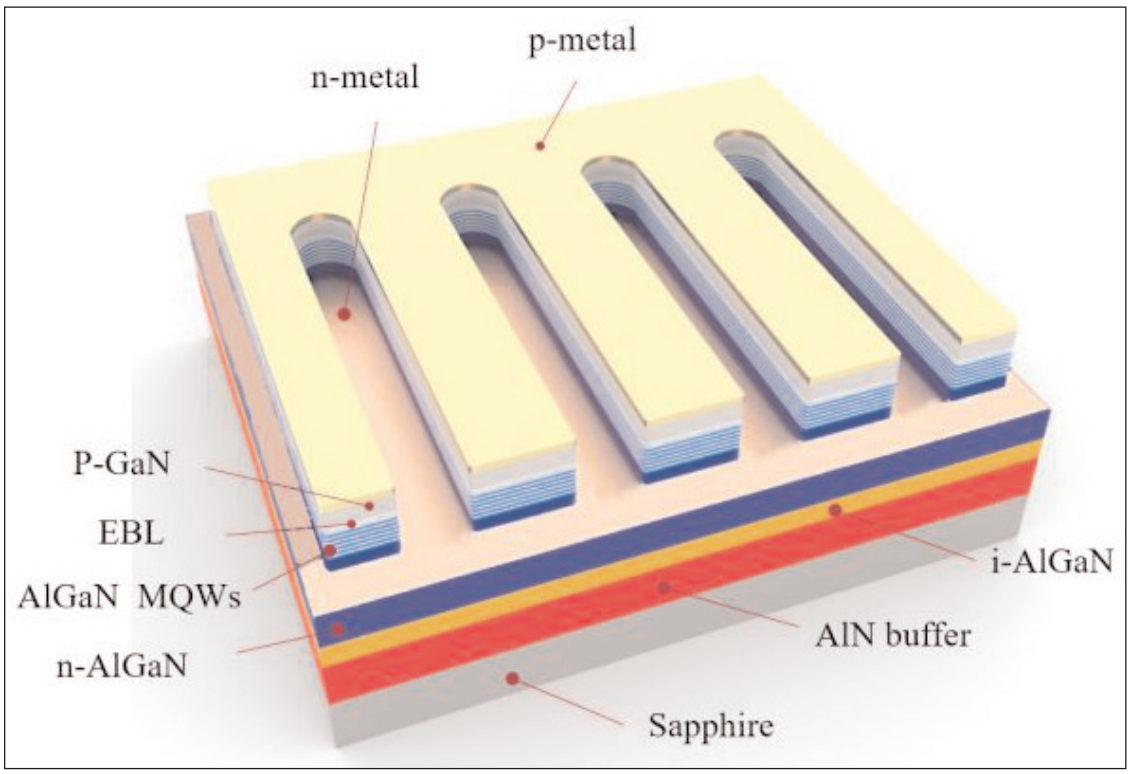


Figure 1. Schematic of flip-chip DUV-LED device.

Al layer to form an ohmic contact and improve the electrical performance."

The DUV-LED material was grown by metal-organic chemical vapor deposition (MOCVD) on c-plane sapphire. The buffer consisted of 2μm AlN. Undoped $Al_{0.55}Ga_{0.45}N$ was used for strain release before a silicon-doped n-$Al_{0.55}Ga_{0.45}N$ contact layer. The light-emitting active region contained five 2.5nm $Al_{0.37}Ga_{0.63}N$ quantum wells separated by 12.5nm $Al_{0.51}Ga_{0.49}N$ barriers. The p-side of the device consisted of magnesium-doped p-$Al_{0.7}Ga_{0.3}N$ and p-GaN contact layers.

The fabrication process was designed to create flip-chips with the DUV light emerging mainly through the sapphire substrate, since the bandgap of p-GaN is less than that of photon energy (Figure 1). The relatively narrow p-GaN gap makes it highly absorbing of the DUV. Unfortunately, magnesium doping of high-Al-content AlGaN results in very low enhancement of the hole concentration at room temperature due to a high activation energy.

DUV-LED fabrication began with inductively coupled plasma etch to expose the n-AlGaN contact layer.

The full scheme for the n-electrode consisted of chromium/aluminium/titanium/gold (Cr/Al/Ti/Au) deposited by electron-beam evaporation. The thicknesses of the Al, Ti and Au layers were 120nm, 40nm and 60nm, respectively. The chromium thickness varied from 1nm to 20nm. The n-electrode was annealed at 850ºC for 30 seconds in nitrogen.

The p-electrode consisted of nickel/gold/nickel/gold (Ni/Au/Ni/Au).

An LED with 2.5nm chromium in the n-contact had the lowest turn-on voltage of 4.7V (LED-2). The same device also had the lowest contact resistance. The ideality factor of the devices was similar, around 5.31.

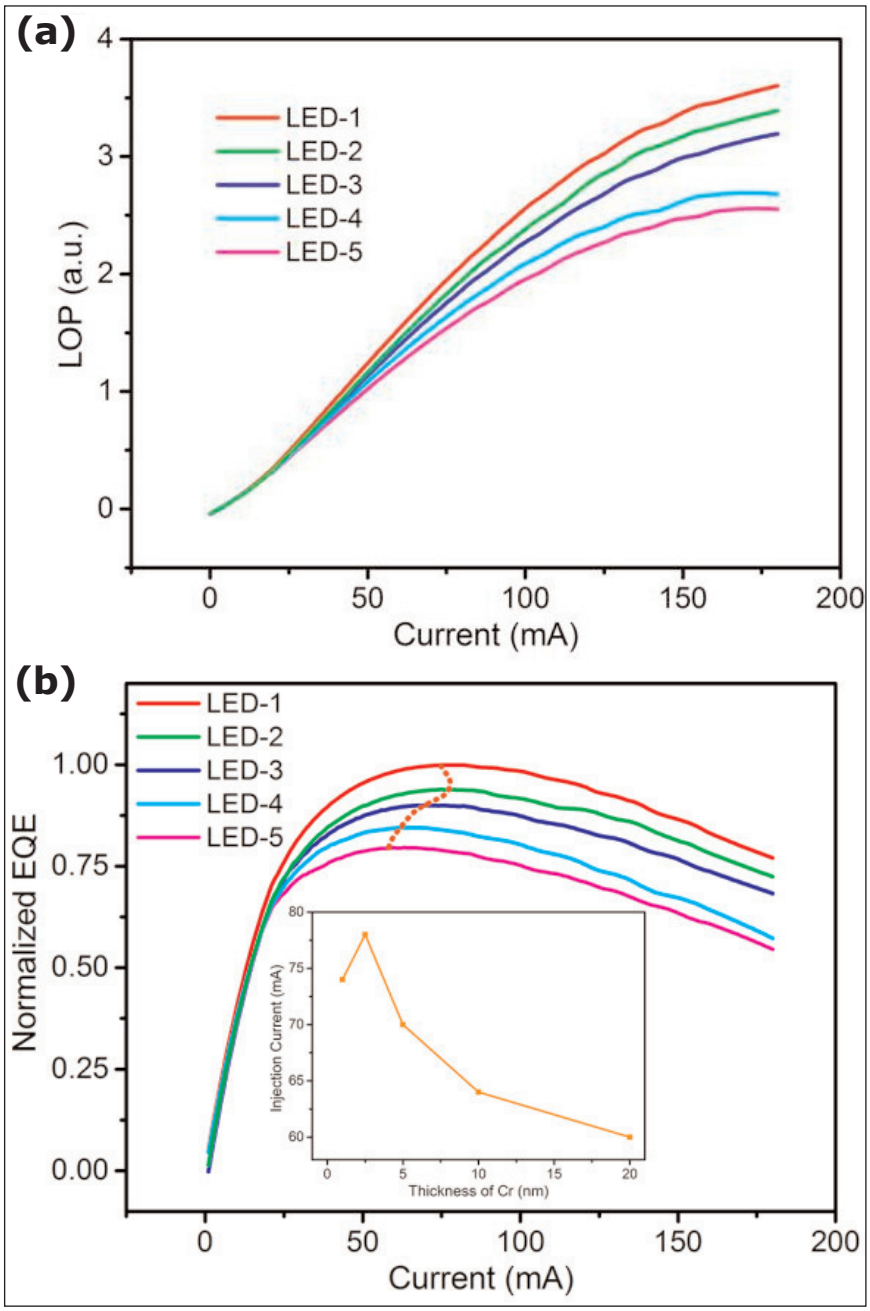


Figure 2. (a) LOP versus injected current for five fabricated DUV-LED devices. (b) EQE in terms of current. Inset: corresponding injection current to achieve peak EQE. LED-3 and LED-4 had 5nm and 10nm Cr, respectively.

In terms of light output power (LOP) at given current injection, the device with 1nm chromium in the reflector (LED-1) gave the highest value (Figure 2). At 180mA injection, the output power was 40.9% higher than that for the LED with the thickest chromium layer – LED-5 with 20nm Cr.

The researchers suggest that the higher turn-on voltage and contact resistance of LED-1 versus LED-2 could be due to the chromium layer being too thin to form the high-quality Al-Cr and Cr-N alloys needed for ohmic contact. The higher light output is attributed to the high reflectivity of the Al layer.

The peak external quantum efficiency (EQE) for LED-1 was 25.4% greater than that of LED-5. The corresponding figure for LED-2 was 17.9%. The current injection point of the peak efficiency varied with device: 74mA for LED-1, 78mA for LED-2, and 60mA for LED-5. The researchers explain the higher current injection for LED-2 as being due to its superior ohmic contact and electrical behavior. "Normally, a lower contact resistance or better ohmic contact can definitely improve current spreading and thus higher current injection efficiency," the team writes.

The reflectivity of Cr/Al metal stacks on sapphire was measured at 280nm center wavelength and compared with results from an unalloyed Al layer. The relative reflection was 93.1% for 1nm and 82.2% for 2.5nm Cr.

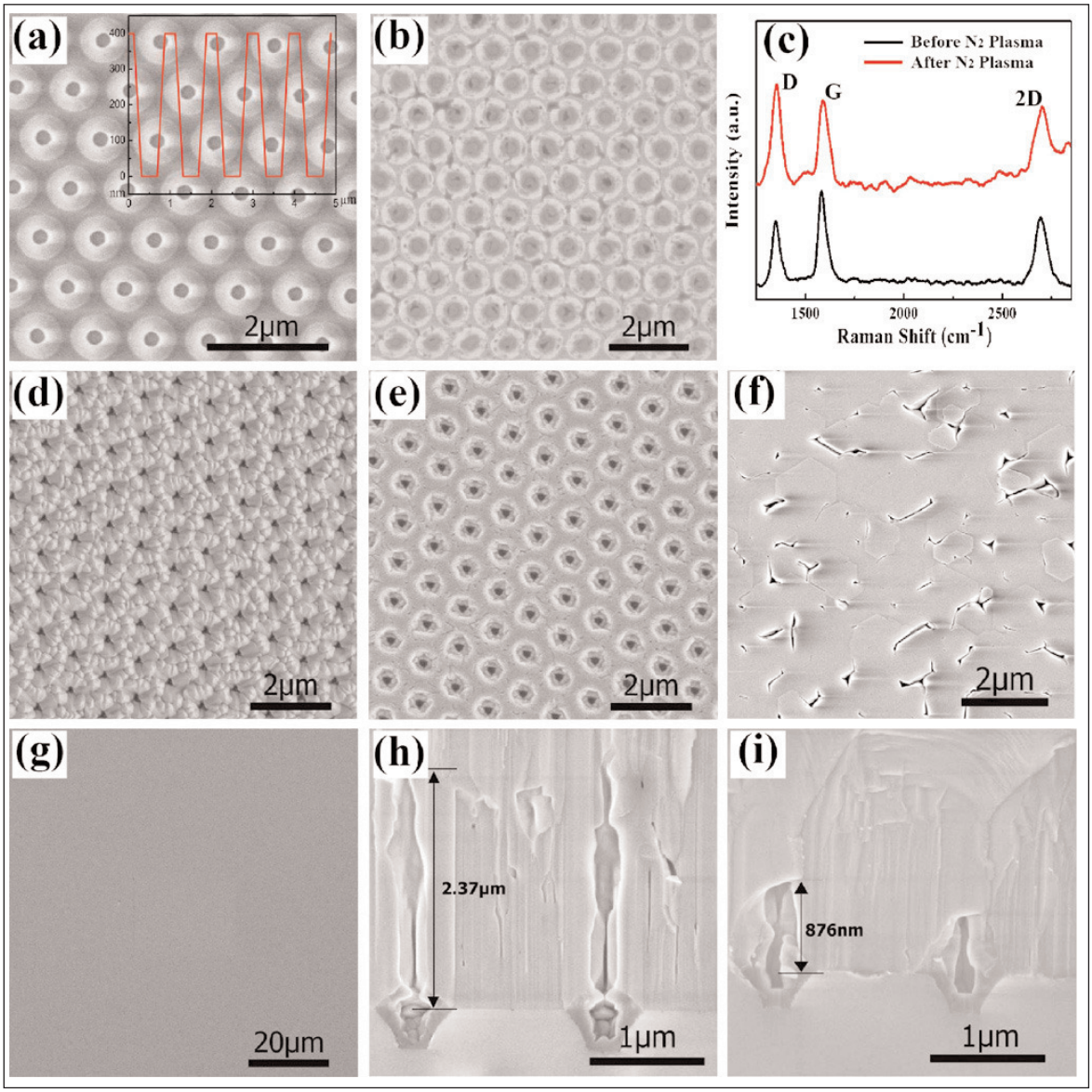


Figure 3. (a) SEM image of bare NPSS. Inset in (a) shows line profile from atomic force microscopy. (b) SEM image of as-grown graphene films on NPSS. (c) Raman spectra of graphene film before (black) and after (red) nitrogen plasma treatment. (d) and (f) SEM images of initial 10 minutes and 2 hours growth of AlN films on NPSS without graphene interlayer. (e) and (g) SEM images of initial 10 minutes and 2 hours growth of AlN films on NPSS with graphene interlayer. (h) and (i) Cross-sectional SEM images of AlN films on NPSS without and with graphene interlayer.

Graphene on nano-patterned sapphire

Researchers in Beijing, China, have used graphene (Gr) to improve AlN growth on nano-patterned sapphire substrates (NPSSs) as a template for AlGaN DUV LEDs [Hongliang Chang et al, Appl. Phys. Lett., vol114, p091107, 2019].

The team was variously based at Research and Development Center for Semiconductor Lighting Technology, University of Chinese Academy of Sciences, Peking University, and State Key Laboratory of Superlattices and Microstructures.

The presence of graphene improved aluminium mobility on the growth surface, improving crystal quality through quasi-van der Waals epitaxy (QvdWE). In turn, this improved the performance of an AlGaN LED grown on the AlN template.

The NPSS consisted of 400nm-deep nano-concave cone patterns with 1μm period produced by nano-imprint lithography on the sapphire surface. The unetched regions were 300nm wide. The ~0.7nm-thick graphene layer was grown by 1050ºC catalyst-free atmospheric pressure chemical vapor deposition (APCVD). The graphene growth process took three hours. The precursor was methane in hydrogen/argon carrier.

The graphene was subjected to reactive ion etch to introduce defects that would increase chemical reactivity with the subsequent AlN growth. Without defects, AlN does not attach easily to graphene, slowing AlN growth.

The graphene on NPSS was prepared with 30-second exposure to nitrogen plasma before loading into the metal-organic chemical vapor deposition reactor for AlN growth. Raman spectroscopy suggested that the nitrogen plasma treatment generated increased numbers of dangling bonds.

The 1200ºC AlN growth used trimethyl-aluminium and ammonia precursors in hydrogen carrier gas. There was no low-temperature nucleation step. The full growth time was two hours. Some samples were grown for just 10 minutes to allow study of the initiation of AlN deposition.

Without a graphene interlayer, two hours of growth on NPSS resulted in rough, non-uniform AlN layers (Figure 3). By contrast, the graphene interlayer

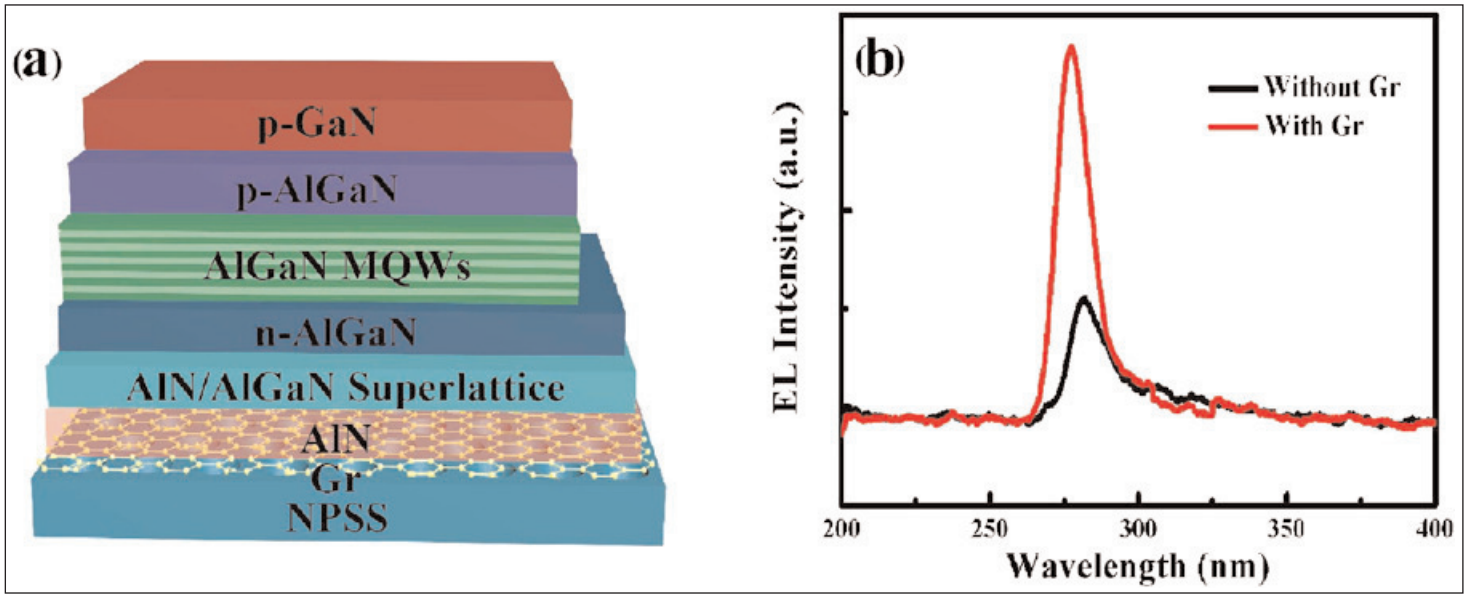


Figure 4. (a) Schematic of AlGaN-based DUV-LED. (b) Electroluminescence spectra with and without Gr interlayer.

enabled rapid coalescence of the AlN, giving a continuous, flat surface. Cross-sectional scanning electron microscopy (SEM) showed the coalescence occurred within 1μm of the full ~2.4μm growth.

X-ray rocking-curve analysis showed a reduction in the full-width at half maximum (FWHM) of the peak associated with the (0002) plane of the AlN lattice from 455.4arcsec to 267.2arcsec, arising from the graphene interlayer. The $(10\bar{1}2)$ peak FWHM also decreased from 689.2arcsec to 503.4arcsec. These values resulted in respective estimates for screw and edge dislocations: $4.51 \times 10^8/cm^2$ and $4.40 \times 10^9/cm^2$ without graphene interlayer, reducing to $1.55 \times 10^8/cm^2$ and $2.60 \times 10^9/cm^2$ with graphene.

According to Raman spectroscopy, the biaxial stress was reduced from 0.87GPa to 0.25GPa by the use of graphene interlayers.

Simulations of the growth process suggested that the effect of the graphene layer was to increase the mobility of aluminium adatoms, compared with the bare NPSS surface. The researchers comment: "The strong binding of Al adatoms to the defect sites and the free diffusion on the non-defective regions ensure the effective nucleation and fast growth for AlN layers, as observed in our experiments."

The AlN on bare NPSS undergoes "three-dimensional longitudinal island growth" due to the sluggish diffusion of the Al adatoms. The coalescence of the islands is therefore delayed. On graphene, the Al adatoms can diffuse further in shorter time, allowing "lateral two-dimensional growth" with rapid lateral coalescence.

The researchers used the AlN/Gr/NPSS template to produce a deep-ultraviolet LED (Figure 4). The epitaxial structure consisted of 1130ºC 20-period 2nm/2nm $AlN/Al_{0.6}Ga_{0.4}N$ superlattice, 1.8mm n-$Al_{0.55}Ga_{0.45}N$ contact, 5-period 3nm/12nm $Al_{0.4}Ga_{0.6}/Al_{0.5}Ga_{0.5}N$ multiple quantum well, 50nm p-$Al_{0.65}Ga_{0.35}N$ electron blocking layer, 30nm p-$Al_{0.5}Ga_{0.5}N$ cladding and 150nm p-GaN contact. Post-growth annealing was used to activate the p-type layers (800ºC for 20 minutes in nitrogen).

At 40mA, the 280nm-wavelength peak was around 2.6x higher than that for electroluminescence from an LED grown on bare NPSS. The researchers attribute the higher intensity to a reduced defect density in the Gr-based sample.

Shell/core nanowires

National Institute of Standards and Technology (NIST) and University of Colorado in the USA have reported AlGaN/GaN shell/core nanowire 365nm near-UV LEDs that demonstrated ~5x the light output compared with GaN/GaN nanowire devices [Matt D Brubaker et al, Nanotechnology, vol30, p234001, 2019].

Nanowire structures might also be useful in boosting the pitiful efficiencies in high-Al-content AlGaN DUV LEDs based on conventional technology.

First ordered arrays of nanowires were grown using plasma-assisted molecular beam epitaxy (PAMBE) on nitrogen-polar GaN/AlN templates on (111) silicon with a silicon nitride mask. The holes in the mask for nanowire growth were 80–240nm diameter with 300–10,000nm pitch. The silicon-doped n-GaN cores were grown at 860ºC substrate temperature. The core length was about 2μm. The ~40nm-thick silicon-doped $Al_{0.09}Ga_{0.91}N$ shell was grown at 700ºC.

Photoluminescence spectra measured at 5K suggested that the Al mole fraction of the shell tip decreased with nanowire diameter. By contrast, reducing the pitch increased Al concentration. The decrease in Al content at the nanowire tip was related to reduced mobility of the atoms at the growing tip, compared with Ga.

The Al content of the main shell of the nanowire stems was more difficult to determine, probably due to

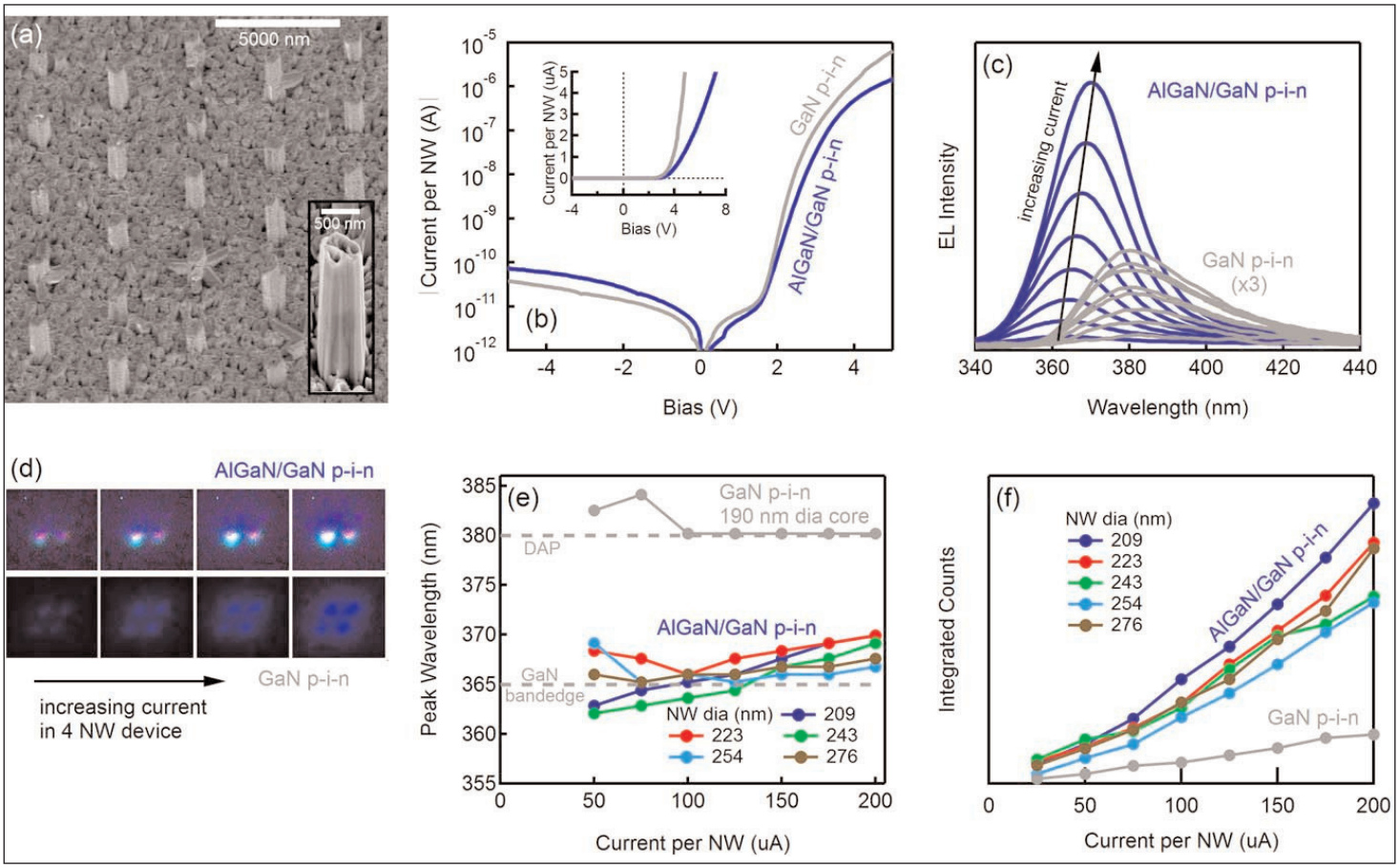


Figure 5. Core–shell p–i–n nanowire LED characteristics comparing AlGaN/GaN heterojunctions and GaN/GaN homojunctions. (a) Scanning electron micrograph of post-metallization AlGaN/GaN core–shell LEDs, with (inset) pre-metallization single nanowire. (b) Current-voltage characteristics and (c) EL spectra for 25 nanowire LEDs. (d) EL images for 4 nanowire LEDs are shown in the figure. GaN p–i–n EL intensities multiplied by factor of three. (e) Peak emission wavelength and (f) integrated intensity versus current for various core diameters.

non-radiative recombination, surface states and defects. The researchers used emissions from excitons (bound electron-hole states) to estimate Al content. Smaller-diameter nanowires were found to have higher-Al-content shells. Smaller-pitch arrays had low Al concentration.

The nanowire growth process was modified to include doping for p-i-n LEDs. The n-GaN core region was grown to a height of 3.3μm pitched at 5μm. Shell growth was initiated with 15nm n-GaN followed by ~85nm intrinsic AlGaN, ~285nm p-AlGaN, and ~5nm heavily doped p^{++}-AlGaN.

The LED p-contact electrode was constructed by 20nm/200nm Ni/Au deposition at normal incidence, followed by 200nm Au at 45º. This covered one side of the wires with metal while the other side allowed light extraction. The n-side current flow was through the buffer with electrical isolation provided by the silicon nitride nanowire growth mask.

The researchers compared the performance of the AlGaN/GaN heterojunction LEDs with GaN/GaN homojunction nanowire devices previously reported by the group (Figure 5). The turn-on voltage of the AlGaN/GaN LEDs was higher than that for GaN/GaN, "likely related to the reduced electron overflow current and increased barrier to hole injection expected for higher Al mole fractions," according to the team.

Subjecting the AlGaN/GaN LED to prolonged current injection seemed to have an electrical annealing effect on the p-contact, giving increased electroluminescence (EL) intensity and lower series resistance. The researchers comment: "Further development of optimized p-contact metallization and annealing processes are expected to reduce burn-in effects and improve overall device performance."

The EL from the AlGaN/GaN was around 365nm wavelength, close to the band edge of GaN. This was in contrast to the GaN/GaN LEDs, which emitted around 380nm, corresponding to donor-acceptor-pair (DAP) recombination from electrons injected into the p-GaN shell, according to the researchers. The team also suggests that GaN core emissions could be reabsorbed in the GaN shell, unlike with the wider-bandgap AlGaN.

The 380nm emission and 365nm reabsorption effects are stopped by the wider-bandgap AlGaN, which is also commonly used as an electron-blocking layer in standard GaN LEDs. The researchers report that the integrated EL intensity in the AlGaN/GaN nanowire LEDs

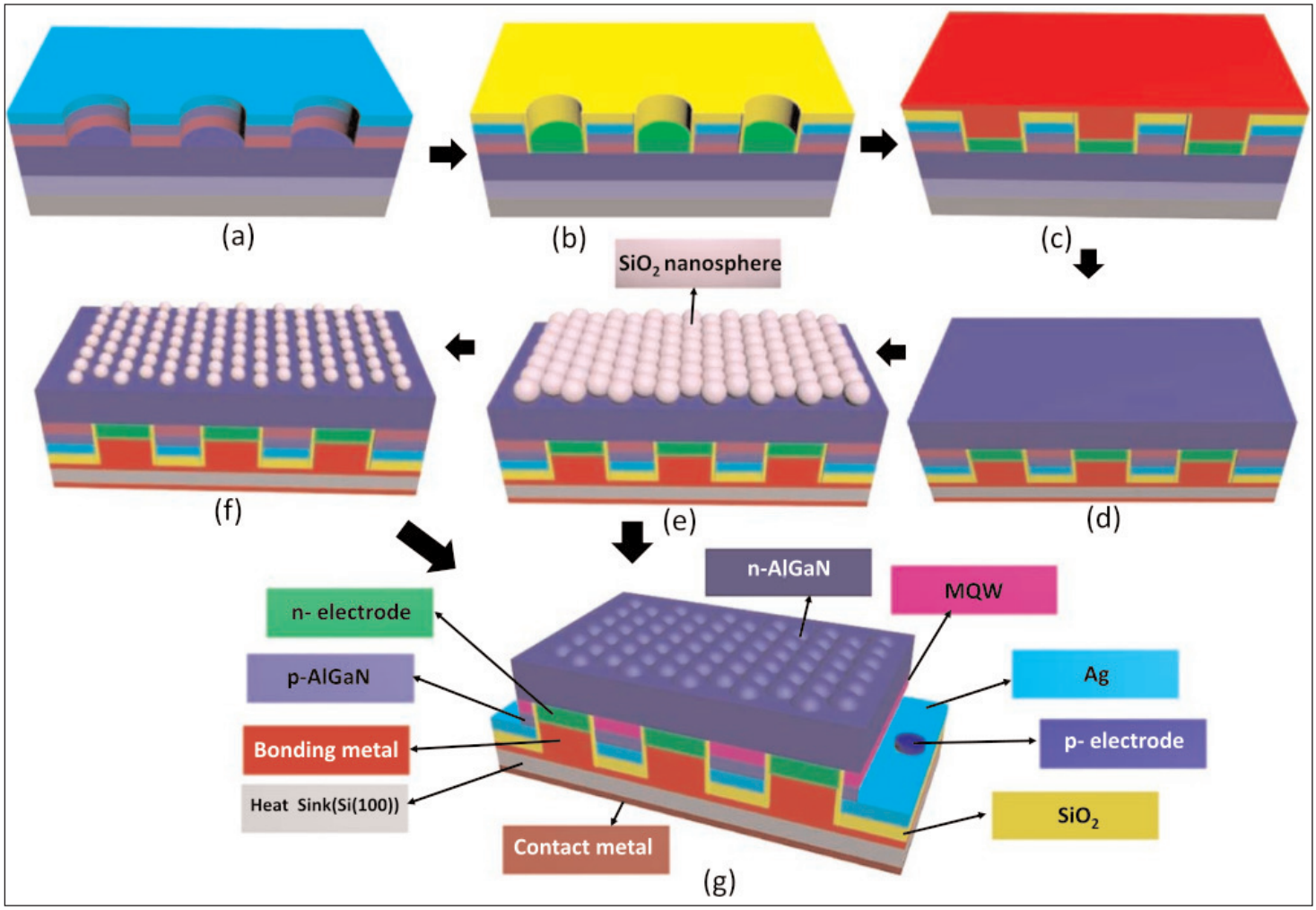


Figure 6. Schematic fabrication process: (a) deposition and patterning of silver-based reflective electrode with ICP etched vias for embedded n-contact to n-AlGaN layer; (b) deposition of Cr/Al n-type contact metal and silicon dioxide (SiO_2) insulating layer; (c) deposition of nickel/tin bonding metal and flipping onto silicon (100) wafer; (d) removal of silicon growth substrate and etch away AlGaN buffer layer, (e) SiO_2 nano-sphere single layer fabricated on N-face n-AlGaN, (f) tailored SiO_2 nanosphere on N-face n-AlGaN, (g) AlGaN nanostructure (nanorod, nano-trapezoid, nanodome and nanocone) arrays on UV LED chips.

was around 5x that of the GaN/GaN reference for a given current injection.

Thin-film surface nano-structuring

Researchers based in China have used thin-film and surface nanostructuring to boost the performance of ~370nm near-UV LEDs by a factor of 3.9 [Chuanfei Ma et al, Nanotechnology, vol30 p185201, 2019].

The nanostructuring was performed on the thick AlGaN n-side of the devices. This was enabled by flipping the LED material over onto another wafer and removing the silicon growth substrate. The nanostructuring was designed to reduce total internal reflection that traps light due to the large contrast in refractive index between III–nitride materials (~2.4) and air (1). The light emission was from indium gallium nitride (InGaN) multiple quantum wells (MQWs).

The team from Suzhou Institute of Nano-Tech and Nano-Bionics and University of Science and Technology of China grew the UV LED structure on silicon in the (111) crystal orientation. Metal-organic vapor phase epitaxy (MOVPE) deposited AlN/AlGaN as a multi-layer buffer, n-AlGaN cladding, an InGaN/AlGaN pre-strained superlattice, InGaN quantum wells in AlGaN barriers, p-AlGaN electron blocking, p-AlGaN current spreader and p-GaN contact.

The epitaxial material was processed into vertical thin-film LED chips (Figure 6). The structure included an embedded n-contact and a silver-based reflective p-electrode. The embedded n-contact clears the ultimate emission surface from blockage by contact electrodes and pads.

The nanostructuring of the nitrogen-face AlGaN was prepared with an oxygen-plasma treatment to convert the bonding from hydrophobic to hydrophilic for spin-coating of the SiO_2 nanospheres to create a self-assembled array. Fluorine-based reactive ion etch was used to 'tailor' the sphere sizes to enable subsequent chlorine-based inductively coupled plasma (ICP) etch of the AlGaN surface into 'nanodomes'. The nanospheres

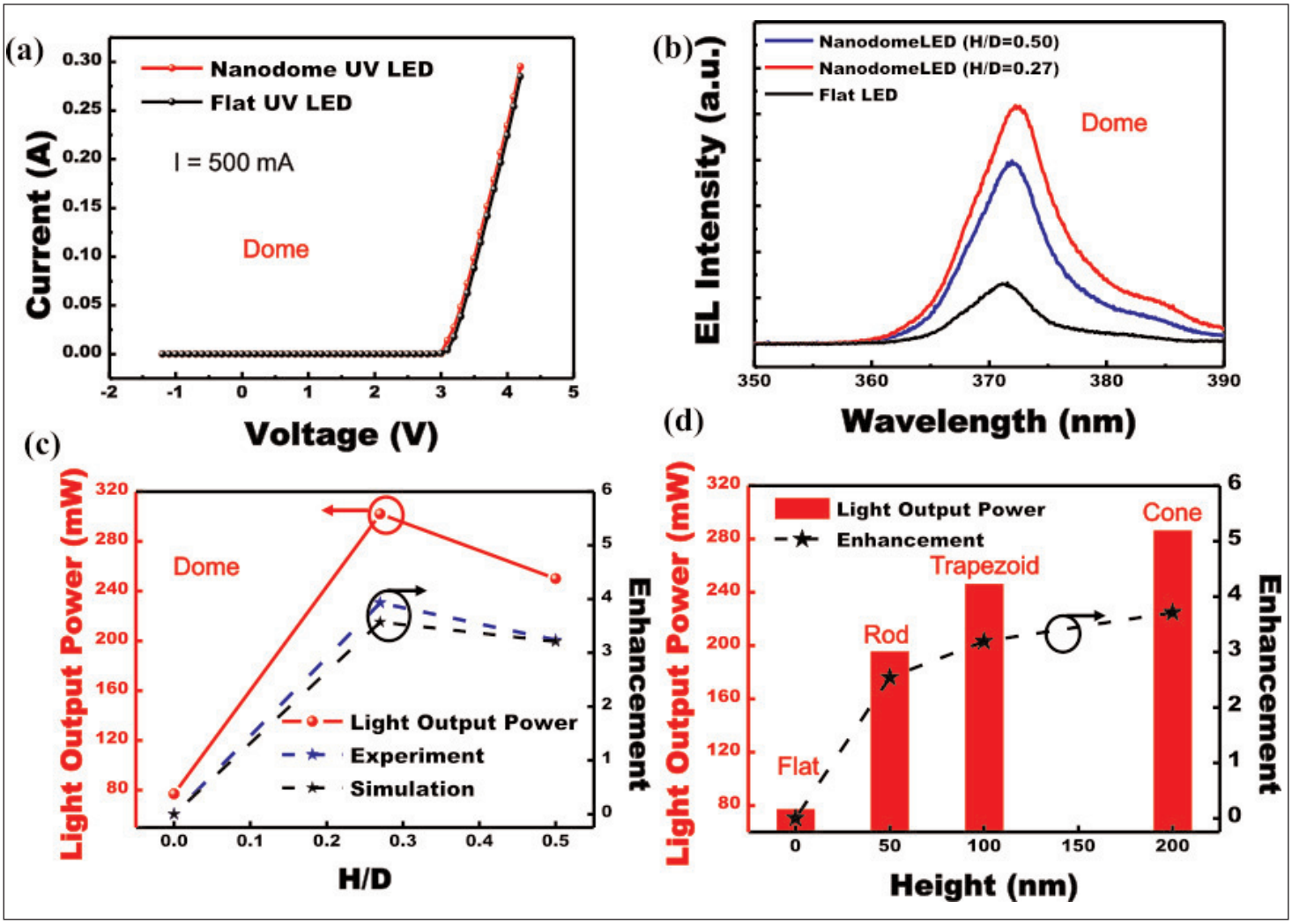


Figure 7. (a) Current-voltage curves of nanodome and flat UV LEDs, (b) electroluminescence spectra, (c) experimental and simulated light output power with various H/D nanodomes, (d) experimental light output power with nanorod, nano-trapezoid and nanocone arrays.

were removed with a buffered oxide etch and dry etch damage of the nanodomes was smoothed with hydrochloric acid treatment.

The group performed ray-tracing Monte Carlo simulations and chose 250nm-diameter SiO_2 nanospheres to create the domes. The simulations suggested an optimum height/diameter (H/D) ratio of 0.27, which gave a 68% light extraction efficiency, compared with 19% for a flat surface.

The current–voltage performance of LEDs with and without nanodomes was almost identical (Figure 7). The researchers point out that nanostructuring of the 2.5μm-thick n-AlGaN layer allows a large process window, in contrast to nanostructuring the thin ~100nm p-side of the device. Dry etching of the thin p-side layer carries risks of reducing conductivity, current spreading, etc. Further, such processing can also affect the underlying MQWs, reducing the efficiency of photon emission. Combined, one expects adverse effects on electrical and light-emission performance.

The integrated electroluminescence of the nanodome LEDs with 0.27 H/D ratio achieved 3.9x the performance of flat reference devices. Simulations suggested a 3.6x boost. The researchers also compared the performance of flat LEDs, against devices with 'rod', 'trapezoid' and 'cone' nanodome structures. The structures were achieved by not reducing the 250μm-diameter nanospheres with reactive ion etch and just performing the inductively coupled etch for different process times.

The researcher also examined the far-field radiation pattern and found that nanodomes cast the emissions more in the forward direction, compared with the flat LEDs. The researchers comment: "This phenomenon was more pronounced for the nanodome structure with H/D = 0.5, indicating that the nanostructures would facilitate the light extraction along the vertical direction, which is particularly useful to UV curing and other related applications of UV LEDs."

The team adds that the AlGaN nanostructuring technique could be easily extended to deep UV vertical LEDs for enhancing light extraction. ■

The author Mike Cooke has worked as a semiconductor and advanced technology journalist since 1997.

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Distributed feed-back gratings for indium gallium nitride laser diodes

Researchers increase side-mode suppression ratio to 36.9dB.

Saudi Arabia's King Abdullah University of Science and Technology (KAUST) claims the highest side-mode suppression ratio (SMSR) for indium gallium nitride (InGaN) distributed feed-back (DFB) laser diodes (LDs) so far [Jorge A. Holguín-Lerma et al, Appl. Phys. Express, vol12, p042007, 2019]. The highest SMSR achieved in the KAUST work was 36.9dB. The researchers comment: "This could enable immediate implementation of narrow-line green laser diodes on various applications, such as atom cooling, spectroscopy and optical communications."

Narrow-line emissions usually require external, complex and bulky filtering techniques to reduce the presence of side-modes relative to the main peak. An attractive alternative is monolithic integration of DFB gratings into the structure of the laser diode. Such an approach is already common in laser diodes constructed in other compound semiconductor systems serving wavelengths in the infrared and red parts of the electromagnetic spectrum. Also, DFBs have been applied to blue and ultraviolet InGaN devices, but with lower SMSR values.

The KAUST researchers used an Osram PLP520 laser diode. The DFB grating was etched into the device surface using exposure to a focused ion-beam to create grooves. The grating period was 4.12μm, targeting an output wavelength of 515nm, assuming an effective refractive index in the laser diode material of 2.5. The green laser diode had a Fabry-Perot (FP) cavity length of ~905μm and the ridge width was ~4μm.

Two devices (A & B) were produced. The first, device A, used a DFB that was built up in three stages (DFB+1-+3) with the sections consisting of 22 groove/semiconductor pairs (Figure 1). As the DFB was lengthened, the SMSR increased. Under 300mA (8.28kA/cm2) continuous-wave current injection and the temperature maintained at 20°C, the SMSR was 0.2dB for the original device without DFB, while as the DFB was built up to the third +3 stage the SMSR increased successively in steps: 0.34dB, 1.45dB and 2.23dB (Figure 2).

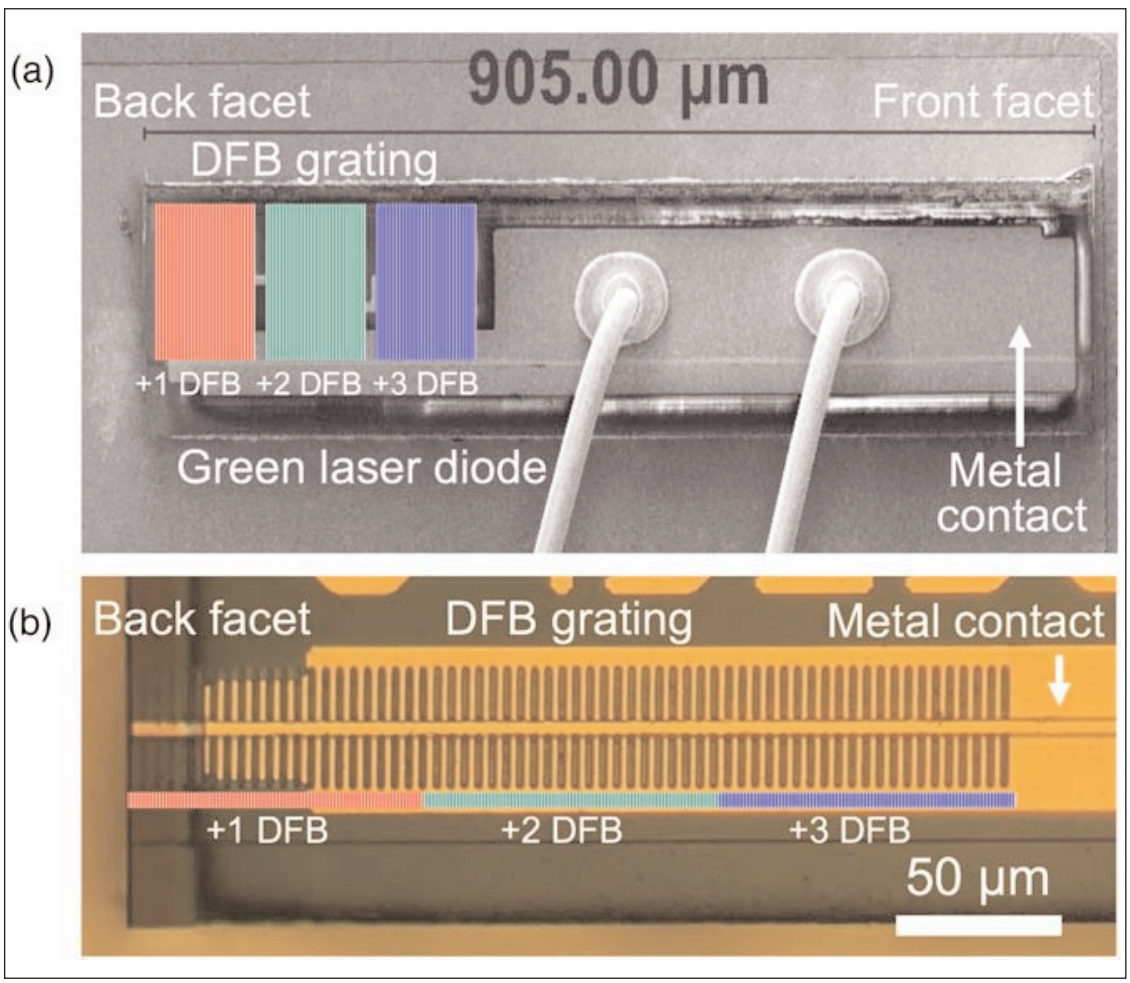

Figure 1. Device A: (a) scanning electron micrograph; (b) optical microscope image of back-facet section of laser diode with DFB grating. Red, green and blue periodic lines overlaid to represent DFB grating sections: +1 DFB, +2 DFB, and +3 DFB.

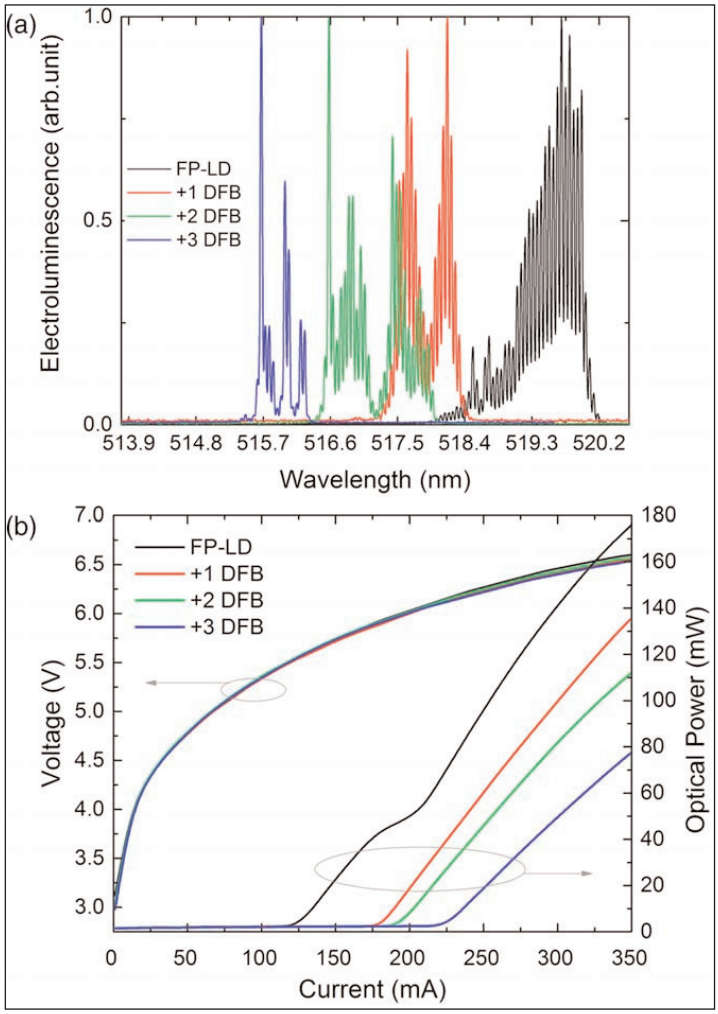

Figure 2. Electro-optical characteristics of device A: (a) spectral evolution after each consecutive DFB grating segment (i.e. +1 DFB, +2 DFB, +3 DFB); (b) light-output—current–voltage characteristics after each DFB grating segment.

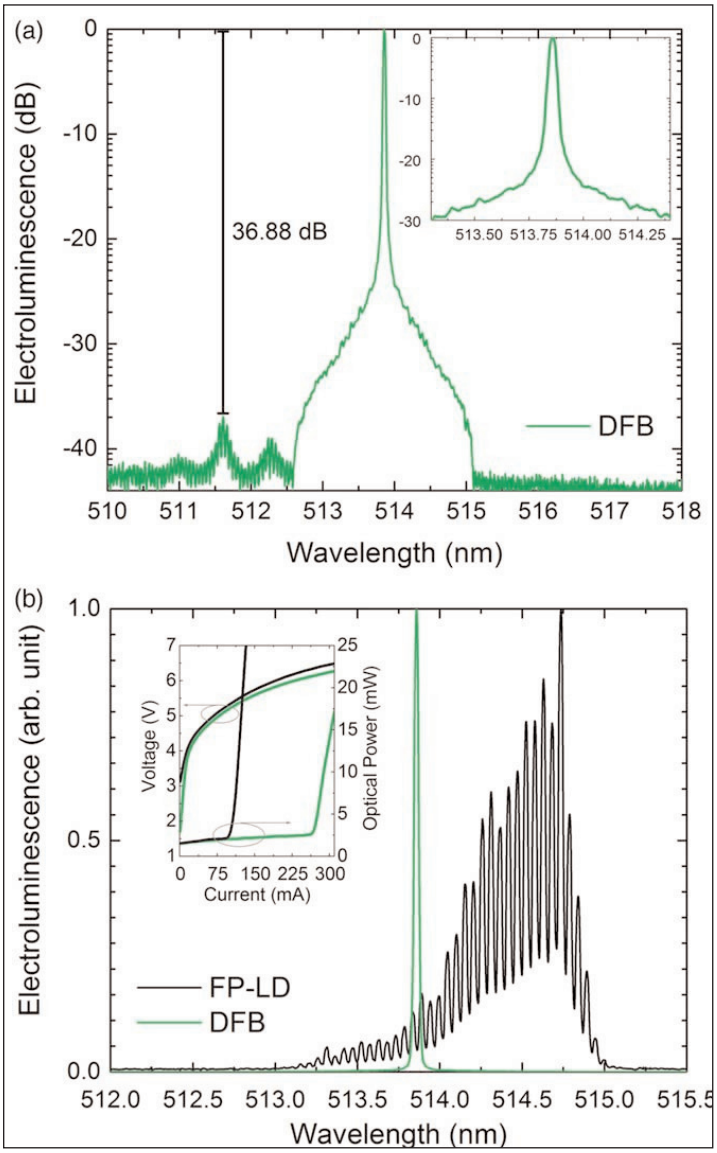

Figure 3. Electro-optical characteristics of DFB-LD (device B). (a) High-resolution optical spectra of green laser narrow-line emission (with detail inset). (b) Comparison of emission spectra before and after fabrication of DFB grating (DFB-LD). Inset: light-output–current–voltage characteristics.

The peak shifted to shorter wavelengths due to mismatch between the Bragg resonant wavelength and the main resonance of the Fabry-Perot cavity of the original laser diode. Another effect of the grating was to reduce the output power at 300mA: 141mW for the original laser diode and 49.6mW for the laser diode with +3 DFB. Mode selection and annihilation in the original laser diode did give a kink in the current-power curve, which was not seen in the DFB versions that are expected to have greater mode stability. The electrical voltage-current performance of the various device As was almost identical.

Using parameters derived from device A with +3 DFB sections, the researchers designed an improved 40-order DFB grating for device B. The new gating period was 4.114μm, giving narrow-line emission at 513.85nm. Under 300mA injection, device B achieved an SMSR of 36.9dB (Figure 3). The full-width at half-maximum (FWHM) linewidth of the laser diode without DFB was 544pm; adding the DFB to device B reduced this to 31pm. The corresponding optical powers were 149mW and 14mW. Again, the two set-ups had similar electronic behavior in terms of the current-voltage performance.

Another factor was an increase in threshold current for the laser diode B with DFB: 263mA, compared with 102mA for the raw laser diode. The slope efficiency was also impacted: 0.54W/A without DFB and 0.32W/A with DFB. The external and maximum wall-plug efficiencies for device B with/without DFB were 20.7%/3.5% and 7.7%/1.3%, respectively.

The researchers think improvements could come from optimization of fabrication parameters such as ridge width and length, grating order and duty cycle, etching depth, and passivation. ■

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Author: Mike Cooke

First demonstration of RF N-polar GaN MISHEMT

Reduced-dislocation-density gallium nitride substrate used to reduce carrier scattering at low carrier concentration for use in AB-mode amplification.

University of California Santa Barbara (UCSB) in the USA has reported the first radio frequency (RF) nitrogen-polar gallium nitride-on-gallium nitride (GaN-on-GaN) metal-insulator-semiconductor high-electron-mobility transistor (MISHEMT) [Shubhra S Pasayat et al, Semicond. Sci. Technol., vol34, p045009, 2019]. Using GaN substrates enabled the dislocation density to be reduced, minimizing carrier scattering at the low charge densities typical for transistors used in AB-mode amplification.

The researchers are keen to develop solutions for millimeter-wave RF applications in sensing and communication that variously employ frequency bands in atmospheric absorption and transmission windows. The N-polar orientation reverses the usual Ga-polar structure. In particular, the channel layer of mobile charges is induced by a back-barrier rather than a top barrier. N-polar devices tend to have higher power output, but reduced efficiency.

AB-mode amplification biases transistors towards pinch-off when channel carrier densities are low. AB operation reduces dissipation losses and higher efficiency is obtained when the bias is towards the B-mode rather than A-mode end of the trade-off, so-called 'deep' AB biasing. In N-polar devices, such biasing suffers from a degradation in electron mobility that apparently arises from scattering off the back-barrier. By contrast, in Ga-polar devices deep AB biasing pushes the electrons away from the top barrier interface.

The epitaxial structure for the device (Figure 1) was grown by plasma-assisted molecular beam epitaxy (PAMBE) on on-axis semi-insulating bulk GaN. The carbon (C) doping of the 200nm GaN buffer continued the semi-insulating character of the substrate. The back-barrier was prepared with 100nm of unintentionally doped (UID) material, followed by 10nm of n-GaN, which was used to control the position of the Fermi level in the overlying structure.

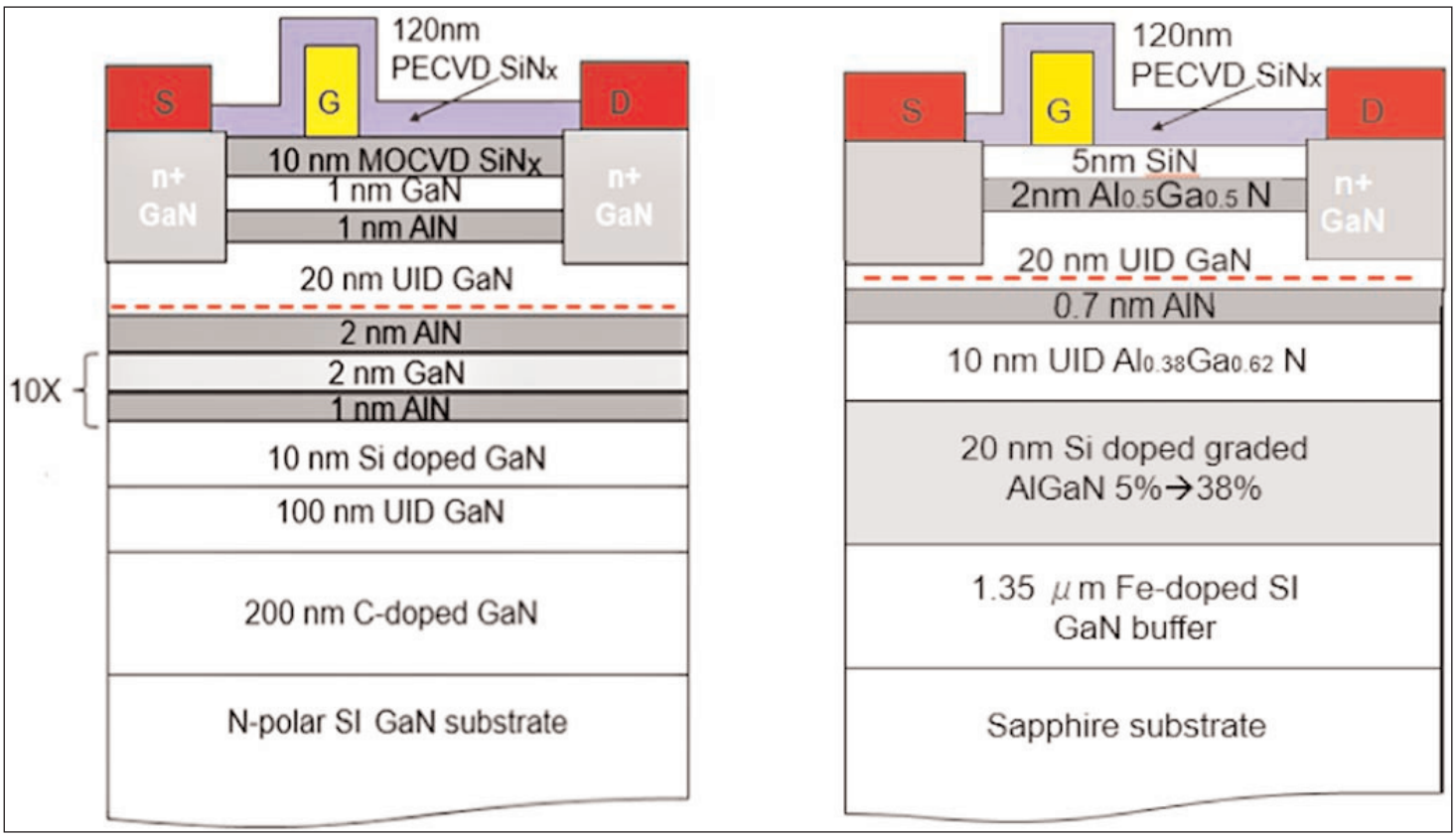

Figure 1. (a) N-polar HEMT device PAMBE structure and fabrication cross-section. (b) Conventional MOCVD-grown N-polar GaN HEMT.

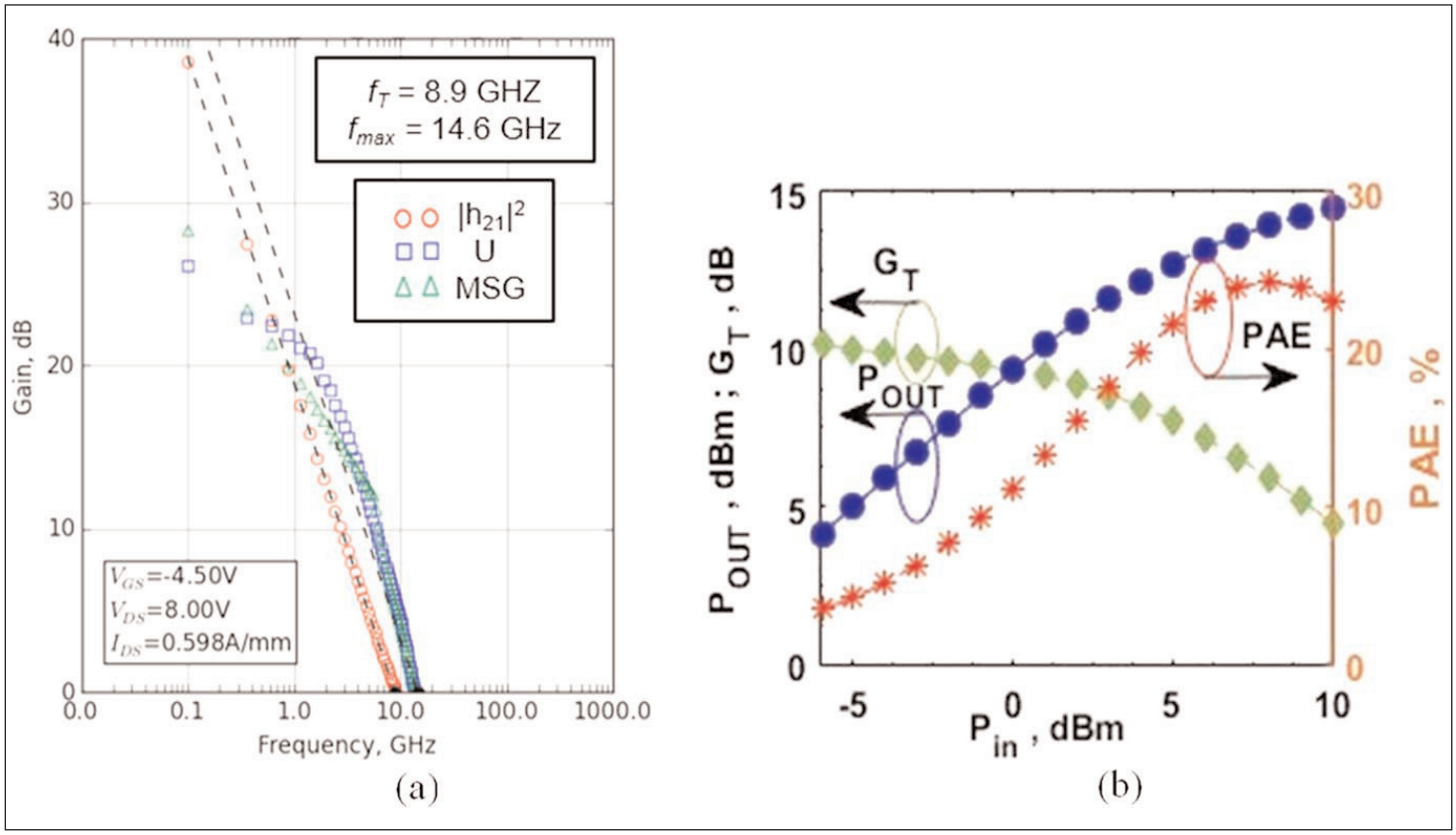

Figure 2. (a) Small-signal gain data for simultaneous peak f_T and f_{max} and (b) 4GHz load-pull power sweep.

The barrier itself consisted of a 10-period super-lattice of 1nm/2nm AlN/GaN, and capped with 2nm of AlN. This structure induced a two-dimensional electron gas in the 20nm UID GaN channel layer. The 2nm AlN layer reduced barrier interface scattering.

The researchers explain why they used the super-lattice structure: "Due to a lag between the rate of aluminium cell temperature change in PAMBE and the optimum growth rate for N-polar AlGaN/GaN structure, an interruption-free linearly graded AlGaN growth was not possible."

The epitaxial material was completed with 1nm/1nm AlN/GaN. The super-lattice was designed to have an effective 33% Al content, while the cap had an effective 50% Al content. The channel mobility was 800cm^2/V-s, about 60% higher than for a GaN-on-sapphire structure.

Further PAMBE was used to selectively deposit n^+-GaN contacts through a silicon dioxide mask. Further transistor fabrication included metal-organic chemical vapor deposition (MOCVD) of silicon nitride gate dielectric, reactive-ion mesa etching, source/drain contact titanium/gold ohmic metal electrode deposition, and gate and contact pad deposition of titanium/gold. A 120nm plasma-enhanced chemical vapor deposition (PECVD) silicon nitride layer provided passivation.

The gate had two wings of 25μm width (2x25μm) and 0.75μm length. The gate was placed at 0.5μm distance from the source contact. The source–drain distance was 5μm. With the gate at 0V relative to the source (V_{GS}), the on-resistance was ~2Ω-mm. The maximum drain current was 1.1A/mm at almost 5V V_{DS}. The peak transconductance was ~200mS/mm with the gate at –4.2V and the drain at 4V.

The current was slightly higher under pulsed operation, suggesting a self-heating effect. In many GaN-based transistors there is significant current collapse/dispersion where the charge flow is lower under pulsed operation. There was no such dispersion/collapse observed with the UCSB device.

Frequency cut-offs (Figure 2) were determined with the device biased at -4.5V V_{GS} and 8V V_{DS}: 14.6GHz for maximum oscillation/power gain (f_{max}) and 8.9GHz for current gain (f_T). The biasing produced a drain current of 0.598A/mm. The cut-off values were determined without pad de-embedding.

Load-pull measurements at 4GHz were performed to assess large-signal performance. Class AB biasing was used with the drain current at 270mA/mm, about a quarter of the maximum (-6V V_{GS}, 5V $V_{DQ,Q}$). This optimized power-added efficiency (PAE) at 4GHz in its trade-off with gain. The output power density reached 0.56W/mm. The maximum PAE was 24%.

The researchers hope to achieve deep AB biasing in future scaled and optimized devices. For example, the gate-to-drain breakdown voltage of ~15V needs to be increased to enable increased gain and PAE at low charge density. ■

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Author:
Mike Cooke

Positive threshold in GaN transistors with p-type aluminium titanium oxide

An AlTiO gate insulator combined with recessing enables the first demonstration of normally-off, enhancement-mode operation.

The Indian Institute of Science claims the first enhancement-mode (e-mode) operation of aluminium gallium nitride/gallium nitride (AlGaN/GaN) high-electron-mobility transistors (HEMTs) using p-type aluminium titanium oxide (AlTiO) gate insulation [Sayak Dutta Gupta et al, IEEE Transactions on Electron Devices, vol66, issue 6 (June 2019), p2544].

The metal-oxide-semiconductor (MOS) gate stack combined the high-k dielectric properties of TiO_2 (k greater than 60) with the p-type properties supplied by Al_2O_3 doping (k ~9). The Al_2O_3 substitutes the 2Als on Ti sites and the 3Os have a deficit of one vacancy that is doubly positively charged. The charged O vacancy can release two holes, which can subsequently be reabsorbed by uncharged O vacancies. The compensating negative charges on the 2 Al sites are fixed.

The researchers comment: "The ON-state performance of e-mode HEMTs in this paper with p-type AlTiO was found to be on par with the best reports till date."

GaN HEMTs are being developed as power switches, where enhancement-mode as opposed to depletion-mode is desired for low power loss and fail-safe performance. Enhancement-mode devices are in the low-current OFF-state when the gate potential is at 0V. By contrast, depletion-mode operation has the current on with 0V gates and requires a (negative) potential to pinch off the electron flow.

Unfortunately, simple GaN HEMTs are depletion-mode and special extra processing is required to push threshold voltages in a positive direction to give enhancement-mode, normally off performance. The placing of p-type materials, such as magnesium-doped p-GaN, under the gate is one such method for moving to enhancement-mode devices. Recessing the gate into the barrier also pushes the threshold positive, but removing all the barrier material increases on-resistance due to etch damage of the GaN channel surface.

High-k dielectrics give increased electrostatic control of current under the gate with sharper turn-on (low subthreshold swing), while reducing gate leakage, compared with Schottky gate HEMTs.

Metal-organic chemical vapor deposition (MOCVD) on 6-inch (111) silicon substrates produced epitaxial structures with 150nm AlN nucleation, 1µm AlGaN transition, 3µm GaN buffer/channel, 22nm $Al_{0.22}Ga_{0.78}N$ barrier, and 40nm in situ silicon nitride cap.

Fabricated transistors (Figure 1) consisted of annealed titanium/aluminium/nickel/gold source-drain contacts, plasma-etched mesa isolation, atomic layer etching (ALE) of the AlGaN barrier for gate recessing, surface treatment and deposition of gate oxide, and nickel/gold gate metal formation and low-temperature annealing.

The gate oxide was applied using BENEQ atomic layer deposition (ALD) equipment. Water (H_2O) was used as

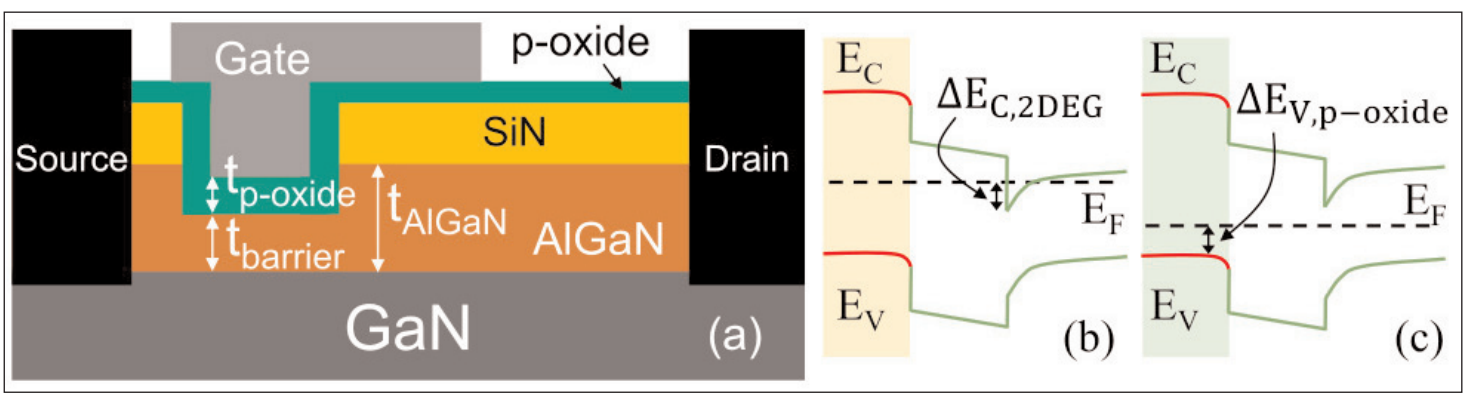

Figure 1. (a) Cross-sectional view of HEMT with p-type metal oxide gate and partially recessed AlGaN barrier. Energy-band sketch of AlGaN/GaN HEMTs with (b) conventional dielectric and (c) p-type oxide: p-type oxide shifts Fermi level (E_F) beneath conduction band (E_C) in two-dimensional electron gas (2DEG) channel.

precursor for oxygen in both the TiO_2 and Al_2O_3 components. The titanium was sourced from titanium tetraisopropoxide (TTIP), and aluminium from trimethylaluminium (TMA). The oxide was built up from cycles of Al_2O_3 and TiO_2 layers.

Hall measurements on $Al_{0.52}T_{0.48}O$ showed p-type conductivity with a majority hole concentration at $1.4x10^{14}/cm^3$. The $Al_{0.52}Ti_{0.48}O$ material was compared as a p-type gate oxide against MOS-HEMT structures incorporating pure TiO_2, sputtered copper oxide or electron-beam evaporated nickel oxide.

Pure TiO_2 gate insulation resulted in depletion-mode operation with a threshold voltage at –4V. With 52% Al in the TiO_2, the threshold shifted in a positive direction to –0.2V. Post-deposition annealing also pushed the threshold positively as the temperature increased, but the effect became less pronounced for higher Al contents of the AlTiO. The more positive effect at lower contents is due to greater activation of the Al, it is thought. At 52% Al, the number of Ti sites where Al can be activated is limited.

Copper oxide gave a smaller threshold shift than AlTiO. In addition, the gate leakage was increased by up to four orders of magnitude. With nickel oxide, the gate leakage was even worse.

Thinning the barrier by recessing the gate enabled positive threshold voltages to be attained. With the barrier thickness at 8nm, the threshold was +0.5V. The resulting transistor operated in enhancement-mode with the device in the OFF-state at 0V gate potential. The thinner barrier also improved channel control with lower OFF-state current (100x lower) and improved/lower subthreshold swing at 73mV/decade (Figure 2).

The threshold voltage hysteresis for drain current–gate voltage dual sweeps was ~30mV and ~40mV with the drain bias at 0.1V and 15V, respectively.

A device with 3µm gate length and 17.5µm source–drain spacing achieved a drain current ~400mA/mm at +4V gate potential. The on-resistance was 8.9Ω-mm, while the on/off current ratio was 10^7. Gate leakage was less than 200nA/mm.

The OFF-state three-terminal breakdown voltage was more than 600V with the substrate grounded. Catastrophic failure was seen in the mesa isolation, not as usual in the gate–drain region. The researchers expect an increased breakdown voltage from improved mesa isolation processes.

The researchers believe that the threshold can be pushed beyond +1V with optimization of the p-oxide gate insulation. ■

https://doi.org/10.1109/TED.2019.2908960

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Author: Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

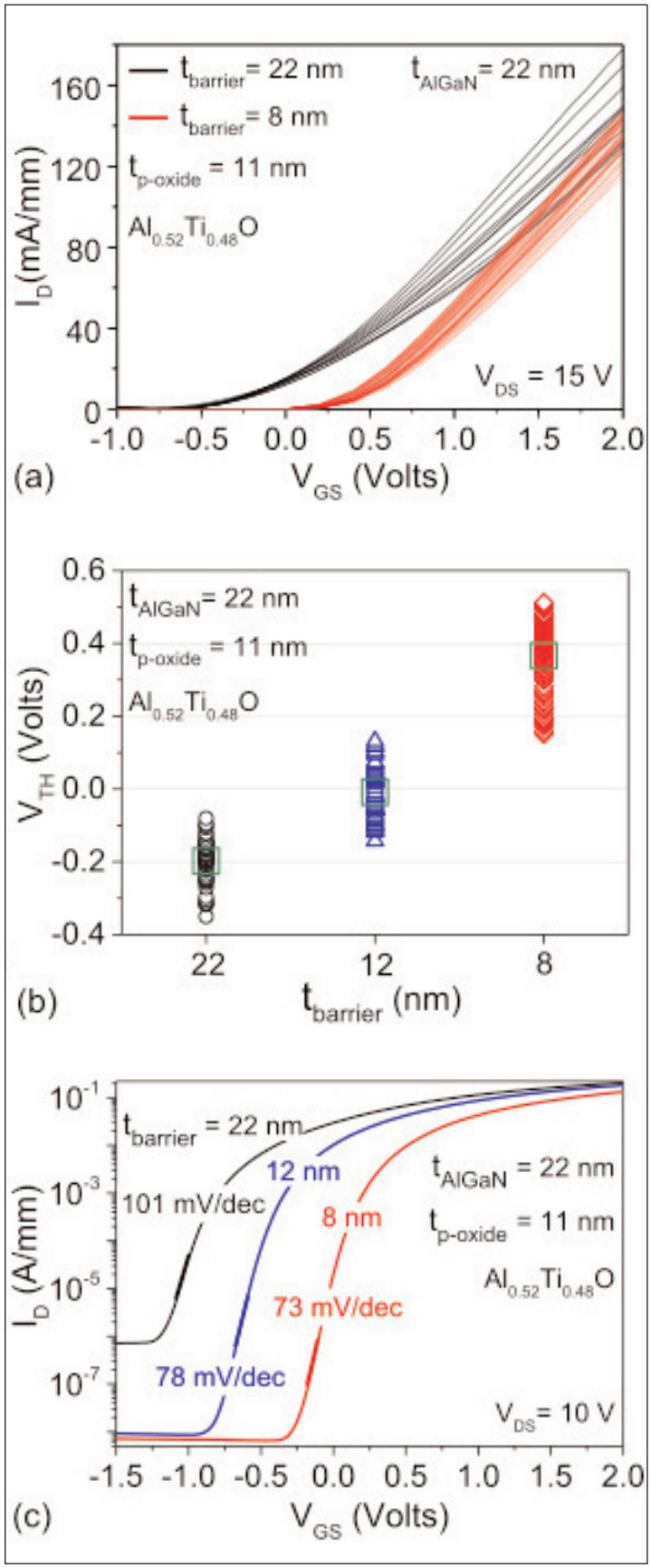

Figure 2. (a) Transfer characteristics of HEMTs with optimized p-oxide and different barrier thicknesses. (b) Shift in threshold (V_{TH}) from negative to positive when barrier thickness under the gate was scaled. (c) Logarithmic plot of transfer characteristics and derived subthreshold swing (SS) values.

GaN transistor power boosted by diamond thermal management

Chemical vapor deposition substrate replacement gives record DC power density.

A team of researchers mainly based at the US Naval Research Laboratory (NRL) claim record DC power density from aluminium gallium nitride (AlGaN) barrier high-electron-mobility transistors (HEMTs) [Marko J. Tadjer et al, IEEE Electron Device Letters, published online 11 April 2019]. Other researchers in the team were variously from Southern Methodist University, TMX Scientific, University of California Los Angeles (UCLA) and Akash Systems Inc in the USA.

The high power was achieved by replacing the silicon substrate on which the III-nitride device layers were grown with diamond to allow enhanced thermal management.

The team targets the high frequency and high power density needed for commercial and military electronics. Diamond has previously been used to manage the high temperatures generated in such applications, due to its very high thermal conductivity. One technique for this is wafer bonding, but an attractive alternative is to grow diamond directly on the backside of the device layers.

Building on previous work, the NRL-led team inverted the GaN/Si substrate and removed the silicon substrate. Etching of the exposed N-polar III–N nucleation layers left some 700nm of GaN buffer. A 30nm silicon nitride (SiN) barrier was applied before chemical vapor deposition (CVD) of a thick polycrystalline diamond layer at Element Six Technologies (E6, part of the De Beers Group).

E6 specializes in synthetic diamond and tungsten carbide growth processes. In addition to thermal management, applications for these 'supermaterials' cover sectors such as oil and gas extraction, automotive and aerospace parts, mining and construction, consumer electronics, optics, and wear reduction in mechanical systems. The firm claims employment of 1900 people with production facilities in UK, Ireland, Germany, South Africa and the USA. E6's history goes back to 1946.

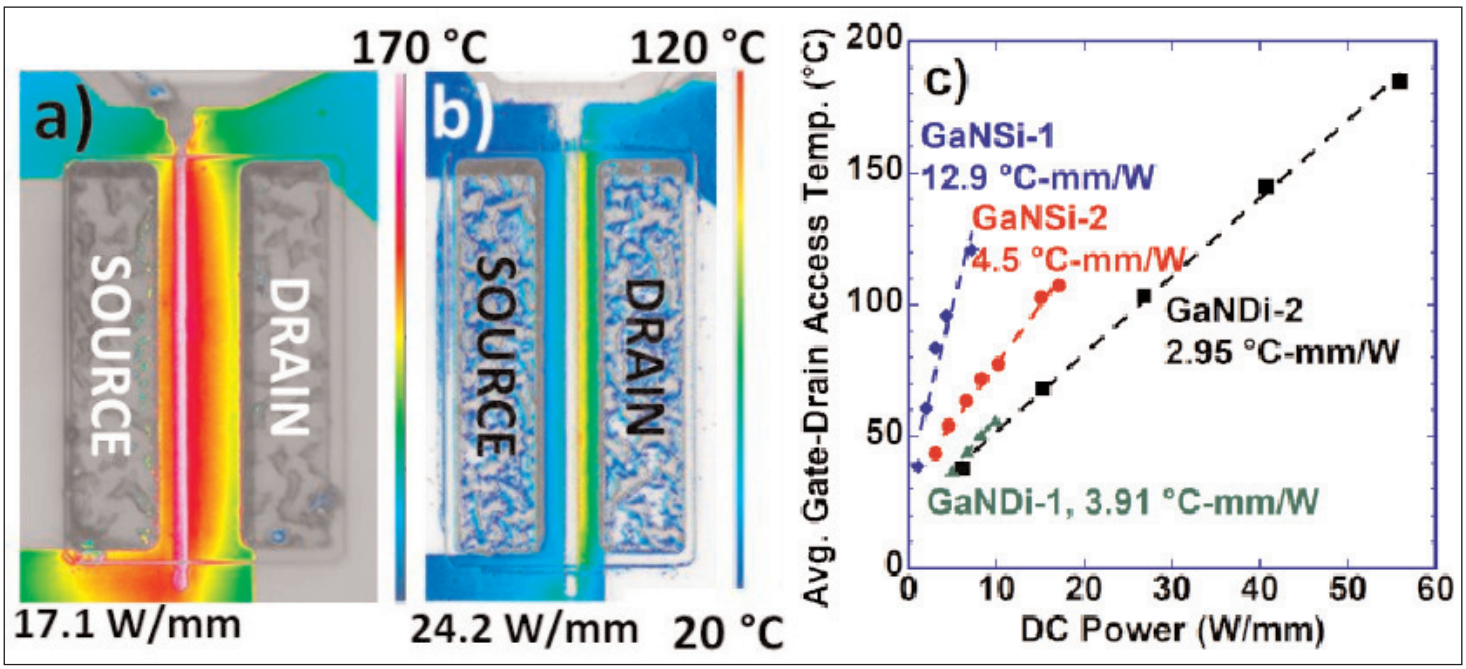

Figure 1. Steady-state thermoreflectance maps of AlGaN/GaN HEMTs before and after backside diamond deposition process measured at 365nm illumination as function of DC output power: (a) silicon-based sample GaNSi-2; (b) diamond-based ample GaNDi-2; and (c) average temperature in gate-drain access region as function of DC power (IDS xVDS) for range of AlGaN/GaN HEMTs.

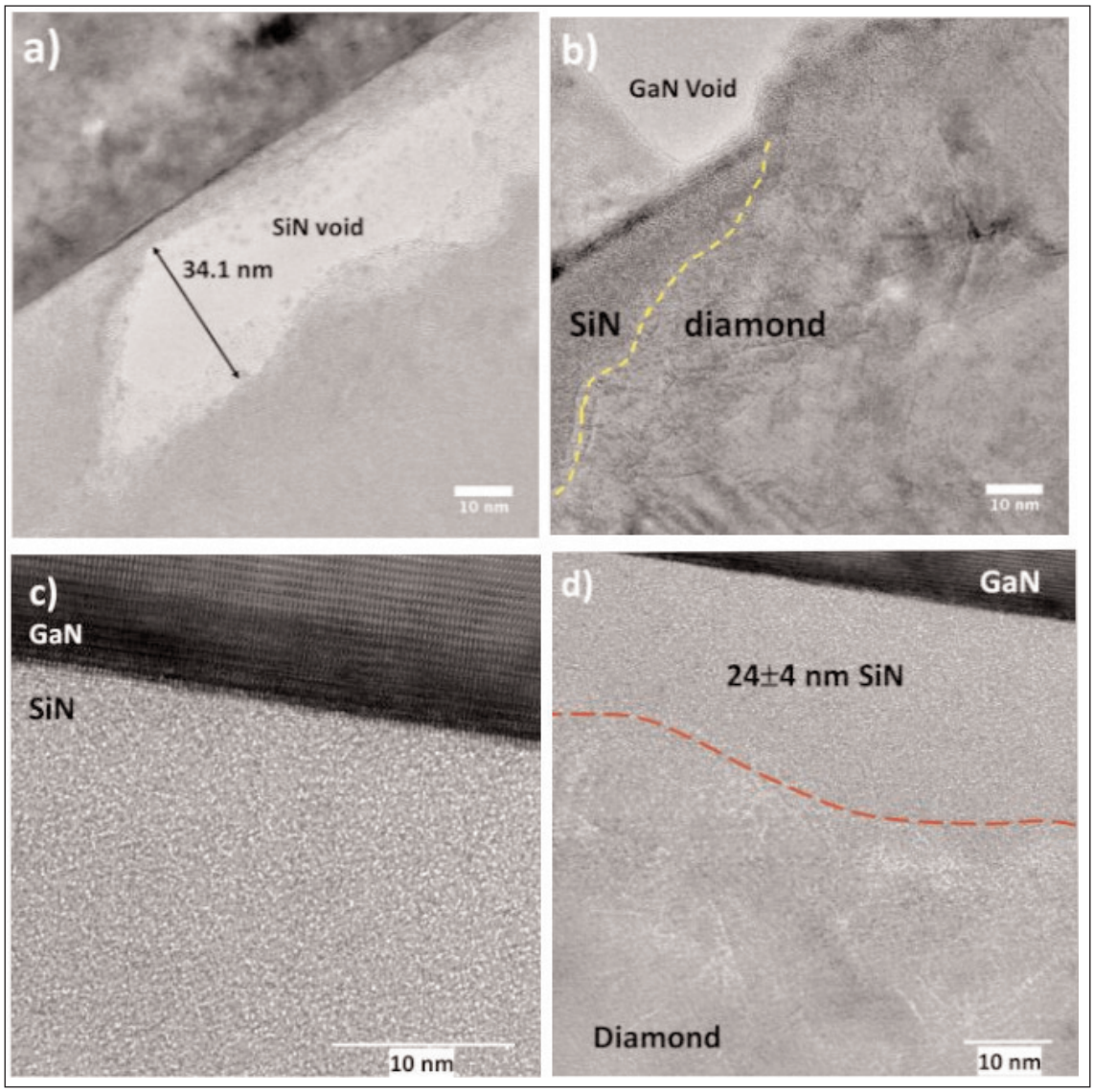

Figure 2. High-resolution TEM image of GaN/SiN/diamond interface of (a) sample GaNDi-1 showing void in SiN, (b) sample GaNDi-1 showing void in N-polar side of GaN caused by H-plasma etching during diamond CVD, (c) sharp, void-free interface between amorphous SiN and crystalline GaN for sample GaNDi-2, and (d) SiN/polycrystalline diamond substrate interface for sample GaNDi-2 (delineated by dashed red line).

The NRL device structure was completed with a 20nm $Al_{0.2}Ga_{0.8}N$ barrier layer, mesa plasma etch, titanium/aluminium/nickel/gold ohmic source–drain contact deposition and annealing, nickel/gold Schottky gate deposition, titanium/gold contact pad overlay, and plasma-enhanced chemical vapor deposition (PECVD) silicon nitride passivation. The device fabrication was carried out both before and after the silicon substrate replacement with diamond. The silicon nitride passivation was optimized for avoiding current collapse under pulsed operation.

The researchers report: "Room-temperature Hall measurements and DC current–voltage characteristics indicated that the substrate-side process did not significantly influence the mobility and sheet carrier density, and thus the on-resistance of the HEMTs. Additionally, only minimal effects on threshold voltage and transconductance were observed."

Thermoreflectance imaging (TRI) showed temperature increases near contacts beyond 150°C under 15W/mm power density direct current (DC) operation of HEMTs on silicon (Figure 1). By contrast, the device on diamond demonstrated no significant temperature increase with 24.2W/mm power density. Above 24.2W/mm, the temperature did increase, largely due to gate leakage current. Even so, the temperature did not exceed 176°C in the access/contact region with the power density at 56W/mm. The maximum temperature of 205°C was seen in the gate region at the drain edge.

The diamond-based GaN HEMT (GaNDi-2) achieved a thermal resistance as low as 2.95°C-mm/W. A device from an earlier version of the diamond replacement (GanDi-1) process had a higher thermal resistance of 3.91°C-mm/W. The higher value was attributed to defects at the interface with the diamond substrate. Transmission electron micrography (TEM) showed nanometer-sized voids in the GaNDi-1 sample's 30nm silicon nitride layer and at the GaN interface (Figure 2). The GaNDi-2 sample, by contrast, achieved "a sharp GaN-diamond interface and lower thermal resistance". The thermal resistance was significantly higher for GaN HEMTs on the original silicon substrates (GaNSi-1&2).

The researchers suggest that thinning or eliminating the silicon nitride barrier layer could decrease the thermal resistance by up to 48%. However, such a process would need also eliminate voids from the interface. ■

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Author: Mike Cooke

Imec demos optimized process flows for high-performance Ge-based devices

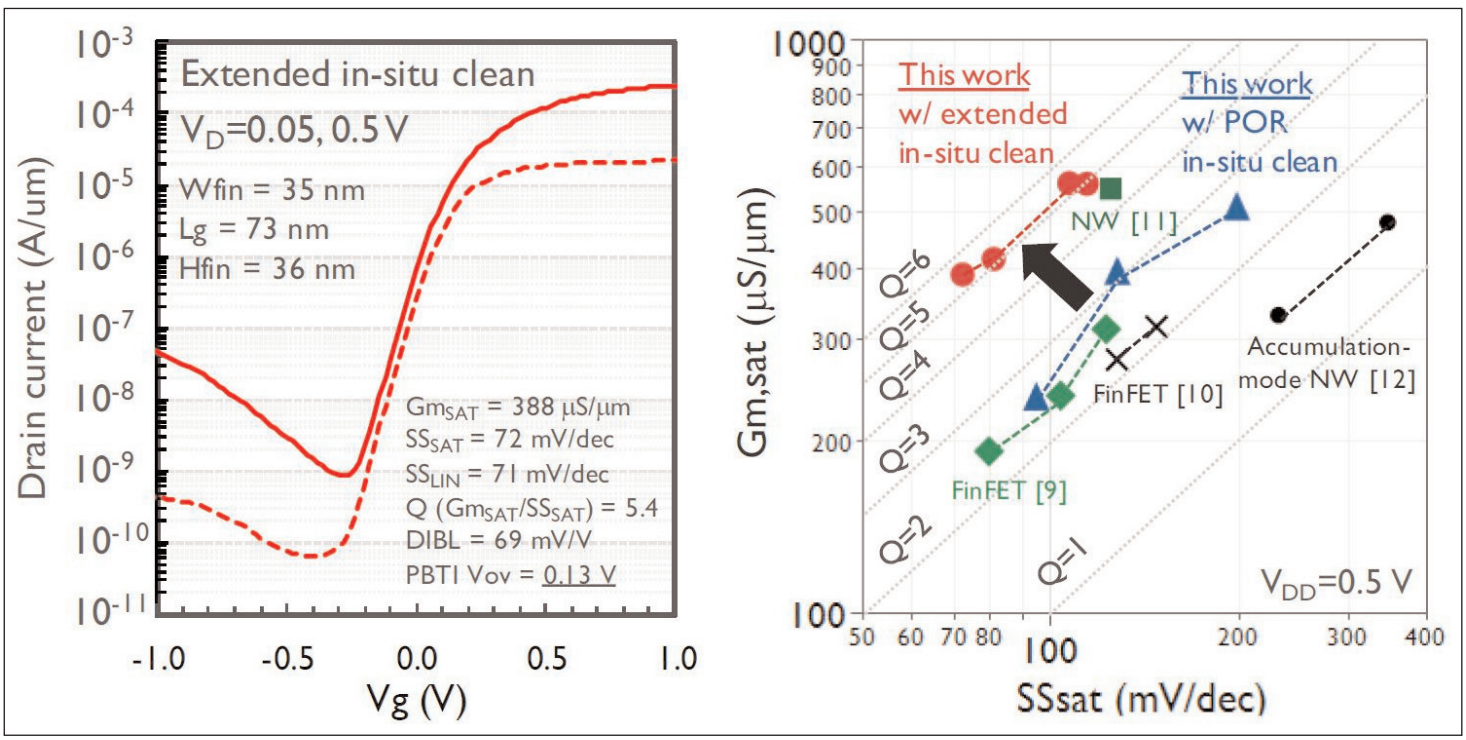
G_{mSAT}/SS_{SAT} benchmark has been improved in both n-type FinFETs and p-type gate-all-around devices.

At the 2019 Symposia on VLSI Technology and Circuits in Kyoto, Japan (9–14 June), nano-electronics research centre imec of Leuven, Belgium reported improved performance for two types of germanium (Ge)-based device: both n-type FinFETs and p-type gate-all-around (GAA) devices.

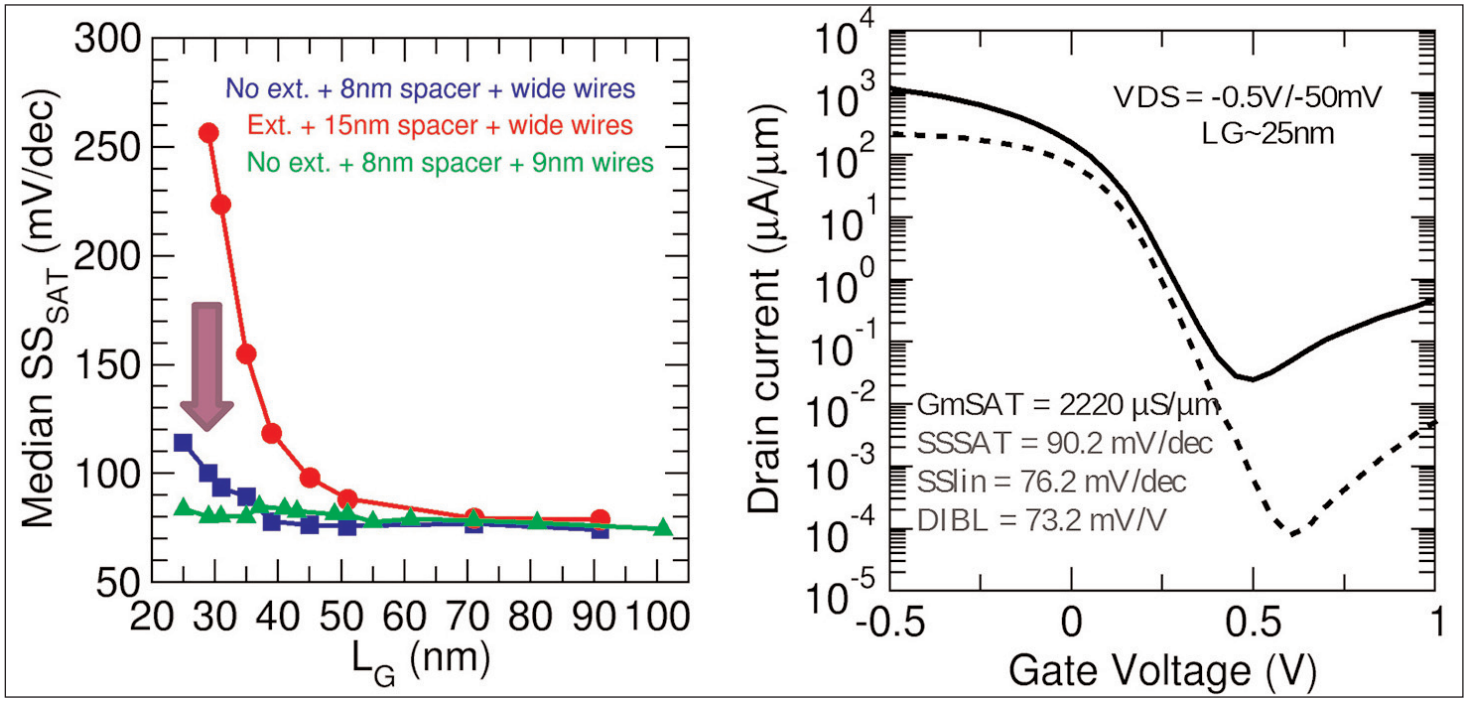
For Ge n-type FinFETs, pre-gate stack process optimization dramatically improved reliability and performance, with 100% improvement in positive-bias temperature instability (PBTI) and improvement in the benchmark of transconductance (G_{mSAT}) versus sub-threshold slope (SS_{SAT}). For the Ge-based p-type GAA device, excellent short-channel control and performance were achieved with an improved extension-less junction scheme. The results are said to confirm the potential of Ge-based CMOS transistors as high-performance solutions for the 3nm-and-beyond technology nodes.

Due to the higher intrinsic mobility of Ge compared to Si, Ge-based FinFET devices have emerged as non-disruptive performance boosters for future technology nodes. While Ge p-type FinFET devices have been studied extensively, the development of well-performing, reliable Ge n-type FinFET devices is lagging behind. Imec says that it has now proposed an optimized process flow for the gate stack, solving one of the major challenges for Ge n-type FinFET development.

Key to the successful gate-stack formation are an improved pre-cleaning and an optimized dummy gate oxide deposition and removal process, as part of a replacement metal-gate (RMG) process flow. Imec's optimized process flow resulted in 100% improved positive-bias temperature instability (PBTI) and a 100% improvement in G_{mSAT} versus SS_{SAT} benchmark — a measure for the interface quality and electron mobility. "With our process flow, the oxide-free Ge



Improved performance and reliability of Ge nFinFET device. (Left) Best I_D–V_G curves obtained from 35nm-wide Ge nFinFET with dummy gate oxide and extended in-situ clean. (Right) Extrinsic G_{mSAT} versus SS_{SAT} benchmark of n-channel Ge fin and nanowire FETs at V_{DD}=0.5V.



(Left) Median SS_{SAT} versus physical gate length for strained p-type Ge GAA devices with double nanowires. Significantly improved electrostatic control below L_G=40nm. (Right) Best I_D-V_G characteristic of 9nm wires diameter Ge GAA with 25nm gate length by using extension-less scheme and scaled 8nm spacer. Reported data are normalized to total effective channel perimeter.

channel surface can be prepared prior to the gate and efficiently protected from oxidation," says logic program manager Naoto Horiguchi. "The paper describing these results was selected by the committee members of the VLSI Symposium as a highlight 2019 VLSI technology paper. It underlines the importance of our improved dummy gate oxide process for the formation of high-performance and reliable Ge n-type FinFETs."

In a second paper, imec proposes an improved junction scheme to solve one of the major challenges for p-type strained Ge-based GAA devices, i.e. achieving good short-channel control while preserving transistor performance. A dramatic improvement in short-channel control — allowing gate-length scaling down to 25nm — was achieved by using an extension-less scheme, i.e. without dopant implantation in the 'extension' region next to the gate. To maintain the transistor's performance, the extension-less scheme was combined with spacer thickness reduction, and with the implementation of highly boron-doped Ge or GeSn as the source/drain material. The optimized process flow resulted in a 55% improvement in the G_{mSAT} versus SS_{SAT} benchmark on Ge GAA devices compared with previous work. A short-channel (L_G~25nm) device has also shown excellent G_m ($G_{m,lin}$=512µS/µm, G_{mSAT}=2220µS/µm).

"Ge GAA devices have the potential to further extend gate-length scaling beyond what is possible with Ge-based FinFETs," says Horiguchi. "They can be fabricated by using a process flow that is not so disruptive compared to FinFET processing," he adds. "Much of the learnings we obtain from FinFET development can be transferred to GAA devices. By using our extension-less scheme, we have now demonstrated the feasibility of these Ge-based GAA devices for gate-length scaling down to 25nm, while preserving excellent performance." ■

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Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

CS CLEAN SOLUTIONS AG
Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24000
Fax: +49 89 96 2400122
www.csclean.com

SAES Pure Gas Inc
4175 Santa Fe Road,
San Luis Obispo,
CA 93401,
USA
Tel: +1 805 541 9299
Fax: +1 805 541 9399
www.saesgetters.com

11 Process monitoring and control

Conax Technologies
2300 Walden Avenue,
Buffalo, NY 14225,
USA
Tel: +1 800 223 2389
Tel: +1 716 684 4500
E-mail: conax@conaxtechnologies.com

Ideas. Solutions. Success.
www.conaxtechnologies.com
Conax Technologies is a designer and manufacturer of standard and custom-engineered temperature sensors, compression seal fittings and feedthroughs, probes, wires, electrodes and fiber-optic cables. The company is headquartered in Buffalo, New York, with locations on the US West Coast, Canada, Europe and Asia.

k-Space Associates Inc
2182 Bishop Circle
East, Dexter, MI 48130,
USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com

KLA-Tencor
One Technology Dr,
1-2221I, Milpitas,
CA 95035,
USA
Tel: +1 408 875 3000
Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str. 10–13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de
LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)
Bregstrasse 90,
D-78120 Furtwangen im Schwarzwald,
Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187,
Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.
645 M Street Suite 102,
Lincoln, NE 68508, USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
575 McCorkle Boulevard,
Westerville, OH 43082, USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

Keithley Instruments Inc
28775 Aurora Road,
Cleveland, OH 44139, USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

15 Assembly/packaging materials

ePAK International Inc
4926 Spicewood Springs Road,
Austin, TX 78759,
USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak
31398 Huntwood Avenue,
Hayward, CA 94544, USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc
(see section 3 for full contact details)

Materion Advanced Materials Group
2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

Ismeca Europe Semiconductor SA
Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries
1005 Virginia Drive,
Fort Washington, PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc
2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc
2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054,
USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego, CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

W.L. Gore & Associates
401 Airport Rd, Elkton,
MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Ansoft Corp
4 Station Square,
Suite 200,
Pittsburgh, PA 15219,
USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

Crosslight Software Inc
121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc
10404 Patterson Ave.,
Suite 108, Richmond, VA 23238,
USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc
5302 Snapfinger Woods Drive,
Decatur, GA 30035,
USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn, London WC1V 6EG,
UK

Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart, Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

Fishbone Consulting SARL
8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources

Al Shultz Advertising Marketing for Advanced Technology Companies
1346 The Alameda,
7140 San Jose, CA 95126,
USA
Tel: +1 408 289 9555
www.alshuktz.com

SEMI Global Headquarters
3081 Zanker Road,
San Jose,
CA 95134,
USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

Yole Développement
45 rue Sainte Geneviève,
69006 Lyon,
France
Tel: +33 472 83 01 86
www.yole.fr

event calendar

If you would like your event listed in *Semiconductor Today*'s Event Calendar, then please e-mail all details to the Editor at mark@semiconductor-today.com

8–10 July 2019
2019 Summer Topicals Meeting Series
Fort Lauderdale, FL, USA
E-mail: i.donnelly@ieee.org
www.sum-ieee.org

9–11 July 2019
SEMICON West 2019
Moscone Center, San Francisco, California, USA
E-mail: semiconwest@xpressreg.net
www.semiconwest.org

10–11 July 2019
UK Semiconductors 2019 (UKS'19)
University of Sheffield, UK
E-mail: edmund.clarke@sheffield.ac.uk
www.uksemiconductors.com

21–24 July 2019
AVS 19th International Conference on Atomic Layer Deposition (ALD 2019), featuring the 6th International Atomic Layer Etching Workshop (ALE 2019)
Bellevue, Washington, USA
E-mail: della@avs.org
www.ald2019.avs.org

22–24 July 2019
International Congress on Advanced Materials Sciences and Engineering (AMSE-2019)
ANA Crown Plaza Osaka, Japan
E-mail: eve@istci.org
www.istci.org/icamse2019

6–8 August 2019
PowerAmerica's 2019 Wide Bandgap Summer Workshop
James B. Hunt Jr. Library, N.C. State University's Centennial Campus, Raleigh, NC, USA
E-mail: poweramerica@ncsu.edu
www.poweramericainstitute.org

11–15 August 2019
SPIE Optics + Photonics 2019
San Diego Convention Center, San Diego, CA, USA
E-mail: customerservice@spie.org
http://spie.org/Optics_Photonics

29–30 August 2019
EPIC World Photonics Technology Summit 2019
Grand Hyatt Hotel, Berlin, Germany
E-mail: carlos.lee@epic-assoc.com
www.epic-assoc.com/world-photonics-technology-summit-2019

2–5 September 2019
21st Conference on Power Electronics and Applications (and Exhibition), EPE'19 ECCE (Energy Conversion Congress & Expo) Europe
Genova, Italy
E-mail: info@epe2019.com
www.epe2019.com

4–7 September 2019
CIOE 2019: 21st China International Optoelectronic Exposition

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Shenzhen Convention & Exhibition Center, China
E-mail: cioe@cioe.cn
www.cioe.cn/en

18–20 September 2019
SEMICON Taiwan 2019
Taipei Nangang Exhibition Centre, Taiwan
E-mail: semicontaiwan@semi.org
www.semicontaiwan.org

22–25 September 2019
35th North American Conference on Molecular Beam Epitaxy (NAMBE 2019)
Ketchum, ID, USA
E-mail: della@avs.org
www.nambe2019.avs.org

22–26 September 2019
45th European Conference on Optical Communications (ECOC 2019)
Dublin, Ireland
E-mail: ecoc2019@thiet.org
www.ecoc2019.org

24–26 September 2019
19th International Metrology Congress (CIM 2019)
Paris, France
E-mail: info@cfmetrologie.com
www.cim2019.com

29 September – 3 October 2019
Eleventh Annual Energy Conversion Congress and Exposition (ECCE 2019)
Baltimore, MD, USA
E-mail: ecce@courtesyassoc.com
www.ieee-ecce.org/2019

29 September – 4 October 2019
International Conference on Silicon Carbide and Related Materials (ICSCRM 2019)
Kyoto International Conference Center, Japan
E-mail: icscrm2019-regist@or.knt.co.jp
www.icscrm2019.org

29 September – 4 October 2019
22nd European Microwave Week (EuMW 2019) including:
49th European Microwave Conference (EuMC 2019)
14th European Microwave Integrated Circuits Conference (EuMIC 2019)
Paris Expo Porte de Versailles,
Paris, France
E-mail: eumwreg@itnint.com
www.eumweek.com

30 September – 3 October 2019
SCTE-ISBE Cable-Tec Expo 2019
Ernest N Morial Convention Center, New Orleans, LA, USA
E-mail: expo@scte.org
https://expo.scte.org

6–11 October 2019
22nd European Microwave Week (EuMW 2019)
Paris Expo Porte de Versailles, Paris, France
E-mail: eumwreg@itnint.com
www.eumweek.com

17–19 October 2019
LASER World of PHOTONICS INDIA 2019
Bombay Exhibition Centre (BEC), India
E-mail: info@world-of-photonics-india.com
www.world-of-photonics-india.com

20–22 October 2019
9th Annual World Congress of Nano Science & Technology 2019 (Nano S&T-2019) – Small World, Big Thinking, Big Pattern, and Great Development
Suzhou, China
E-mail: selina@bitconferences.com
www.bitcongress.com/nano2019

29–31 October 2019
7th IEEE Workshop on Wide Bandgap Power Devices & Applications (WiPDA 2019)
Marriott Stateview Hotel, NCSU, Raleigh, NC, USA
E-mail: rodriguesrostan@ieee.org
www.wipda.org

3–6 November 2019
2019 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS)
Loew's Vanderbilt Hotel, Nashville, TN, USA
E-mail: bruce.green@nxp.com
www.bcicts.org

5–8 November 2019
5th International Conference on Advanced Electromaterials (ICAE 2019)
Ramada Plaza Jeju Hotel, Jeju Korea
E-mail: secretary@icae.kr
www.icae.kr

7 November 2019
Interlligent UK's 2019 RF & Microwave Design Seminar
Møller Centre, Cambridge, UK
E-mail: info@interlligent.co.uk
www.eventbrite.co.uk/e/interlligent-uks-2019-rf-microwave-design-seminar-tickets-59049393325

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