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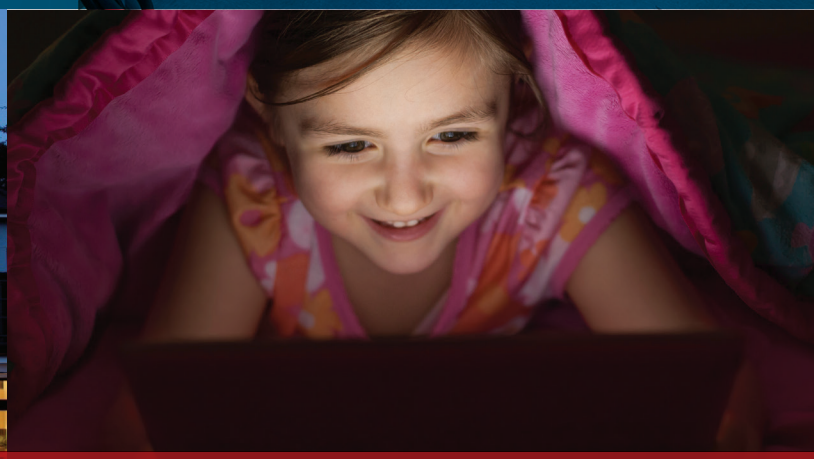
Infrared devices

Automotive lighting and sensing

Exagan forms Taiwan subsidiary • Leti and NARLabs collaborate
NTT invests in QD Laser • Osram Opto joins ISELED Alliance

Lower Cost LEDs



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Veeco's New TurboDisc EPIK700 GaN MOCVD System

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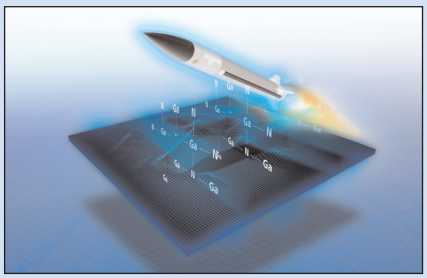
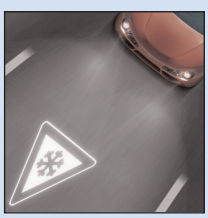
p16 France's Exagan has established a Taiwan subsidiary with a new sales and applications center in Taipei's Nankang Software Park.



p21 Raytheon is providing technology for the first missile to use GaN, the US Army's Guidance Enhanced Missile – Tactical Ballistic Missile (GEM-T).

p24 The Compound Semiconductor Centre has won the title for collaboration at the 'Made in Wales' awards.



Cover: Osram Opto Semiconductors' new Oslon Boost HX LED can be operated at 3A/mm^2 and enable each car headlight to achieve a resolution of more than 1 million pixels, offering drivers not only illumination but also optional support from information projected onto the road. **p41**

editorial

Extending LED and laser applications

In this issue we focus on developments in infrared devices, including the emission and detection in the mid-wavelength infrared (MWIR, 3–8μm) and long-wavelength infrared (LWIR, 8–15μm), targeting operation at room temperature — by using mechanisms such as quantum cascade lasing for emission and 2D Van der Waals materials for detection — for applications as diverse as missile guidance and medical imaging (see pages 54–59).

Driven by the proliferation in applications and the diversity of technology, the market for infrared light sources is forecasted by Yole Développement to rise at a compound annual growth rate (CAGR) of 29% from $1.8bn in 2018 to $6.5bn in 2023 (pages 60–62).

Yole notes that, although initially developed for optical communications, IR light-emitting diodes and laser diodes are now integrated into high-value functions for datacom/telecom, industrial, automotive and consumer applications. Specifically, IR LEDs are increasingly being used in smartphones for proximity sensing, automotive for gesture recognition, and virtual reality/augmented reality (VR/AR) headsets for eye tracking. 3D sensing in particular is forecasted to become the largest application (at $3bn), outgrowing optical communications ($2bn). The latter has traditionally driven demand for edge-emitting lasers (EELs), but these are increasingly in demand for emerging applications such as light detection and ranging (LiDAR), which should grow to $101m in 2023. Meanwhile, vertical-cavity surface-emitting lasers (VCSELs) — initially applied in short-range data communications — have been rapidly adopted for 3D sensing in consumer electronics (e.g. facial recognition in Apple's iPhone X smartphone). The overall VCSEL market is forecasted to rise at a CAGR of 16.9% from $1.78bn in 2018 to $3.89bn by 2023 (see page 6).

For example, in September Germany's Osram Opto Semiconductors, which has previously focused on LEDs and edge-emitting lasers, launched its first VCSEL product family (emitting at the IR wavelength of 940nm, targeting facial recognition, as well as VR/AR, robotics and drones) – see September issue (page 45). The firm also launched a near-infrared LED aimed at integrating spectroscopy into smartphones (allowing consumers to check the composition of food and pharmaceuticals, for example).

Meanwhile, San Jose-based Lumileds has launched its 'LUXEON IR for Automotive' emitter product family, targeting both interior and exterior automotive sensing, such as driver monitoring systems, gesture control and night vision (page 37). The automotive industry is increasingly driving demand for IR devices through the advent of advanced driver-assistance systems (ADAS), in both interior applications such as driver monitoring systems (DMS) and exterior applications such as lane-departing systems.

Such infrared applications are building on established developments in visible applications. Osram has just launched its high-current Oslon Boost HX LED, which can be combined in automotive forward lighting with a digital mirror device (DMD) system to project driver-assistance information onto the road ahead (see page 41). In addition, Osram's new Osire E4633i RGB LED for dynamic in-car lighting (being unveiled at electronica 2018) aims to provide not only ambient lighting but also functions such as traffic-responsive alerts. System-level applications like these tie in with Osram Opto in September joining the ISELED Alliance (Integrated Serial/Smart Embedded Light Emitting Diode) to develop the 'digital LED' (controller chip with three coloured LED chips) for vehicle interior lighting (page 40).

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

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

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news

VCSEL market to grow at 16.9% CAGR from $1.78bn to $3.89bn by 2023

The vertical-cavity surface-emitting laser (VCSEL) market will rise at a compound annual growth rate (CAGR) of 16.9% from $1.78bn in 2018 to $3.89bn by 2023, according to a report 'VCSEL Market Report 2018 — Global Forecast to 2023' by the firm Markets and Markets.

Growth is due mainly to the rising adoption of VCSELs in proximity sensing and medical applications, the increasing use of VCSELs for datacoms, the growing usage of VCSELs in infrared illumination, and the surge in demand for VCSELs with advancements in automotive electronics. However, limited data transmission range is restricting the growth of the VCSEL market.

InP VCSELs to grow fastest

By material, the VCSEL market is segmented into gallium arsenide (GaAs), gallium nitride (GaN), indium phosphide (InP), and others, including gallium indium nitrogen arsenide (GaInNAs), indium gallium arsenide (InGaAs), indium aluminum gallium arsenide (InAlGaAs), and aluminum gallium arsenide (AlGaAs).

The market for InP is expected to grow at the highest CAGR. VCSELs operating in 1300–1550nm wavelength range are rapidly evolving and are mostly InP-based. The high growth of this material can be attributed to its high wavelength compatibility and use in high-speed communication applications.

Single-mode to grow fastest

By device type, compared with multi-mode VCSELs, the market for single-mode VCSELs is expected to grow at a higher CAGR, due to their ability to provide solutions to many sensing applications, especially in the consumer electronics industry.

Emerging applications to grow at highest CAGR

The market for emerging applications — such as light detection and ranging (LiDAR), night vision, atomic clocks, GPS, magnetometers and displays — is expected to grow at the highest CAGR. Currently, this market is in the nascent stage, but it is expected to see high growth in the coming years due to the use of VCSELs for high-quality vision and obstacle detection etc.

Data center held largest share of VCSEL market in 2017

By end user (data center, consumer electronics, automotive, industrial, healthcare, and military data center, consumer electronics, automotive, industrial, healthcare, and military), data centers (which largely use 850nm-emitting VCSELs, especially for applications where the size of the data transmitted over a network is very large) accounted for the biggest share of the VCSEL market in 2017.

In data centers, high data transfer rates are extremely important as they allow fast transmission of data for processing and obtaining results. As the adoption of data analytics increases in businesses worldwide to improve decision-making capabilities, demand for VCSELs in data centers is expected to rise further.

The market for consumer electronics is expected to grow at the highest CAGR. With increasing implementation of VCSELs for advanced features such as laser autofocus and proximity sensors in smartphones, the consumer electronics segment has created a huge shift in the overall VCSEL market. Also, other applications such as video signal to display, video signal from one or more cameras, low-noise microphone, and gesture recognition are expected to create huge demand.

The VCSEL market is expected to grow at the highest CAGR in the Asia-Pacific region during 2018–2023

Americas the largest shareholder; APAC to grow fastest

The Americas accounted for the major share of the overall VCSEL market in 2017, and is the largest market due to demand from technology giants such as Facebook, Google, Apple and Amazon. Moreover, the growing emphasis of businesses on the use of cloud infrastructure has contributed to the increasing demand for VCSEL-based optical transceivers in the Americas.

The VCSEL market is expected to grow at the highest CAGR in the Asia-Pacific (APAC) region during 2018–2023. This growth can be attributed to the rising number of data centers and increasing demand for consumer electronic devices and premium automobiles. APAC countries such as China, India, Singapore and Indonesia are emerging as hubs for data centers due to advancements in basic telecom infrastructure and encouragement from respective governments.

Major players in the VCSEL market are cited as Finisar (USA), Lumentum (USA), Broadcom (USA), Philips Photonics (Germany), II-VI (USA), IQE (UK), AMS Technologies (Germany), Vixar (USA), Santec (Japan), VERTILAS (Germany), Agiltron (USA), Alight Technologies (Denmark), Ultra Communications (USA), Laser Components (Germany), Litrax Technology (Taiwan), Coherent (USA), TT Electronics (UK), Newport (USA), NeoPhotonics (USA), and Necsel Intellectual Property (PD-LD) (USA).

Factors such as technological advancements in the consumer electronics sector and the evolution of laser-based hard disc drive technology are expected to generate opportunities for players in the VCSEL market.

www.researchandmarkets.com

CSP LED market to grow at 18.2% CAGR from $757.7m in 2018 to $1744.8m in 2023

General lighting and automotive segments to drive growth

The chip-scale package (CSP) LED market will rise at a compound annual growth rate (CAGR) of 18.2% from $757.7m in 2018 to $1744.8m by 2023, according to a report 'Chip Scale Package (CSP) LED Market by Application (Back-lighting Unit (BLU), Flash Lighting, General Lighting, Automotive, Others), Power Range (Low- & Mid-Power, and High-Power), and Geography (APAC, North America, Europe, RoW) - Global Forecast to 2023' from MarketsandMarkets.

With a low bill of materials due to the manufacturing process (where several packaging steps are omitted), the low-cost potential of CSP LEDs is a major factor driving growth. Small form factor and wide beam angle (due to high package density) coupled with low thermal resistance and uniform current spreading are other factors that are contributing significantly to the adoption of CSP LEDs in different applications. Heightened competition in the packaged LED market has led to the development and launch of new and innovative CSP LEDs with improved designs and high-end specifications, notes the report.

General lighting and automotive segments to define growth

The adoption of CSP LEDs in the general lighting and automotive segments will play a crucial role in market growth during the forecast period. Demand for CSP LEDs is expected to increase rapidly in the next five years mainly from these two segments offering growth opportunities to CSP LED makers. The automotive segment is expected to grow at the fastest CAGR. There is currently negligible adoption of CSP LEDs in the automotive segment, mostly in replaceable headlights (supplied by local/regional vendors by using CSP LEDs from manufacturers such as Seoul Semiconductor). Although the market for CSP LEDs in the automotive segment is very small, demand for mid- and high-power CSP LEDs is expected to rise exponentially from 2018 onwards when automotive manufacturers and automotive lighting suppliers begin adopting CSP LEDs for new installations.

High-power CSP LEDs to be main focus

High-power CSP LEDs are expected to dominate the CSP LED market during the forecast period. With the exponential growth in demand in the automotive and general lighting segments, high-power CSP LEDs will find use in several applications such as automotive headlights, high-bay lighting, street lighting and architectural lighting, it is reckoned.

APAC to account for most demand

Most LCD displays are produced in the Asia-Pacific (APAC) region, which registered the most shipments of CSP LEDs. APAC's dominance is due mainly to South Korea, followed by China, Japan and Taiwan, with high demand for CSP LEDs for display backlighting, mobile flash and other applications. CSP LEDs reduce the total number of LEDs required per backlighting panel along with the form factor of the back-light unit (BLU). The presence of leading CSP LED makers and customers (i.e. smartphone vendors, backlighting panel integrators, and display panel makers) in APAC is the reason for the region's dominance in the market.

APAC's growth will also be driven by the rise of newer CSP LED applications in general lighting and automotive, for which the surge in demand will driven by high economic growth rates in the region and the focus of governments on energy-efficient lighting.

Major players in the market are cited as Lumileds (The Netherlands), Samsung (South Korea), Seoul Semiconductor (South Korea), LG Innotek (South Korea), Osram (Germany), Nichia (Japan), Epistar (Taiwan), Cree (USA), Genesis Photonics (Taiwan) and Lumens (South Korea).

www.marketsandmarkets.com

Micro-LED display market to grow at CAGR of 115% from $250m in 2018 to over $14bn in 2024

Rising demand for smartwatches to boost industry expansion

The micro-LED display market will surpass $250m in 2018, and shipments will grow at a compound annual growth rate (CAGR) of over 115% to more than $14bn in 2024, forecasts a report by Global Market Insights Inc.

The micro-LED display market has proliferated from several consumer and commercial applications, where innovations in displays led to continuous demand. Consisting of arrays with each micro-LED operating as a pixel, modules are becoming smaller, resulting in better, brighter image quality and much improved response time in displays.

As it is increasingly being substituted for primitive display technology, the micro-LED display industry has also allowed for power saving in applications where large-size panels used excessive energy to communicate information.

In an era when flexibility and ease of adaptability are considered to be paramount features for long-term survival of any technology, the ability to be integrated into both small as well as large display equipment (depending on use) has accentuated global micro-LED display market growth.

The rising number of miniaturized electronic products has inspired manufacturers to develop small-size panels incorporating micro-LED technology, since an improved display not only signifies a product's quality but is also safer for a consumer's eyes. Adoption of the technology in everyday display devices such as screens, signage, near-to-eye devices, head-mounted displays (HMDs) and automotive lights will hugely benefit the micro-LED display market. Compared with organic light-emitting diodes (OLEDs) or other display technologies, the brighter micro-LEDs do not lose their luster due to natural aging over time (maintaining the quality of picture and brightness) whereas OLEDs manufactured at the same time start to fade. Placing individual parabolic mirrors behind LEDs causes all the light to be reflected towards the viewer, resulting in a very high brightness capability and making the micro-LEDs more power efficient. Due to these characteristics of long life and high efficiency, the micro-LED display industry is gradually being embraced by the booming smartwatch segment.

It is forecasted that in the next three years smartwatch sales could surpass 80 million units, indicating the micro-LED display market's growth potential. Smartwatches can perform numerous functions, ranging from displaying time & messages, picking up phone calls to GPS tracking, measure heart rates and other health factors. Needing to communicate all this information throughout the day while consuming less energy in order to last a whole day, the smartwatch segment is regarded as an ideal consumer market for powerful and long-lasting small micro-LED display panels. Prospects for the micro-LED display market can be surmised by looking at the sales figures of smartphone giant Apple, which sold 8 million Apple watches in fourth-quarter 2017.

Apple recently said that it shipped about 3.5 million smartwatches in second-quarter 2018, leading the smartwatch segment. The firm is investing heavily in using micro-LED technology in its smartwatches. Fossil, which is primarily into analog and chronograph watches, has ventured into the smartwatch domain and reported improved sales of $300m from wearable devices. With a host of other players like Fitbit, Garmin, Xiaomi and Samsung looking to introduce better smartwatch products, and other near-to-eye display devices like AR/VR headsets gaining popularity at an immense rate, the small micro-LED display market is expected to see a CAGR of over 105% from 2018 to 2024.

The progress of the large micro-LED display market has also been extraordinary, ensuing from significant advances in developing innovative display panels that can fit together to create big screens or signs.

In early 2018 Samsung unveiled its new 146-inch screen ('The Wall'), which is a micro-LED modular TV consisting of several 9.37-inch display modules. At the same time, another Korean company Lumens also revealed its 139- and 130-inch signs, made of large-size micro-LED displays. With businesses worldwide depending on effective marketing channels to convert their investments into profits, billboards and public signages are a prominent solution to market all kinds of products. Digital signage can be built depending on outdoor or indoor use, and LED panels can easily be added or removed to adjust the sizes. With closely placed fine-pitched LED panels, high-resolution images and videos can be displayed to consumers and directly affect sales of displayed products.

Overall, the micro-LED display market is driven by continuous innovations, for example the recent collaboration of Taiwan's Industrial Technology Research Institute (ITRI) with Unimicron, Macroblock and PlayNitride for producing ultra-fine pitch micro-LED signage modules by 2019. The introduction of commercially viable products by dominant industry players — including Samsung, Apple, Epistar, Lumens, Innolux, LG, Oculus VR, Allos Semiconductors and VueReal — will critically expand the micro-LED display market in the ensuing years, concludes Global Market Insights.

www.gminsights.com/industry-analysis/micro-led-display-market

GaN RF device market to grow at double-digit CAGR to over $1.5bn by end-2026

Telecoms application to comprise nearly half of the market

The gallium nitride (GaN) radio-frequency (RF) devices market is projected to register a high double-digit compound annual growth rate (CAGR) over 2017–2026, surpassing $1.5bn in revenue by end-2026, according to a report from Fact.MR.

With the upsurge of the wireless communication industry and steady yet continuous progress in conventional military applications, RF devices are playing a pivotal role in several respects, further increasing demand for high-performance RF devices, notes the report.

In mobile communications, next-generation smartphones need improved efficiency and wide bandwidth. RF amplifiers with higher frequency and power are essential for TV broadcasting and developing satellite communications, in order to reduce antenna size in terminals. A similar requirement holds for broadband wireless internet connections due to the ever increasing data transmission rate.

These requirements have necessitated the development of higher-performance RF devices based on GaN, in order to benefit from its wider bandwidth.

More sectors are incorporating RF technology in their operating systems, creating new application areas for RF engineers to work on.

The selection of an RF technology depends greatly on the heat, size, cost, power, advancement rate, efficiency and speed required for the application. GaN RF devices are preferred for such applications. GaN RF technology has hence emerged as an effective choice for new millimeter-wave and microwave electronics such as electronic warfare, communications, satellite and radar.

Future of GaN RF device market

- On the basis of end-users, telecoms will remain the dominant application, with revenues poised to account for nearly half of the market by the end of 2026. Aerospace & defense and automotive are also expected to hold major market shares during the forecast period. Sales of GaN RF devices for medical devices and industrial end-uses are projected to see a parallel expansion through 2026. Revenue from industrial end-users of GaN RF devices will continue to be sluggish.
- Wireless infrastructure will continue to be the most lucrative application of GaN RF devices, with revenues set to account for more than two-fifth market share by end-2026. Photovoltaic (PV) inverters are also expected to remain a financially worthwhile application of GaN RF devices.
- GaN RF device sales for applications in hybrid and electric vehicle (HEV) components are projected to rise at the highest CAGR through 2026. HEV charging equipment and wireless infrastructure applications are expected to grow at equal CAGRs through 2026. Satellite communications and cable TV (CATV) will continue to be the least lucrative applications of GaN RF devices.
- On the basis of product type, discrete GaN RF devices are expected to remain dominant in the market in terms of revenue (projected to hold more than four-fifths of market share by end-2026). Demand for module GaN RF devices is expected to remain sluggish.
- The Asia-Pacific region excluding Japan (APEJ) is expected to remain the largest market for GaN RF devices, surpassing $1bn by end-2026. The market share of Japan and North America will also remain significant, but revenue from APEJ will remain larger than that combined from Japan and North America.

The report cites key market players as Infineon, Renesas, Panasonic, Mitsubishi Electric, Toshiba, Hitachi, STMicroelectronics, Bosch, Sumitomo Electric, and Raytheon.

www.factmr.com/report/383/gan-rf-devices-market

Skyworks validates Sky5 platform for 5G NR bands

Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) says that new solutions from its flagship Sky5 platform have been validated to enable the fast-approaching rollout of 5G.

The firm has launched several products for 5G New Radio (NR) bands n77, n78 and n79 — frequencies that mobile operators plan to use to deploy next-generation cellular services. These devices represent the latest additions to Skyworks' expanding portfolio of connectivity solutions specifically designed to operate across all 5G NR spectrums worldwide.

Skyworks has supported several live demonstrations with Sky5, authenticating performance to the new 5G NR standards (3GPP Release 15). In particular, the Sky5 suite exceeded compliance for power, efficiency, error vector magnitude and spectral emission requirements — all of which can be further enhanced using wideband digital pre-distortion techniques.

"Our innovative Sky5 platform is enabling up to a 100x increase in data transfer speeds versus 4G/LTE, near zero latency and expanded carrier capacity," says Joel King, VP & general manager of Mobile Solutions for Skyworks. "Leveraging our systems expertise and operational scale, we are streamlining architectural complexities for both network infrastructure and user equipment to drive unprecedented mobile data experiences across a wide range of end-market applications," he adds.

According to the GSM Association, 5G will primarily support enhanced mobile broadband in early deployments. Other usage cases for massive Internet of Things (IoT) and critical communications will follow as operators seek to address incremental opportunities, principally in key enterprise verticals. By 2025, the GSMA expects 5G connections to reach 1.1 billion and forecasts overall operator revenue to reach $1.3 trillion.

Second 5G white paper

Skyworks has issued its second 5G white paper '5G New Radio Solutions: Revolutionary Applications Here Sooner Than You Think', which expands on its initial publication '5G in Perspective: A Pragmatic Guide to What's Next' and offers an in-depth exploration of 5G challenges and opportunities as well as practical connectivity solutions.

Skyworks says that it is leveraging its technology experience to meet system requirements for low, mid, high and ultra-high cellular frequency bands. All Sky5 solutions support new 5G waveforms and spectrum in addition to enhanced carrier aggregation and 4G/5G dual connectivity while delivering high levels of integration and performance. The highly flexible, customizable architectures deliver what is claimed to be breakthrough performance, footprint and power efficiency with 100MHz CP-OFDM modulation. Select standard Sky5 products include:

- SKY5-8250 — 5G NR transmit/receive module with integrated wideband filter;
- SKY5-3728 — 5G NR diversity receive module with integrated filtering and dual-path low-noise amplifiers (LNAs);
- SKY5-5811 — LAA receive module with integrated bypass LNA; and
- SKY5-9256 — 4 x SPST shunt MIPI antenna tuning switch.

www.skyworksinc.com/Sky5
www.skyworksinc.com/Products_5G_Whitepaper.aspx

Skyworks introduces LTE universal front-end module for IoT

Skyworks has launched the SKY68020-11, an LTE-M/NB-IoT (narrow-band Internet of Things) front-end module (FEM) for low power, low-data-rate IoT applications.

The multi-band front-end module is system-on-chip (SoC) agnostic and designed to meet the most difficult network operator band specifications including harmonic performance across stringent protocols.

The device also supports 20 LTE bands, enabling single stock-keeping unit (SKU) designs to cover future LTE-M/NB-IoT requirements.

www.skyworksinc.com/Product/4178/SKY68020-11

Skyworks launches family of front-end modules for LPWAN Internet of Things and industrial applications

Skyworks has introduced its newest family of compact, high-performance RF front-end modules (FEMs) designed specifically for low-power wide-area network (LPWAN) and high-power industrial, scientific & medical (ISM) applications including the connected home, M2M, tracking and other emerging Internet of Things (IoT) platforms.

The highly integrated modules support LoRa, SigFox and other unlicensed band technologies, occupy minimal board space and are power efficient, making them suitable for sensors, beacons, smartwatches, thermostats, wireless cameras, medical pendants and smoke and CO detectors.

The new modules also enable direct operation from a battery and deliver more than quadruple the range with improved sensitivity versus a standalone system-on-chip (SoC).

GlobalFoundries adds nine firms to its RFwave Partner Program

New partners to provide mmWave test and characterization plus design services, IP and EDA solutions

GlobalFoundries of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with operations in Singapore, Germany and the USA) has expanded its growing RFwave Partner Program by adding nine new partners, including Akronic, Ask Radio, Catena, University of Waterloo Centre for Intelligent Antenna and Radio Systems (CIARS), Giga Solution, Helic, Incize, Mentor Graphics and Xpeedic Technology. They join existing RFwave Program members including asicNorth, Cadence, CoreHW, CWS, Keysight Technologies, Spectral Design, and WEASIC.

The new partners will provide unique mmWave test and characterization capabilities along with design services, intellectual property (IP) and electronic design automation (EDA) solutions that should enable clients to rapidly implement RF designs in applications spanning Internet-of-Things (IoT), mobile, RF connectivity, and networking markets.

Launched in March, the RFwave Partner Program builds on GlobalFoundries' radio frequency (RF) solutions, such as fully depleted silicon-on-insulator (FD-SOI), RF CMOS (bulk and advanced CMOS nodes), RF SOI and silicon germanium (SiGe) technologies. The program provides a low-risk, cost-effective path for designers seeking to build highly optimized RF solutions for a range of wireless applications such as IoT across various wireless connectivity and cellular standards, standalone or transceiver integrated 5G front-end modules, millimeter-wave (mmWave) backhaul, automotive radar, small-cell and fixed-wireless and satellite broadband.

"As the RFwave program continues to expand, partners play a critical role in helping to serve our growing number of clients and extend the reach of our RF ecosystem by providing innovative RF-tailored solutions and services," says Mark Ireland, VP of ecosystem partnerships. "These new partners will help drive deeper engagement and enhance technology collaboration, including tighter interlock around quality, qualification and development methodology, enabling us to deliver advanced highly integrated RF solutions," he adds.

GlobalFoundries says it is focused on building strong ecosystem partnerships with industry leaders. With the RFwave program, partners and clients can benefit from a greater availability of resources to deliver innovative, highly optimized RF solutions.

www.globalfoundries.com/design-services/rfwave-partner-program

Anokiwave opens office in Taiwan to support growing customer base in Asia-Pacific

Anokiwave Inc of San Diego, CA, USA — which provides highly integrated silicon core chips and III–V front-end integrated circuits for millimeter-wave (mmW) markets and active antenna-based solutions — has opened a new office in Taiwan, allowing it to enhance its support to its growing customer base in the region, to deepen its engagement with local distribution partners, and to expand its reach to customers by continuing to provide solutions that will commercialize mmW active antennas with silicon ICs.

Offering sales and application engineering functions, the office is located in Xinyi District's Taipei Nanshan Plaza (the second tallest building in Taipei), and provides space for meetings as well as office space for the firm's growing team in the region.

Anokiwave's new Taiwan office in Xinyi District's Taipei Nanshan Plaza building.

"Anokiwave's leadership in the mmW silicon IC solutions and growing customer base in Asia required a presence in the region to accommodate our growing sales and applications support staff," says Abhishek Kapoor, VP of sales. "The new office represents our strong commitment to the market and the region by offering a high level of service and support to our end users, distributors and partners."

www.anokiwave.com

Custom MMIC receives Gold Supplier Rating award from BAE Systems' Electronic Systems

Monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA has received a Gold Supplier rating (for the 12-month period ending to end-June) from BAE Systems' Electronic Systems sector in Nashua, NH.

BAE Systems instituted the annual Supplier Scorecard program to recognize suppliers that have provided outstanding service and partnership in exceeding customer requirements. Suppliers are judged on certain criteria including overall quality and on-time delivery. A Gold Medal Rating is the highest a supplier can achieve for excellence in quality and performance.

www.baesystems.com/en/our-company/our-businesses/electronic-systems

WIN showcases its sub-6GHz and millimeter-wave integrated GaAs front-end solutions for 5G user equipment and network infrastructure at EuMW

At European Microwave Week (EuMW 2018) in Madrid, Spain (23–28 September), WIN Semiconductors Corp of Taoyuan City, Taiwan — the largest pure-play compound semiconductor wafer foundry — showcased its solutions for the deployment of 5G user equipment and network infrastructure in the sub-6GHz and millimeter-wave (mmWave) frequency bands.

Front-end semiconductor technology has a significant influence on battery life and total power consumption of mobile devices and active antenna arrays employed in mmWave network infrastructure, notes WIN. Gallium arsenide (GaAs) is the technology of choice for front-ends used in LTE mobile devices and satisfies stringent linearity and efficiency requirements, providing high quality of service while maximizing battery life. 5G user equipment and MIMO access points will impose more difficult linearity/power consumption specifications than LTE, and WIN reckons that its portfolio of high-performance GaAs technologies is positioned to meet these new requirements for front-end solutions.

The fundamental performance advantages of GaAs make it the dominant semiconductor technology for cellular and Wi-Fi RF front-ends used in mobile devices, says WIN. The technical and manufacturing demands of these large and highly competitive markets have driven significant advances in GaAs technology, and now offers what is claimed to be best-in-class front-end performance in all 5G bands and multi-function integration necessary for complex mmWave active antenna systems. WIN's GaAs platforms integrate transmit and receive amplifier technologies with high-performance switch, logic and ESD protection functions to realize compact single-chip front-ends for mobile devices and MIMO access points operating in the sub-6GHz and mmWave 5G bands.

WIN's GaAs technologies, such as PIH1-10, can now monolithically integrate a high-efficiency Tx power amplifier (PA), ultra-low F_{min} Rx low-noise amplifier (LNA) and low-loss PIN switch in a single-chip mmWave front-end. In addition, the highly integrated GaAs technology provides optional linear Schottky diodes for power detectors and mixers, low-capacitance PIN diodes for ESD protection and optimized E/D transistors for logic interfaces. This suite of capabilities comes in a humidity-rugged back-end, available with a copper redistribution layer and copper pillar bumps to reduce die size and allow flip-chip assembly, enabling GaAs front-ends to fit within 28GHz and 39GHz antenna lattice spacing.

www.eumweek.com
www.winfoundry.com

Littelfuse launches its first 1700V SiC MOSFETs

New devices targeted at high-frequency, high-efficiency power control applications such as EVs/HEVs, data centers & auxiliary power supplies

Littelfuse Inc of Chicago, IL, USA, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), has expanding its portfolio of silicon carbide (SiC) MOSFETs by launching its first 1700V device.

The LSIC1MO170E1000 adds to the firm's 1200V SiC MOSFETs and Schottky diodes already released. End-users will benefit from more compact, energy-efficient systems and also from a potential lower total cost of ownership, says the firm.

High-efficiency benefits powered by SiC MOSFET technologies offer multiple advantages to many demanding applications including electric and hybrid vehicles (EV/HEV), data centers, and auxiliary power supplies, says Littelfuse. Compared with similarly rated silicon insulated-gate bipolar transistors (IGBTs), the LSIC1MO170E1000 SiC MOSFET enables system-level optimization opportunities, including increased efficiency, increased power density, decreased cooling requirements, and potentially lower system-level costs, adds the firm.

Also, the SiC MOSFETs deliver on-par or better performance in all aspects compared head-to-head with other industry-leading SiC MOSFET devices on the market, it is claimed. Typical applications for the LSIC1MO170E1000 include: solar inverters; switch-mode power supplies (SMPS) and uninterruptible power supplies (UPS); motor drives; high-voltage DC/DC converters; and induction heating.

"This product can improve existing applications, and the Littelfuse application support network can help new design-in projects," says Michael Ketterer, global product marketing manager, Power Semiconductors, of Littelfuse's Semiconductor business unit. "SiC MOSFETs offer a rewarding alternative to traditional Si-based power transistor devices. The MOSFET device structure enables lower per-cycle switching losses and improved light load efficiency when compared to similarly-rated IGBTs," he adds. "Inherent material properties allow the SiC MOSFET to outclass its Si MOSFET counterparts in terms of blocking voltage, specific on-resistance, and junction capacitances."

The new 1700V, 1Ω SiC MOSFETs offer the following benefits, it is claimed:

- optimized for high-frequency, high-efficiency applications;
- extremely low gate charge and output capacitance; and
- low gate resistance for high-frequency switching.

LSIC1MO170E1000 SiC MOSFETs are available in TO-247-3L packages in tubes in quantities of 450.

www.littelfuse.com/products/power-semiconductors/silicon-carbide/sic-mosfets/lsic1mo170e1000.aspx

ROHM presents power and energy management technologies at electronica 2018

At the electronica 2018 trade fair in Munich, Germany (13–16 November), ROHM Semiconductor is presenting new solutions for power and energy management in the automotive and industrial sectors as well as its commitment to the FIA (Fédération Internationale de l'Automobile) Formula E motor racing series.

Highlights include demonstrating updates of new power devices such as 1700V silicon carbide (SiC) modules and other SiC devices, power management ICs and sensor technologies for the automotive and industrial market.

In addition, ROHM is highlighting local support capabilities by presenting Power-Lab Test benches and sensing solutions by Finland Software Design Center.

For automotive applications, ROHM is exhibiting the latest generation of SiC-based inverters.

New solutions for the industry sector will be presented including 99%-efficient SiC inverters, application examples of a solar inverter, on-board charger, power supply and EV charging station. Further applications showcase AC/DC and DC/DC converter ICs, motor drivers and sensors together with new insulated-gate bipolar transistors (IGBTs) and high-speed switching MOSFET (Presto MOS Series) devices.

SiC power modules for Formula E

Formula E is attracting increasing attention as a platform for further innovation in the electric car sector. As the official technology partner of the VENTURI racing team since the start of Formula E's third season of racing in October 2016, ROHM contributes SiC power modules for the inverter block, which forms the core of an EV's drive system. At electronica ROHM is showcasing the latest generation of inverters as well as the Formula E racing car for the fifth season as an application example for SiC power modules.

After signing a three-year contract, Brazilian former Formula 1 racing driver and world championship runner-up Felipe Massa is driving for VENTURI in Formula E's fourth season (2018/19, starting on 2–3 December in Hong Kong), and will visit ROHM's exhibition stand on the first day of electronica.

www.rohm.com/web/global/full-sic-power-modules

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Exagan forms Taiwan subsidiary

Sales and applications center opened in Taipei to speed use of GaN in charger and server markets

Gallium nitride technology start-up Exagan of Grenoble and Toulouse, France (founded in 2014 with support from CEA-Leti and Soitec) has established the subsidiary Exagan Taiwan Ltd with a new sales and applications center in Taiwan — the firm's first step in its global market deployment — to accelerate the development and use of fast, intelligent GaN power solutions in the region.

The facility in Taipei's Nankang Software Park was officially opened during ceremonies attended by Exagan's president & CEO Frédéric Dupont, chief operating officer Fabrice Letertre and Asia sales director Ralf Kilguss, who is heading up regional sales in Asia (leveraging his 20 years of experience in the semiconductor and power electronics markets).

"With this new application center, our company experts will be able to work closely with local customers on evaluating and designing GaN-based solutions while speeding the technology's adoption in the rapidly growing charger and server sectors, which are being driven by a very dynamic Asian market," says Dupont.

Nankang Software Park in Taipei.

Since 2014, Exagan has developed multiple partnerships in Asia to support its product design, development and manufacturing, establishing a robust supply chain with proven solutions for the targeted markets.

Earlier this year, Exagan launched its G-FET power transistors and G-DRIVE intelligent and fast-switching solution featuring an integrated driver and transistor in a single package. These are designed for easy system implementation in applications including servers and USB chargers.

The number of devices with at least one USB type C port for the simultaneous transfer of electrical power, data and video is forecasted to grow to nearly 5 billion units by 2021, according to market research firm IHS Markit, while total server shipments will expand at a compound annual growth rate (CAGR) of 14% over 2018–2023, forecast Digitimes Research.

www.exagan.com/en/products/gfet-family

Wolfspeed talks 5G and launches new radar technologies

At European Microwave Week (EuMW 2018) in Madrid, Spain (25–27 September), 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) — shared its view on the upcoming 5G market while unveiling its expanded portfolio of radar and 4G/5G products.

Gerhard Wolf, VP & general manager of Wolfspeed's RF division, delivered an industrial keynote on technological challenges posed by the transition to 5G and how the industry can leverage GaN and LDMOS to achieve the greater bandwidth and efficiency that 5G requires. The firm is also featuring its new wideband, two-stage, LDMOS integrated power amplifier (PTNC210604MD) in a live demo at the event.

In addition to showcasing new communications components, Wolfspeed unveiled two new 28V GaN MMIC power amplifiers (PAs) for radar applications: the 25W CMPA5259025F and the 50W CMPA5259050F (commercially available now). The C-band MMIC power amplifiers are designed in a compact 0.5" square package with greater than 30dB small signal and nominally 50% drain efficiency. This combination enables phased-array radar designers to maximize the power per element for C-band radar systems, says the firm.

Both components are also used in linear and compressed amplifier circuits in marine radar, weather monitoring (Doppler weather radar), air traffic control (ATC), maritime vessel traffic control services (VTS), and port security applications. The 50W MMIC PA for C-band radar enables modular system design with increased reliability and lower maintenance costs, making it applicable to a variety of emerging radar applications. For example, the new amplifier is suitable for countries like India and USA as they upgrade radar capabilities at airports across their nations.

www.eumweek.com
www.wolfspeed.com

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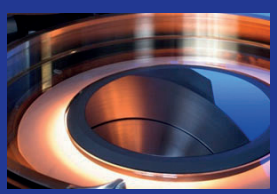

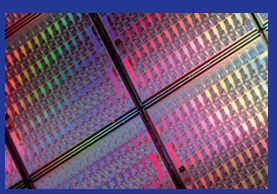

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Zhejiang University reports first current-collapse-free vertical GaN power rectifier

No dynamic ON-resistance degradation at 200ns after switching from reverse stress bias up to 500V

China's Zhejiang University (ZJU) has reported what is claimed to be the first vertical gallium nitride on gallium nitride (GaN-on-GaN) power rectifier that is free from current collapse (i.e. has no dynamic ON-resistance degradation), even at only 200ns after switching from high reverse stress bias up to 500V, outperforming the state-of-the-art lateral gallium nitride on silicon (GaN-on-Si) devices. With the dynamic ON-resistance quantitatively evaluated under various switching conditions using a high-speed double pulse test circuit, the current-collapse-free performance has been experimentally verified in a vertical GaN power rectifier for the first time ('Current-Collapse-Free and Fast Reverse Recovery Performance in Vertical GaN-on-GaN Schottky Barrier Diode' by Shaowen Han, Shu Yang, Rui Li et al; IEEE Transactions on Power Electronics; DOI: 10.1109/TPEL.2018.2876444).

Dynamic ON-resistance degradation has been regarded as the primary challenge in conventional lateral GaN-on-Si devices, the root causes of which include: (1) surface trapping that can easily degrade the two-dimensional electron gas (2DEG) conductivity at a short distance from the III-nitride surface; and (2) a carbon-doped semi-insulating buffer stack containing deep-level traps that can generate negative space charges and partially deplete the 2DEG.

By comparison, featuring a vertical current flow and high-quality homoepitaxial GaN drift layer with well controlled background/compensation doping, the vertical GaN-on-GaN device can fundamentally overcome the grand challenge of dynamic ON-resistance degradation.

The dynamic ON-resistance has been quantitatively evaluated using the double pulse tester with a clamping circuit under different switching conditions, including: (1) OFF-state stress bias up to 500V, (2) OFF-state stress time within 10^{-6}~10^{2}s, (3) high temperature up to 150°C, and (4) different load current levels. Under all the test conditions, the vertical GaN-on-GaN rectifier is free from dynamic ON-resistance degradation at only ~200ns after switching from the OFF-state, outperforming state-of-the-art commercial lateral GaN-on-Si devices and showing great potential for high-frequency applications, reckon the researchers.

https://ieeexplore.ieee.org/document/8493547

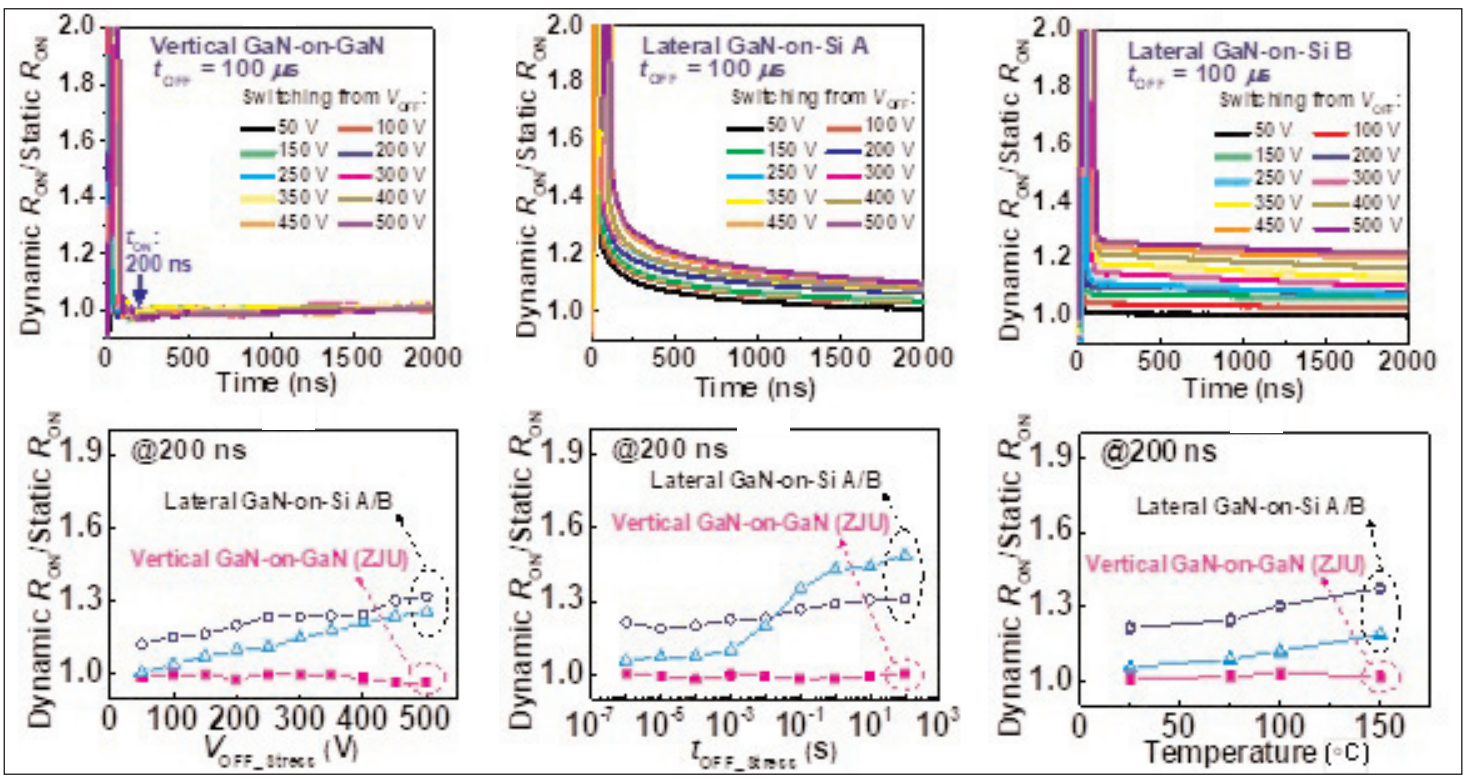


Figure 1: Time-resolved dynamic $R_{ON/static}$ R_{ON} of (a) a vertical GaN-on-GaN Schottky barrier diode developed by ZJU, (b) a lateral GaN-on-Si commercial device A and (c) a lateral GaN-on-Si commercial device B with OFF-state time (t_{OFF_Stress}) of 100μs and OFF-state bias (V_{OFF_Stress}) increasing from 50V to 500V. Also shown are the extracted dynamic $R_{ON/static}$ R_{ON} of the three types of GaN devices at 200ns after switching from (d) various V_{OFF_Stress} up to 500V, (e) various t_{OFF_Stress} up to 100s, and (f) various temperature up to 150°C.

Space satellite industry expert joins Akash as it files for experimental license with FCC

Akash Systems Inc of San Francisco, CA, USA — which was founded in 2016 by Felix Ejeckam and Ty Mitchell and is focused on developing and supplying small satellites (CubeSats) and the RF power amplifiers that power them — has appointed Brian Holz as chief architect. Holz brings extensive space satellite experience from his work directing the design and construction of satellite constellations for leading commercial organizations.

"With competition becoming fierce in the crowded satellite industry, we recognized the need to bring the best minds to our team," says CEO & gallium nitride (GaN)-on-diamond inventor Felix Ejeckam. "Brian will bolster our systems development as we ramp up efforts to deliver next-generation RF communications links to a world that continues to demand increased connectivity."

Ejeckam invented the GaN-on-diamond technology in 2003 while at Group4 Labs Inc by lifting GaN epitaxy from its original growth substrate (for example, silicon) and transferring it to a synthetic CVD diamond substrate. Group4 Labs' assets were acquired in 2013 by Element Six Technologies (a member of the De Beers Group of Companies). In 2016, Ejeckam, together with Akash co-founder & chief operating officer Ty Mitchell, entered into an agreement with RFHIC Corp of Anyang, South Korea (which designs and makes active RF & microwave high-power components and hybrid modules) to jointly negotiate the repurchase of the GaN-on-diamond intellectual property (IP), with Akash acquiring all patents and other IP rights related to GaN-on-diamond technology for use in satellite communications and related markets.

Brian Holz.

With extensive experience in space systems engineering, program management and executive leadership, Holz will further Akash's aim to develop the next generation of small satellites and the components that power them. He was previously CEO of OneWeb Satellites, and executive VP & chief technology officer O3b Networks. He has expertise in startup management, global supply chain operations, multi-discipline team leadership and core technology development.

"The satellite industry is massively hindered by bandwidth constraints, and Akash's components will be game-changing for the entire industry," comments Khosla Ventures investor Delian Asparouhov. "Brian is a key component of helping us transform communications in space."

Holz joins Akash just as it has completed its critical FCC (Federal Communications Commission) filing for an experimental license, which grants organizations the ability to conduct scientific and research missions.

www.AkashSystemsInc.com

US Army awards Lockheed Martin contract extending AN/TPQ-53 radar range by inserting gallium nitride

The US Army has awarded Lockheed Martin a contract modification to insert gallium nitride (GaN) into the AN/TPQ-53 (Q-53) radar as part of the full-rate production configuration.

The Q-53 is the most modern radar in the US Army inventory and has the flexible architecture to address aircraft, drone and other threats in the future. The transition to GaN will provide it with additional power for capabilities including long-range counterfire target acquisition. GaN has the added benefit of increasing system reliability and reducing life-cycle ownership costs.

"The Army is adding Q-53 to our family of fielded GaN based radars," notes Rick Herodes, director of the Q-53 program at Lockheed Martin. "This modification takes advantage of our broad experience with radar production and next-generation radar development experience coupled with Lockheed Martin's continuous investment in GaN and other radar technologies," he adds. "This update enables Q-53 mission growth for changing Army needs. We realize how critical it is to enhance the capabilities of the Q-53 so it can be responsive to the evolving operational demands and emerging threats our deployed troops face every day."

The multi-mission Q-53 radar.

For more than 10 years, Lockheed Martin has used an open GaN foundry model leveraging relationships with commercial suppliers that utilize the power of the expansive telecoms market. This process eliminates the cost of foundry operations, takes advantage of the telecoms industry's investment in GaN, enables competition and ultimately reduces costs, says the firm.

The primary aim of the multi-mission Q-53 is to protect troops in combat by detecting, classifying, tracking and identifying the location of enemy indirect fire in either 360º or 90º modes. Mounted on a five-ton truck, the Q-53 can be rapidly deployed, automatically leveled then operated remotely or from a command vehicle with a laptop computer. The radar is software defined, allowing for quick adjustment to address emerging Army capability needs for air surveillance and counter fire target acquisition.

The Q-53 has protected warfighters around the world since 2010. Lockheed Martin currently produces multiple Q-53 radars annually. Work on the system is performed at Lockheed Martin facilities in New York, New Jersey and Florida.

www.lockheedmartin.com/gbas

Saab to develop prototype GaN-based X-band active aperture array radar for US Navy

The US Naval Air Systems Command's Naval Air Warfare Center Aircraft Division (NAWCAD) Lakehurst has awarded a firm-fixed-price contract (N68335-18-C-0693) to Saab Defense and Security USA LLC of East Syracuse, NY, USA (part of Swedish defence and security firm Saab AB) for R&D on a prototype GaN-based X-band active aperture array radar in support of the US Office of Naval Research (ONR) for evaluation under the Office of the Secretary of Defense (OSD) Foreign Comparative Test (FCT) program.

Work will be in Gothenburg, Sweden (80%) and East Syracuse (20%) and should be completed in June 2020.

Fiscal 2017 and 2018 research, development, test and evaluation (Navy & Defense) funds of $8,184,781 will be obligated at the time of award ($1m of which will expire at the end of the current fiscal year). If all options are exercised, the contract could last 30 months, rising to $13,456,683.

www.saab.com

Integra launches L-band RF power amplifier module for IFF/SSR avionics systems

Integra Technologies Inc (ITI) of El Segundo, CA, USA has launched an RF power amplifier module/pallet designed to solve various size, weight, power and cost challenges (SWaP-C) in L-band avionic systems.

The IGNP1011L2400 is a high-power GaN-on-SiC RF power amplifier module/pallet designed specifically for IFF/SSR (identification friend or foe/secondary surveillance radar) systems operating under either Mode S ELM (48x {32µs on, 18µs off}, 6.4% long-term duty cycle) or standard Mode S (128µs, 2% duty cycle) pulse conditions.

It supplies a minimum of 2200W of peak output power, with typically >16dB of gain and 57% efficiency and operates from a 50V supply. Matched to 50Ω at both input and output, it is suitable for both 1030MHz and 1090MHz frequencies.

www.integratech.com/ignp1011l2400

Raytheon supplying technology for GEM-T, the first missile to harness gallium nitride

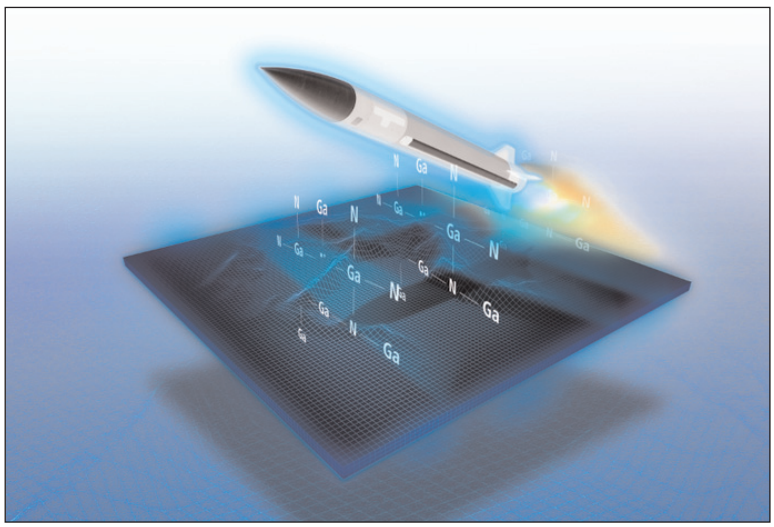
Raytheon Company of Waltham, MA, USA says that it is providing technology for the first missile to use gallium nitride (GaN).

The Guidance Enhanced Missile – Tactical Ballistic Missile (GEM-T), a mainstay of the US Army's Patriot Air and Missile Defense system, is used against aircraft and tactical ballistic and cruise missiles. Now GEM-T is packing a GaN transmitter that never needs to be recertified over the 45-year life of the missile.

"GEM-T has been the beneficiary of all those years of Raytheon's work on GaN technology," says Christine Walsh, Raytheon program manager for an international Patriot program. Nearly two decades have been spent pushing the limits of power and efficiency of GaN in Raytheon's Department of Defense-accredited Trusted Foundry, where GaN amplifiers are made.

Transmitters connect the missile with the ground system, allowing it to control the weapon during flight. The GaN version in GEM-T uses a solid-state design to replace the conventional traveling-wave tube (TWT) design, which requires a supply of parts and recertification to match the life of the missile. The new ones with GaN do not.

The new transmitter has the same form, fit and function as the old one. It is also tough, does not require additional cooling, and is ready to operate within seconds of powering up, so GEM-T with the new GaN transmitter will continue to perform in the most demanding conditions.



Guidance Enhanced Missile – Tactical Ballistic Missile (GEM-T) for defeating aircraft and tactical ballistic and cruise missiles.

The technology is ready for the US Army, and is affordable, according to Jason Rathbone, missile integrated product team lead for the Patriot product line: "The legacy transmitters on the current GEM-T missiles need to be periodically rebuilt and recertified, so replacing the old one with the new solid-state transmitter is a smart move."

Raytheon is ramping up production of the GEM-T missile under a number of international contracts. The new transmitter, which was designed to allow future innovations, is well on its way to completing its qualification programs and will be tested during an upcoming flight test.

The transmitter technology might also see additional testing in other missiles. The Army has shown interest in replacing its entire inventory with these types of long-lasting transmitters, which have reduced recurring costs per unit by 36% in the GEM-T program.

www.raytheon.com/capabilities/products/foundry

www.raytheon.com/capabilities/products/patriot

Raytheon advances in US Army's Lower Tier Air and Missile Defense Sensor competition

Raytheon Company of Waltham, MA, USA is advancing in the US Army's Lower Tier Air and Missile Defense Sensor (LTAMDS) competition and has now entered the Technology Maturation and Risk Reduction (TMRR) phase of the program.

During TMRR, Raytheon will demonstrate LTAMDS performance through multiple technology demonstrations, using a fully operational array and later an integrated radar prototype, to prove the maturity of the Raytheon design.

"We've worked with the US Army for decades to address advancing threats with the latest technology," says Tom Laliberty, VP of Integrated Air and Missile Defense at Raytheon's Integrated Defense Systems (IDS) business in Tewksbury, MA. "Our expertise in the lower-tier air and missile defense domain, combined with our gallium nitride (GaN)-based sensor technology, allows us to offer the US Army the radar they need, when they need it."

As the LTAMDS program progresses, Raytheon will:

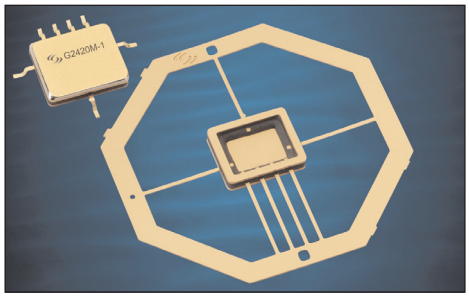
- develop key prototyping that reduces risk and further matures the technology;
- deliver detailed designs that prove capability and production readiness; and
- deliver a support plan to the Army's testing for mobility and sustainability.

www.raytheon.com/capabilities/products/ltamds

StratEdge displays GaN and GaAs packages

StratEdge of San Diego, CA, USA (which designs and manufactures packages and provides chip assembly & test services for microwave, millimeter-wave and high-speed digital devices) displayed its high-frequency, high-speed, thermally efficient packages at the following events:

- at the International Microelectronics Assembly and Packaging Society's 51st Symposium on Microelectronics (IMAPS 2018) in Pasadena (9-11 October);
- at the 2018 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS) in San Diego (14–17 October), which combines the former Compound Semiconductor IC Symposium (CSICS) with the Bipolar/BiCMOS Circuit and Technology Meeting (BCTM); and
- at the Electronic Design Innovation Conference & Exhibition (EDI CON USA 2018) in Santa Clara (17–18 October).



StratEdge says that its packages meet the extreme demands of gallium nitride (GaN) and gallium arsenide (GaAs) devices and the critical requirements of the telecom, mixed-signal, VSAT, broadband wireless, satellite, military, test & measurement, automotive, down-hole and MEMS markets.

StratEdge is showcasing two options for packaging GaN and high-power semiconductor devices, the LL family of leaded laminate copper-moly-copper (CMC) base packages and its off-the-shelf line of molded ceramic packages that can be configured to meet the requirements for chips operating at frequencies up to 18GHz. These packages dissipate heat and come in fully hermetic versions in over 200 standard outlines.

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

"Since StratEdge started manufacturing packages for semiconductor devices in 1992, we have seen the demand for high-speed, high-frequency, data-intensive technologies multiply," says president Tim Going. "This is reflected in the interest in these events."

www.stratedge.com

Cree signs long-term SiC wafer supply deal worth $85m with leading power device maker

Cree Inc of Durham, NC, USA has signed a strategic long-term agreement to produce and supply its Wolfspeed silicon carbide (SiC) wafers to what it says is one of the world's leading power device companies. Worth more than $85m, the agreement governs Cree's supply of 150mm SiC bare and epitaxial wafers during what is described as a period of extraordinary growth and demand for silicon carbide power devices.

"Cree is committed to increasing and accelerating the adoption of silicon carbide-based solutions throughout the semiconductor industry," says CEO Gregg Lowe. "This customer's importance to the power device industry is well known, so partnering with a leading power semiconductor company such as this is another big step in that commitment," he adds.

The supply agreement, to be fulfilled through a Cree distributor, enables silicon carbide applications in broad markets such as renewable energy and storage, electric vehicles, charging infrastructure, industrial power supplies, traction and variable speed drives.

The agreement governs Cree's supply of 150mm SiC bare and epiwafers during what is described as a period of extraordinary growth and demand for silicon carbide power devices

"We are extremely pleased to help drive adoption of silicon carbide in even more applications," says Lowe. "Cree is continuing to expand capacity to meet market demands."

www.wolfspeed.com
www.cree.com

GTAT's chief technology officer speaking on silicon carbide at International Forum on Wide Bandgap Semiconductors

GTAT Corp of Hudson, NH, USA (which produces crystal growth equipment for the solar, power electronics and optoelectronics industries as well as sapphire material for precision optics and other specialty industries) says that, at the 2018 International Forum on Wide Bandgap Semiconductors (IFWS 2018) in Shenzhen, China (23–25 October), its chief technology officer Dr P.S. Raghavan spoke during the Tutorial and Technical Sessions on 22 and 24 October, respectively.

The tutorial session covered the various wide-bandgap semiconducting materials, with emphasis on silicon carbide (SiC) and the issues associated with the material, including crystal growth techniques, challenges with mass production, the wafering processes, and wafer geometry optimization.

The technical session dived into the challenges of silicon carbide crystal growth, recent progress in silicon carbide substrate technology and the need for further improvements of quality and control of silicon carbide crystal growth.

IFWS was held in conjunction with the China International Forum on Solid-State Lighting (SSLCHINA).

www.ifws.org.cn/en/?q=node/209
www.gtat.com

Presto upgrades European testing facility to ISO 9001:2015 standard

Presto Engineering Inc of San Jose, CA, USA — which provides outsourced operations to semiconductor and Internet of Things (IoT) device firms (including developing industrial solutions for RF, analog, mixed-signal and secured applications, from tape-out to delivery of finished goods) — has completed certification to the ISO 9001:2015 quality standard at its facility in Caen, France, which is Europe's largest independent semiconductor test facility.

"We have an extensive and comprehensive range of semiconductor test equipment. This includes testing at every stage from wafer, through die, to final packed device," says Caen site director Dr Alban Colder. "As part of the ISO 9001:2015 quality standard, we have a comprehensive range of equipment for non-destructive analysis such as x-ray to check packaging and bondings, and ultrasound to see inside a device to check for delamination, voids and cracked silicon. There is also equipment to check for failure localization by photoemission or thermal laser stimulation, and deep physical analysis, i.e. strip a device down layer by layer to see exactly where it is failing and why," he adds. "Other advanced equipment such as an atomic force microscope or a scanning electron microscope are used to reveal the precise details of the structure of a chip down to a few nanometers."

The key part of a quality system in semiconductors industry is traceability, notes Presto. Detailed record keeping traces every wafer, every operation, every die and every test so, in the event that there is a faulty chip in the field, it can be traced back to try and determine the cause and to see if any other chips have been affected that might necessitate a recall. In the case of an automotive recall, this could be very expensive, so it is vital to be able to narrow the problem down to only the affected chips.

"We have assembled a suite of state-of-the-art equipment as part of our commitment of quality and this new standard," says Martin Kingdon, VP of sales. "We provide customers with a comprehensive service once they provide us with a design that covers every stage of the chip manufacturing and testing process right through to final product. As part of our quality assurance to customers, we rigorously test at every stage," he adds. "Such a comprehensive test and failure analysis capability all together under one roof is very rare; usually it requires a number of different test houses, which means that issues could be missed. Having all the skills and equipment together in one place means that we can keep searching until we find the cause of a problem so that it can be resolved and quality maintained."

www.presto-eng.com

Compound Semiconductor Centre wins Collaboration title at Made in Wales Awards

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 won the title for collaboration at Insider Media's 'Made in Wales' awards, presented during a gala ceremony at Cardiff City Hall on 4 October.

The title was awarded for the breadth and scope of the firm's collaborations, particularly within the emerging regional compound semiconductor cluster (CSconnected) with partners including; IQE,SPTS, Microsemi, Newport Wafer Fab, Cardiff University, Swansea University, Compound Semiconductor Applications Catapult, Cardiff Capital Region City Deal and Welsh Government.

In the last 18 months CSC has secured and initiated nine collaborative R&D projects (worth over £6m) in a range of applications including Telecommunications, Power Electronics, Sensing, Healthcare and Quantum Technologies.

CSC typically concentrates on delivering opportunities that are 1–3 years from market exploitation through well-defined delivery paths made possible by effective collaboration with our project partners. CSC is currently engaged with 4 UK universities, 2 UK research organizations and 15 UK industrial partners in co-creation of new processes, products and device applications.

"The CSC and our partners are extremely pleased to win this award ahead of tough competition from GE Aviation and Creo Medical, who were also shortlisted," says CSC's managing director Dr Wyn Meredith. "The award recognizes the impact of close and focused collaboration between businesses, academia and government agencies," he adds.

"I would also like to extend my congratulations to [Newport-based] SPTS, who also won the title of 'Manufacturer of the Year'," continues Meredith. "The fact that representatives from the compound semiconductor cluster scooped two awards is testament to the growing importance of our industry sector to the regional economy."

www.compoundsemiconductorcentre.com/projects

SILTECTRA to launch outsourced wafering services business

SILTECTRA GmbH of Dresden, Germany is to begin offering 'outsourced wafering' services to customers, starting in January 2019. The new business aims to provide affordable access to its COLD SPLIT wafering solution to global semiconductor manufacturers and materials providers, and help speed the adoption of new substrate materials.

The first phase of the new business will concentrate on 6" silicon carbide (SiC) wafers. This focus responds to early requests for the new wafering service from manufacturers of SiC-substrates for applications like electric vehicles and 5G technology. The SiC market is expected to grow steadily between now and 2022, with demand from customers in the US, Europe and China, and strong momentum in Japan. SILTECTRA will begin by producing 500 wafers per week, with plans to increase the volume to 2000 wafers per week by the end of 2019.

COLD SPLIT is a high-output, low-cost wafering and thinning technology for substrates like SiC and gallium arsenide, as well as gallium nitride, sapphire and silicon. The laser-based technique employs a chemical-physical process that uses thermal stress to generate a force that splits the material with exquisite precision along the desired plane, and produces virtually no kerf loss. The 'no kerf loss' capability is unique to COLD SPLIT and delivers breakthrough advantages. First, it extracts more wafers per boule than conventional wafering technologies. This drives up output. Second, it dramatically reduces consumables costs.

In addition to semiconductor customers, SILTECTRA will also make the service available to materials manufacturers who stand to gain from COLD SPLIT's technical and economic advantages. The economic benefits are derived from higher output (up to 2x from the same amount of material), as well as lower capex burdens (furnaces, for instance). The technology benefits are derived from COLD SPLIT's inherent capabilities, which includes better depth-of-focus stability for the lithography process which is enabled by edge flatness parameters that are superior to the standard lapping process. In addition, the geometrical profile for COLD SPLIT wafers is better suited for lateral processes, especially epitaxy.

The new 'outsourced wafering' business is a central component of SILTECTRA's growth strategy. The company began preparing earlier this year when it expanded its Dresden facility and created a dedicated manufacturing space. In addition, SILTECTRA invested in new process equipment, pioneered new automation techniques, hired additional technologists, and launched a pilot production line. During this time, SILTECTRA also continued to boost COLD SPLIT's capabilities by adding enabling hardware, software and process innovations. The new innovations further enriched the company's global IP portfolio, which consists of 70 patent families containing 200 patents in total.

"Outsourced wafering services is a natural next step for SILTECTRA and we're excited by the enthusiasm we're hearing from semiconductor manufacturers, as well as materials providers," says David Schneider, head of business development. "It's a compelling service offering for substrate manufacturers seeking an affordable portal to an ultra-high-output wafering solution. Early feedback confirms that customers value the access to COLD SPLIT's unique innovations and SILTECTRA's process expertise, and appreciate our knowledge and experience with diverse substrate materials. We intend to meet their wafering needs with a scalable business plan, starting with one shift and adding additional shifts as demand grows."

www.siltectra.com

IQE recruits chief financial officer from ARM

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has appointed Tim Pullen as chief financial officer. After completion of his current notice period, he will join the board in early 2019.

Pullen is currently chief financial officer of global semiconductor and software design company ARM Ltd (owned by Softbank Group), where he has been focused on executing the investment strategy and scaling its finance and business capabilities.

Previously, Pullen was finance director at O2/Telefonica UK, where he held senior financial positions including responsibility for Technology Operations, B2B and Digital segments and Finance Operations. He was also a non-executive director of Tesco Mobile (O2's joint venture with Tesco Mobile) and a director of Cornerstone Telecommunications Infrastructure Ltd (O2's network sharing joint venture with Vodafone). Before O2, Pullen held senior finance roles at Serco Group plc (a British provider of outsourcing services) including the BPO Division in UK & Europe, the Global Technology business and in Business Transformation. He is a Chartered Accountant and qualified with Ernst & Young.

Executive chairman & interim CFO Dr Godfrey Ainsworth FCA has agreed to remain in post to oversee the handover. As previously announced, Ainsworth will retire from the board on or before the date of the 2019 annual general meeting (AGM). Former Cisco chairman Phil Smith (who joined the board in December 2016) will become non-executive chairman on 31 March 2019.

"Tim has built a successful career leading the finance functions of some of the UK's leading technology and outsourcing companies. With Tim's very relevant sector industry experience, leadership and overall vision for the finance function at IQE, he will continue to build upon the exceptional work achieved by the late Phillip Rasmussen, his predecessor," believes IQE's CEO Dr Drew Nelson. "I would also like to take this opportunity to thank Godfrey for his outstanding support in his role as interim CFO," he adds.

"Following an extensive search and selection process, we have appointed an excellent CFO in Tim Pullen, whose proven track-record in leading-edge technology businesses brings highly credible and relevant experience and a skills-set that will fully support and further enhance IQE's aspirations and ambitions," comments Sir David Grant, chair of the Remuneration and Nominations Committees.

"It is a great testament to the group that someone of Tim's calibre and reputation has accepted the opportunity to be part of IQE team," notes Phil Smith, chairman designate and senior independent director. "He brings extremely valuable experience that will help us step confidently into the next phase of our growth."

www.iqep.com

Riber grows sales 42% year-on-year for the first nine months of 2018, with MBE systems sales almost tripling

Systems orders more than double, outweighing drop in evaporator orders and machine refurbishments

For third-quarter 2018, Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has reported revenue of €4.7m, up 70% on €2.8m a year ago.

Revenue for the three quarters to end-September 2018 hence amounted to €21.7m, up 42% year-on-year from €15.2m due to good performance by all the business lines.

Specifically, Systems sales grew by 193%, from just €2m to €5.9m, following the delivery of five MBE machines over the first nine months of 2018 (including two production systems, compared with two research systems during the same period in 2017).

Revenue for Services & Accessories rose by 26% from €4.1m to €5.2m.

Evaporator sales rose by 16%, from €9.1m to €10.6m, following major deliveries for the screen industry (primarily during the first half of 2018).

Segmenting total revenue by geographic region, 59% came from Asia (up from 50% in the first nine months of 2017), 32% from Europe (down from 34%) and 9% from North America (down from 16%).

The order book at the end of September was €30.6m, up 15% on €26.6m a year previously.

Specifically, Systems orders grew by 120% from €10.1m to €22.2m. This includes 12 systems scheduled for delivery between 2018 and 2019, comprising (following the reclassification of one production machine as a research machine): seven production machines (versus just four in 2017) and five research machines (versus just two in 2017). This does not include the order for a production machine for Asia announced on 18 October.

Services & Accessories orders fell by 20% from €5.8m to €4.7m, linked to a contraction in demand for machine refurbishments.

Evaporator orders fell by 65% from €10.7m to €3.8m, following completion of the major wave of investment in the screen industry.

In line with the delivery schedule for the end of the year, Riber is targeting full-year 2018 revenue of €35m (up 14.4% on 2017's €30.6m) and at least 15% year-on-year growth in income from ordinary operations.

Riber notes that, in a globally positive environment for the compound semiconductor market, it has good visibility for the medium term due to a robust order book that is expected to be further strengthened shortly by several projects currently in negotiations.

www.riber.com

Order from Asia for MBE production system

Riber says an industrial company in Asia has ordered a multi-wafer MBE 6000 production system (for delivery in 2019). The new customer will use it to produce optoelectronic products for fiber-optic communications applications.

Riber says that, after opening a subsidiary in China in July, the commercial success confirms its growth potential in Asia and highlights how its technology is in line with targeted markets.

www.riber.com

Trymax receives system orders from Chinese compound semiconductor foundry for photoresist ashing and descum

Trymax Semiconductor Equipment BV of Nijmegen, The Netherlands (which provides plasma-based solutions for photoresist removal, surface cleaning and isotropic etch) has received orders from a Chinese compound semiconductor foundry for multiple NEO 2000 Series systems. Shipping of the first systems will be in fourth-quarter 2018 and continue during first-quarter 2019.

The NEO 2000 Series was selected to perform photoresist ashing and descum on silicon carbide (SiC) and lithium niobate ($LiTaO_3$) substrates. Main end-applications will be in RF and power electronics that are both facing significant growth driven by the Internet of Things (IoT), 5G and automotive. The SiC market is rising at a compound annual growth rate (CAGR) of 31% from 2017 to more than $1.5bn by 2023, according to the 'Power SiC 2018: Materials, Devices and Applications report' by market research and strategy consulting firm Yole Développement. In parallel, the total surface acoustic wave (SAW) filter market will grow to almost $4bn in 2023 for mobile applications, forecasts Yole in its '5G's Impact on RF Front-End Module and Connectivity for Cell Phones report'.

Trymax says that the NEO 2000 Series is a high-throughput, low-cost-of-ownership dual-chamber system. It will be configured with both high- and low-temperature plasma chambers and process wafers with diameters from 4" up to 8".

The multi-system order follows previous multi-system orders received by Trymax from the same customer a few years ago. "Partnership and best-in-class customer support has been key values of Trymax since the beginning of the company's operations," says executive VP Ludo Vandenberk. "Winning this additional business confirms our strategy is right and we look forward to supporting our customer growing its business."

Trymax is exhibiting at SEMICON Europa 2018 in Munich, Germany (13–16 November).

www.trymax-semiconductor.com

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FBH orders ClassOne's Solstice S8 system for automated plating and solvent processes

ClassOne Technology of Kalispell, MT, USA (which manufactures electroplating and wet-chemical process systems for ≤200mm wafers) has sold one of its flagship Solstice S8 wet process systems to the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) in Berlin, Germany. As a research institute in the fabrication of III-V compound semiconductors, FBH specializes in prototyping microwave and optoelectronic devices for a diverse range of industries, including communications, energy, health and mobility.

"Solstice is a perfect fit for the III-V compound semiconductor processes that FBH specializes in," comments Olaf Krüger, head of FBH's Process Technology Department. "The exceptional flexibility of the Solstice platform will allow FBH to efficiently automate a number of distinct processes on a single tool. We expect to retain the fine-grained control needed in our research environment with the added production benefits of complete cassette-to-cassette automation."

ClassOne says that FBH is the latest example of a growing trend in the compound semiconductor industry — the need for integrated plating-related processes as part of a comprehensive plating solution. The eight-chamber Solstice S8 will provide FBH with electroplating and wet processing capabilities for a range of processes. In particular, gold plating will be performed by a pair of ClassOne's GoldPro chambers, and a new high-pressure spray solvent chamber will process highly efficient metal lift-off. ClassOne has dubbed the wide range of plating-related wet processing capabilities on the Solstice platform as 'Plating-Plus'.

"The configuration flexibility of Plating-Plus and the exceptional quality of our plating chambers are why ClassOne has become the supplier of choice for the compound semiconductor industry," claims Roland Seitz, director of ClassOne's European operations. "By placing several related processes on a single tool, FBH will enjoy processing efficiencies and device quality that simply cannot be achieved by any other supplier," he adds.

www.fbh-berlin.com
www.classone.com/products

Picosun reports method to control and eliminate stress in atomic layer deposition films

Atomic layer deposition (ALD) thin-film technology firm Picosun of Espoo, Finland has reported a method to control and eliminate stress in ALD films.

Various stresses are easily formed in ALD films during the deposition process, either inside the film or between the film and the underlying substrate. As all modern microelectronic devices are basically built by stacking ultrathin layers of various materials on top of each other, these stresses can be detrimental not only to the film itself but to the other functional layers and structures beneath. Especially in MEMS devices, where cavities and freestanding membranes are often employed, stress-free ALD films — or films where the stress is exactly controlled — are very much sought after. The same applies for IC components, where film strains and tensions can lead to material layers detaching from each other, or bending and buckling of the whole structure.

Picosun has now developed a method with which zero-stress and controlled-stress ALD films can be produced. This method is based on intricate tuning of process chemistry and deposition conditions. The desired effect is obtained with the right selection of precursor chemicals and process temperature, so no additional process steps, such as heat or plasma treatments (which might cause structural damage to the film), are required.

Replacing a single material film with carefully designed nanolaminate of materials with opposite stress properties is another way to achieve zero-stress layers. These methods have been validated with HfO_2 for example (one of the key materials in microelectronics industry). Other ALD materials tested include SiO_2, Ta_2O_5 and TiO_2, in collaboration with VTT Technical Research Centre of Finland, where stress measurements were performed — results were initially published in the AVS 18th International Conference on Atomic Layer Deposition (ALD 2018) in Incheon, South Korea.

Other ALD materials tested include SiO_2, Ta_2O_5 and TiO_2

"We are very pleased that we can now offer stress-free ALD HfO_2 process to our customers in MEMS and IC industries," says chief technology officer Dr Jani Kivioja. "Especially medical MEMS is an important market for us, and a prime example of an application area where controlled-stress ALD films are needed to enable a whole platform of novel products. Thanks to our unmatched ALD expertise, we have now developed a solution to one of the fundamental challenges in ALD. This will facilitate the implementation of ALD to yet new, exciting applications in health technology and future IC manufacturing."

www.picosun.com

k-Space grows year-to-date in-line metrology sales by 26% year on year

Thin-film metrology tool maker k-Space Associates Inc of Dexter, MI, USA has increased year-to-date sales (Q1–Q3/2018) for its in-line metrology market segment by 26% year on year. This is attributed to continued strong sales in the solar industry, as well as the entry into new metrology markets such as glass, automotive and building supplies.

"We have leveraged our experience in production-level, thin-film deposition monitoring as well as in-line PV production monitoring to expand into other areas of in-line metrology," says CEO Darryl Barlett. "We can either use our own proprietary optical sensors or existing off-the-shelf sensors to perform real-time, in-line measurements and integrate the metrology with the factory environment, customizing the measurement and control to the customer's needs," he adds.

k-Space provides custom in-line measurement and analysis solutions for production environments. The firm says that it works with customers to understand their specific needs and then develop a solution that meets all measurement requirements. These solutions include technology, software, data analysis, customization, automation of measurements and integration with existing systems.

k-Space's in-line metrology products typically utilize non-contact, non-invasive optical methods for measurement that provide real-time data for process control. The firm's tools and software measure and control variables such as spectral reflectance and transmission properties, uniformity, dimensional tolerance and thickness.

k-Space expects this trend to continue as it keeps pace with the forecast for growth in the global solar and glass coatings markets, as well as any further expansions in the general US manufacturing market.

www.k-space.com

AdTech chooses OIPT etch systems for IR laser manufacturing

UK-based Oxford Instruments Plasma Technology (OIPT) says that its Cobra plasma etch systems have been selected by AdTech Photonics Inc for their manufacturing facilities in City of Industry, CA, USA.

AdTech manufactures quantum cascade (QC), interband cascade (IC) and other types of infrared lasers covering the near-, mid- and long-wave infrared spectral regions. The overall process solutions for QCLs, ICLs, vertical-cavity surface-emitting lasers (VCSELs) as well as other lasers and the local support offered by Oxford Instruments are cited as key factors in their decision to adopt the inductively coupled plasma (ICP) etch Cobra systems.

"We chose Oxford Instruments to supply our ICP etch equipment because of their cutting-edge technology as well as their unparalleled process support, which will be invaluable to our manufacturing processes," comments Xiaojun Wang, director of Laser Development at AdTech.

The Cobra process solutions are designed to support leading-edge device applications such as lasers, RF, power and advanced LEDs.

"IR-based laser products are entering another exciting phase of growth in the defence, security and environmental markets," notes Emiel Thijssen, OIPT's sales director for America. "We are proud to be providing our laser processing solutions to a pioneering production manufacturer such as AdTech Photonics."

www.atoptics.com

www.oxford-instruments.com/plasma

AES acquires Advanced Research Manufacturing

Gas delivery equipment firm add gas purification technology

Applied Energy Systems (AES) of Malvern, PA, USA — which provides high- and ultra-high-purity gas and liquid delivery systems, services and solutions (including design, manufacturing, testing, installation and field services) — has announced the acquisition of specialty gas purification system provider Advanced Research Manufacturing (ARM) Inc of Colorado Springs, CO, USA.

ARM has been manufacturing high- and ultra-high-purity gas purifiers and gas handling equipment for 20 years and has a worldwide installed base of point-of-use, micro-bulk and bulk gas purifiers. ARM's portfolio of solutions will now be offered through AES to supplement and further expand its gas delivery equipment offerings.

"ARM brings getter, catalyst and absorber purification technology to Applied Energy Systems that will complement our existing product offerings, allowing AES to provide a more complete and unique solution at a very competitive price," says AES president Steve Buerkel.

ARM's ultra-high-purity gas purifiers and associated gas handling equipment are used across the industrial, semiconductor, energy, medical and pharmaceutical markets both in the USA and internationally — the same verticals where AES has a track record of enabling safe, precise gas delivery. "There is already a great deal of synergy between the AES and ARM teams in terms of our knowledge of gas handling requirements for innovative processes and applications," says AES' general manager Jim Murphy. "ARM's products are a natural extension of our equipment offerings, and together we'll offer customers our collective expertise to benefit their projects — whether they require gas purification or gas delivery solutions, or both," he adds.

"With AES' and ARM's combined resources, the research of new technologies and subsequent development of new products can occur at a more rapid pace," reckons ARM's director of technology Brian Warrick. "This will enable us to efficiently add to ARM's existing portfolio of offerings that include purifiers as well as field engineering support," he adds.

"We look forward to growing our market share in the purification of high- and ultra-high-purity gas," says Dan Spohn, ARM's director of global sales & market development.

www.arminc.com
www.appliedenergysystems.com/semi-gas/gigaguard-control-technology

France's Leti and Taiwan's NARLabs to collaborate on research and development projects

Collaboration to facilitate scientific and technological exchanges in microelectronics

In a new collaboration to facilitate a scientific and technological exchange between France and Taiwan, Grenoble-based Leti (a micro/nanotechnology research institute of France's CEA Tech) and Taiwan's National Applied Research Laboratories (NARLabs) — a non-profit research institute established in 2003 under the guidance of Taiwan's Ministry of Science and Technology (MOST) — have agreed to explore opportunities for joint R&D projects in high-performance computing and networks, photonics, bio-medical nanotechnologies and brain-computer interface.

The research institutes' scientists will meet in a series of workshops to initiate joint R&D projects. The agreement also includes access to each other's unique equipment and platforms, and will offer opportunities to researchers with a specific exchange program.

The agreement was signed by CEA-Leti's CEO Emmanuel Sabonnadière and NARLabs' president Yeong-Her Wang on 19 October during the Leti Day Seminar in Hsinchu Science Park, Taiwan.

"CEA-Leti and NARLabs have the same goals: to create differentiating technologies and transfer them to industry," said Sabonnadière. "This cooperation agreement will be the starting point for a strategic research cooperation between our organizations that will strengthen R&D and inspire microelectronics innovation in both Taiwan and France," he added.

"The National Chip Implementation Center (CIC) and the National Nano Device Laboratories (NDL) of National Applied Research Laboratories (NARLabs) have fostered close ties with CEA-Leti since 2017," noted NARLabs' vice president Wu Kuang-Chong.

"Around the Leti Day Taiwan, we held seminars together, and our researchers were able to meet and exchange ideas. Topics included silicon photonics, intelligent image sensors, RF technology, 3D IC+ and device fabrication technology, among others," he adds. "With this memorandum of understanding, CEA-Leti and NARLabs will continue to collaborate together to complement and to enlighten each other to formulate innovative research projects."

www.narlabs.org.tw/en
www.leti.fr

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Seoul sees demand for horticultural lighting

At the 2018 Horticultural Lighting Conference in Portland, OR, USA (9 October), Seoul Semiconductor showcased its complete spectrum of solid-state lighting sources from UV-C to far-red for a wide range of applications.

Seoul Semiconductor, which claims to be the first LED maker to deliver a complete spectrum of solid-state light sources for growing plants from ultraviolet (UV-C) to far-red, says it is seeing a surge of interest in its Horticultural Series LEDs in chip-on-board (COB), mid-power and high-power packages.

"One of the areas where we have seen significant interest from our horticultural lighting customers in the last six months is the installation of supplemental UV LED lighting to boost production of cannabinoids in medicinal crops," says Dr Peter Barber, product marketing manager for Seoul Semiconductor's UV division Seoul VioSys. "Using targeted wavelengths of UV lighting during specific parts of the grow cycle, growers are able to get increased cannabinoid and terpenoid production from less expensive plants, boosting them to potency levels equivalent to those found in higher-cost crop strains."

Cannabinoids, specifically tetrahydrocannabinol (THC) and cannabidiol (CBD), are the active ingredients used in medicinal products made from cannabis plants. Terpenoids are naturally occurring molecular compounds found in virtually all plants, and are responsible for enhancing flavors and fragrances derived from a variety of crops.

"Another application area that growers are investigating is the use of UV LED lighting to combat powdery mold in strawberry, cucumber and hemp growing operations," says Barber. "Applying low-dose, short-duration pulses of UV light timed with periods of darkness has shown promise as a method to reduce fruit and crop disease."

Seoul introduced its Horticultural Series LEDs at the 2017 Horticultural Lighting Conference in Denver, CO. These horticultural-optimized LEDs span the light spectrum from multiple ultraviolet bands (UV-A, -B and -C) to far-red bands (700–800nm), providing horticultural lighting designers with the capability to develop a wide range of light sources to enhance the growth and propagation of different types of vegetables and plants in indoor settings.

SunLike Series LED technology, which delivers a light source close to the spectrum of natural sunlight, is part of the Horticultural Series LEDs, providing lighting designers with more options as they develop horticultural-specific lighting systems. SunLike Series' natural-spectrum LEDs are light sources that combine Seoul Semiconductor's latest optical and compound semiconductor technology with Toshiba Materials' TRI-R technology (which, supported by Toshiba Materials, defines its original concept as "the light closest to the sun for human wellbeing"). TRI-R technology enables the spectrum of natural sunlight to be reproduced by a white LED light source technology.

www.horticulturelightingconference.com

Seoul wins patent lawsuits against Archipelago

Seoul Semiconductor says that it and Seoul Viosys Co Ltd have resolved two patent infringement lawsuits filed in the US Federal District Court for the Central District of California against LED light bulb retailer Archipelago Lighting Inc.

In September 2017, Seoul filed the first lawsuit regarding 12 LED patents covering aspects of Seoul's Acrich technology. A second lawsuit in March accused further products of infringing eight other Acrich patents.

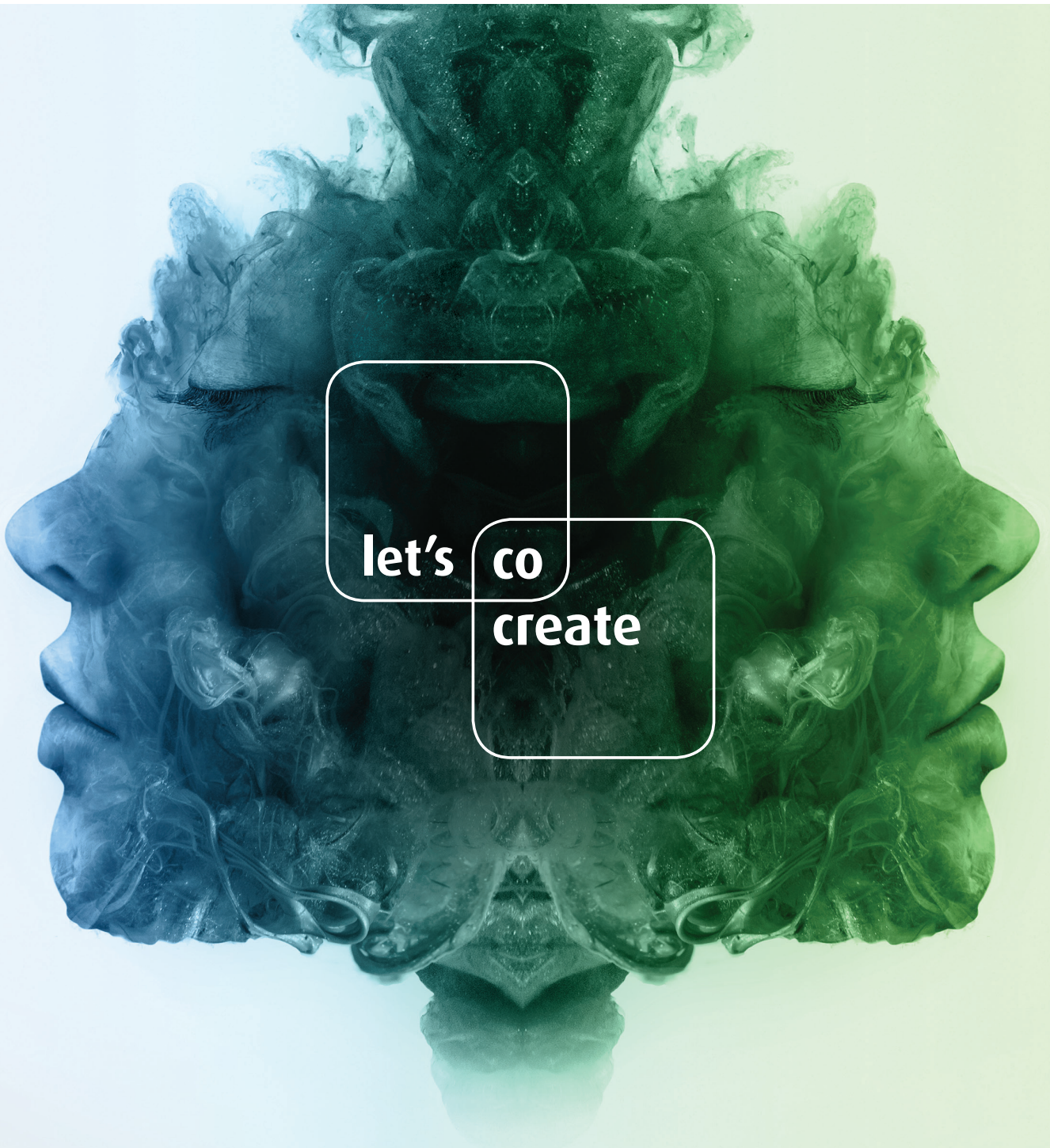
In the lawsuits, Archipelago acknowledged that LED components used in its LED light bulbs were made by several third-party suppliers. Although it had no knowledge of any Seoul Semiconductor patents, or the possibility of infringement, it did not dispute that the light bulbs infringed Seoul Semiconductor's patents. It also did not dispute the validity of the relevant patents and agreed to pay a license fee to affirm its commitment to respecting the intellectual property rights of others. Based on these admissions, the California Central district court entered judgments in favor of Seoul.

Seoul's asserted patents include technologies for drivers for high-voltage operations, Acrich MJT (multi-junction technology — >6V high-power chip), filament LED bulb structures, LED packaging, epitaxial growth and chip fabrication.

Acrich enables high-voltage operation with a high power output using only a small number of LEDs. Specifically, it uses proprietary driver technology to enable high-voltage operation, and proprietary MJT technology for mounting and integrating many LEDs within a small area. This maximizes the available space in LED products and power efficiency by 20%, facilitating a simple circuit design and significantly cutting the size and cost of LED products.

"We will offer a license program with reasonable terms for companies that recognize and respect the value of Acrich technology," says Nam Ki-bum, executive VP of Seoul Semiconductor's Lighting Department. "This will promote the distribution of innovative technology products in the market," he adds. "For young entrepreneurs and small entities that wish to pursue technology innovation, this will help them achieve business success, while Seoul continuously works to encourage a fair competition market where intellectual property rights are respected."

www.SeoulSemicon.com



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Lumileds appoints VP sales & business development for illumination in North and South America

LED maker Lumileds LLC of San Jose, CA, USA has appointed Brian Wilcox, located in the Atlanta area, as regional VP of sales & business development for illumination in North and South America, tasked with driving strategic sales and growth solutions among account leaders, channel partners and the development teams of LUXEON Matrix Platform configurable solutions.

Wilcox joins Lumileds from Samsung LED, where he was senior director of LED sales. He is an industry veteran with expertise in sales management and LED applications at firms including Seoul Semiconductor, Feit Electric and Philips Lumileds.

Brian Wilcox.

Wilcox received his Bachelor of Science in Electrical Engineering from Texas A&M University and his Juris Doctor from Chapman School of Law.

"Brian has long-standing relationships with the world's leading lighting manufacturers," comments Steve Barlow, senior VP at Lumileds. "That, coupled with his insight into industry direction, makes him the ideal candidate to extend our comprehensive portfolio through key accounts at this time."

www.lumileds.com

Lumileds joins Legrand partnership to speed adoption of tunable white LED lighting

Legrand, North & Central America (a specialist in electrical and digital building infrastructures) and LED maker Lumileds LLC of San Jose, CA, USA have partnered to bring to market a simple-to-integrate and easy-to-install plug-and-play solution that delivers high-quality tunable white light.

Through its Matrix Platform, Lumileds will provide intelligent light sources (based on its LUXEON LEDs) that are uniquely characterized and programmed to work with Legrand's Wattstopper blanco tunable-white logic modules within the Wattstopper Digital Lighting Management (DLM) lighting controls solution. Lumileds joins existing Legrand partnerships in tunable-white light engine as the exclusive LED array provider.

"The lighting industry is beginning the transition from providing only static white light to enabling dynamic end-user-selectable color temperature solutions as a subset of what is becoming possible with intelligent and human-centric lighting fixtures and controls," says Steve Barlow, senior VP/general manager of Lumileds' Illumination Business. "Our joint commitment is to optimize the customer experience by offering perfect fixture-to-fixture color matching over a wide correlated color temperature (CCT) range through simple, seamless integration of light sources into fixtures that interface with Wattstopper tunable white modules and their lighting controls," he adds.

The partnership — combining expertise in LED light sources, drivers and controls, along with the blanco intellectual property from Lumenetix Inc (which offers tunable light sources for commercial, residential and professional film/studio lighting applications) — ensures the development of market-ready solutions for a range of tunable white applications across commercial, healthcare, hospitality and education market segments.

Legrand's Wattstopper Blanco 2 is a two-channel LED light engine providing high-quality light with a tunable range of 3000–5000K. With a tunable range of 2700–6500K, Blanco 3 is a three-channel LED light engine that adjusts correlated color temperatures precisely along the blackbody locus to replicate natural daylight.

Blanco logic modules connect to dedicated LED arrays developed by Lumileds LUXEON LED-based Matrix Platform. The arrays are available in a wide range of Zhaga-compliant linear or custom form factors to meet the requirements of lighting fixture manufacturers. Both Blanco light engines provide white light with a color rendering index (CRI) and TM-30 fidelity index of at least 90. Both also provide flicker-free dimming from 100% to 0.1%.

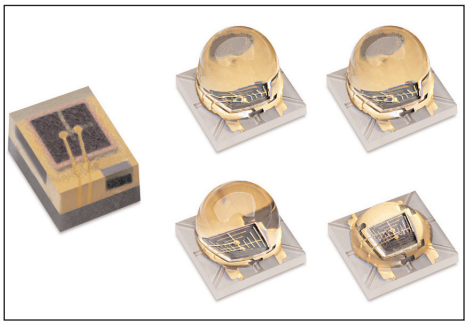
"Legrand's collaboration with partners like Lumileds, as a leader in the LED industry, is essential in the adoption of dynamic lighting control," says Andrew Wale, VP product marketing at Legrand. "As high-performance buildings shift their focus towards a total building performance model, occupant comfort and productivity become paramount," he adds. "Tunable lighting, as part of this shift and a dynamic lighting control strategy, plays a key role. But its potential is only realized when quality of light can be delivered from an end-to-end solution that integrates lighting source, fixture and controls with ease of system design, install, commissioning and first use."

www.legrand.us/wattstopper
www.lumenetix.com

Lumileds adds LUXEON IR for Automotive family of emitters for automotive sensing

LED maker Lumileds LLC of San Jose, CA, USA has launched LUXEON IR for Automotive, an infrared (IR) emitter product family targeting both interior and exterior automotive sensing applications, such as driver monitoring systems, gesture control and night vision. The new family features optical and thermal performance enabling what is claimed to be high system efficacies and easy integration.

The LUXEON IR Domed Line includes four different radiation patterns (50°, 60°, 90° and 150°) with industry-compatible footprint for seamless implementation in existing designs. The LUXEON IR Compact Line brings what is claimed to be the world's smallest high-power infrared emitter to the automotive market, enabling miniaturization while providing freedom for custom optical designs. Both LUXEON IR Domed Line and LUXEON IR Compact Line use a ceramic substrate for optimal heat dissipation and the best thermal conductivity in its class.



Lumileds' LUXEON IR Family for Automotive.

The LUXEON IR Family for Automotive is compliant with AEC-Q102 (the international standard for automotive components). Lumileds also offers extensive application knowledge to support customers in designing them into their applications.

"With the introduction of the LUXEON IR Family for Automotive, Lumileds is offering the automotive industry a range of infrared emitters that will enable further implementation of advanced driver-assistance systems (ADAS) in the next generation of cars," says Wouter Schrama, senior product manager for the LUXEON IR Family. "The LUXEON IR Domed Line for Automotive is ideal for use in interior applications like driver monitor systems (DMS) and occupancy detection. The LUXEON IR Compact Line for Automotive is very well suited for integration in exterior optical systems, such as head or tail lights for lane-departing systems, IR illumination at night or during bad weather conditions," he adds.

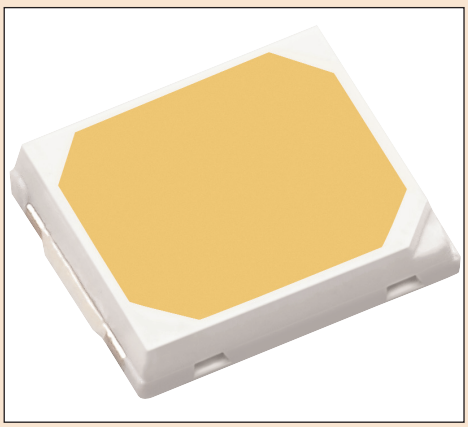
The LUXEON IR Domed Line and LUXEON IR Compact Line for Automotive will start shipping at the end of 2018.

www.lumileds.com/infrared-automotive
www.lumileds.com/LUXEONIR

Lumileds' new LUXEON 2835 HE LED drives luminous efficacy over 200 lumens per Watt in a 2835 package

LED maker Lumileds LLC of San Jose, CA, USA has introduced the LUXEON 2835 HE, which achieves luminous efficacy of over 200lm/W while providing high color consistency.

Expanding on the LUXEON 2835 Line, the new LED is optimized to deliver high efficacy and 2-step MacAdam ellipse color consistency in applications such as troffers and high-bay/low-bay fixtures. "The LED's tight color point distinguishes it from other mid-power devices in its class," says Sam Wu, product manager of Mid Power Products. "Design kits to 2-step MacAdam ellipse are available for the ultimate in color consistency for demanding lighting applications," he adds. The LED delivers luminous flux of 36lm at 65mA drive current and 202lm/W, or 220lm when driven at 480mA (4000K and 80 CRI).



Lumileds' new LUXEON 2835 HE high-efficacy LED.

"LUXEON 2835 HE is ideally suited to troffers, downlights and lamps where fixture efficacy greater than 150 lumen per watt is paramount and LED count must be minimized," says Wu. Lumileds says that its high-reliability design enables the LUXEON 2835 HE to deliver more light for smaller-profile, general lighting applications. Unlike many 2835 LED packages on the market, it is lumen-maintenance tested (LM-80) to 12,000 hours, ensuring lumen maintenance of 72,000 hours in the field (L70, TM-21 basis).

The LUXEON 2835 HE is available in a wide range of color temperatures and color rendering indexes (CRIs) of 70–90 to address a variety of general lighting designs. The LED is available immediately as a drop-in replacement for 2835 LED packages (2.8mm x 3.5mm) or can replace 5630 (5.6mm x 3.0mm) or 3030 (3.0mm x 3.0mm) mid-power sockets with similar optical requirements.

www.lumileds.com/luxeon2835line

Cree's quarterly revenue grows 13% year-on-year, driven by Wolfspeed's organic growth of 50%

LED and Lighting Products margins rise despite impact of China tariffs

For fiscal first-quarter 2019 (to 23 September 2018), Cree Inc of Durham, NC, USA reported revenue of $408.3m, down slightly on $409.5m last quarter but up 13% on $360.4m a year ago, led by its Wolfspeed business (Power & RF devices and silicon carbide materials).

Revenue for Wolfspeed was $127.4m (31.2% of total revenue), up 16% (more than the expected 13%) on $110m (26.9% of total revenue) last quarter and up 93% on $66.2m (18.4% of total revenue) a year ago. Even excluding the Infineon RF Power business (acquired on 6 March), organic growth was still a strong 50% year-on-year.

Although down 6% on $155.8m (38% of total revenue) last quarter, revenue for LED Products of $146.8m (36% of total revenue) is up 2% on $144.5m (40.1% of total revenue) a year ago.

Lighting Products revenue was $134.1m (32.8% of total revenue), down 7% (more than the expected 6%) on $143.7m (35.1% of total revenue) last quarter and 10% on $149.7m (41.5% of total revenue) a year ago.

On a non-GAAP basis, gross margin has risen further, from 28.3% a year ago and 30% last quarter to 32.1% (above the targeted 30.6%).

Wolfspeed gross margin was 47.4%, down from 49% a year ago but only slightly from 47.9% last quarter as Cree managed the challenges of ramping new capacity and integrating the acquired Infineon RF business. "We accomplished our goal of doubling capacity for power devices and material sales a full quarter ahead of plan," notes president & CEO Gregg Lowe. "The result is a business where revenues have more than doubled, and gross margins have improved by roughly 20 basis points over the five quarters since we embarked on the expansion plan [from 45.5% for fiscal Q4/2017]."

LED Products gross margin has grown further, from 26.9% a year ago and 27.4% last quarter to a better-than-targeted 28.1% (its highest level in almost 2 years), as the effects of lower revenue and tariff-related costs were more than offset by strong factory execution, favorable mix and better-than-expected average selling prices (ASPs). "LED Products business demonstrated further progress relative to its objective of driving value through greater focus," says Lowe. During the quarter, Cree introduced the XLamp XP-G3 S Line of LEDs (optimized for connected lighting). "Through innovations and component architecture, this new line can withstand double the number of switching cycles compared to competing LEDs in its class," claims Lowe. "This is significant because connected lighting systems will dim or switch off lights up to 10x more often than standard lighting systems."

Lighting Products gross margin has recovered further, from 20.3% last quarter to a better-than-targeted 23.2%, the third consecutive quarter of more than 100 basis points improvement (and up on 21.3% a year ago), demonstrating "continued progress in the path to fixing this business". This is attributed to better mix, product cost reductions, improved operational efficiencies and being more selective with respect to the business pursued. "The team has done an outstanding job of improving quality through improved processes. Over the last three quarters, we have released 21 new products and shipped over 220,000 of those new products with excellent quality metrics that demonstrate our new processes are paying off," says Lowe.

Operating expenditure (OpEx) was $104m (25.5% of revenue), cut more than expected from $108m (26.4% of revenue) last quarter, due mainly to good discipline around discretionary spending and the timing of certain R&D projects. "Our plan is to reinvest the OpEx savings from our Lighting restructuring into Wolfspeed, so you shouldn't consider this OpEx level to be the new baseline," notes chief financial officer Neill Reynolds.

Driven by the continuing robust growth in Wolfspeed combined with strong gross margin improvement in LED Products and Lighting Products, net income has continued to recover, from just $4.1m ($0.04 per diluted share) a year ago and $11.5m ($0.11 per diluted share) last quarter to $22m ($0.22 per diluted share), far exceeding the targeted $10–14m ($0.10–0.14 per diluted share). This is despite the negative impact of $0.02 per diluted share from the China-related tariffs that went into effect on 6 July, as well as the challenges presented by Hurricane Florence in the USA and Typhoon Mangkhut in Asia.

Cash flow from operations has fallen further, to $34m. However, capital expenditure (CapEx) has been cut from $59.5m to $39.7m. So, free cash flow has improved from –$17.5m last quarter to –$5.8m.

In late August, Cree raised $575m in a private offering to qualified institutional buyers of its 0.875% convertible senior notes due 2023 (a conversion premium of 31% or $59.97 per share). "It allows us to reduce interest expense, lock in at fixed rate, add cash to the balance sheet, and is accretive," notes Reynolds. "As a result of the increased cash available to invest and a lower interest rate relative to our working capital line of credit, we will move from a position of incurring net interest expense each quarter [$575,000 in fiscal Q1] to earning net interest income [targeted at about $1m in fiscal Q2]. Also, the risk of dilution is quite modest as our stock price could double from the issue price and the

additional shares required would only amount to a few percent compared to the current share count."

With zero borrowed on the firm's line of credit and convertible debt with a face value of $575m, overall cash and investments rose during the quarter from $387.1m to $665.5m.

"Fiscal year 2019 is off to a strong start, with first quarter non-GAAP earnings per share that exceeded the top end of our target range driven by another quarter of robust growth in Wolfspeed combined with strong gross margin improvement in LED Products and Lighting," says CEO Gregg Lowe. "This is an excellent result given the headwinds facing the businesses related to tariffs and global trade tensions. While these headwinds may persist for some time, we remain optimistic about the opportunity to increase shareholder value over the long term by executing our strategic plan," he adds.

"The company has a clear strategic vision, employee engagement has improved materially, and execution is improving in all three of the businesses," says Lowe. "One terrific example of that is in our materials business where we exited Q1 achieving record output, improved yield and shorter cycle times."

For fiscal second-quarter 2019 (to 30 December 2018), Cree expects revenue to be roughly level sequentially at $398–418m, with 5% growth in Wolfspeed revenue counteracting slight declines in LED Products revenue (as the positive growth trends in the firm's four focus areas are more than offset by softer demand in China related to the latest round of tariffs) and Lighting Products (as Cree focuses on increasing gross margins by improving product mix).

"There are numerous headwinds facing our businesses in the short term," notes Lowe. "These include direct and indirect impacts of tariffs in our LED and Lighting business, the impact of trade tensions on the global economy, and the seasonality that our LED and Lighting businesses typically experience in the March quarter."

However, net of a targeted 75 basis point reduction from the tariffs, gross margin should rise for all three business segments.

OpEx is expected to rise to $111m, due mainly to higher Wolfspeed R&D spending and a greater number of days in the quarter as well as a full-quarter impact of the annual merit increases that went into effect in September. "While changes in OpEx can vary from quarter-to-quarter for a variety of reasons, including the timing of R&D projects, marketing spend around trade shows and when IP cases go to trial, our long-term objective remains to drive OpEx lower as a percent of sales, even as we increase our investments in growth initiatives," stresses Reynolds.

Cree expects a drop in net income to $15–19m ($0.15–0.19 per diluted share). This includes a reduction of $0.03 from the impact of the tariffs that went into effect in fiscal Q1. Tariffs applied to some Lighting Products (coming in from China) that went into effect on 24 September are expected to increase this impact to $0.05 per share in fiscal Q3. "We are evaluating ways to further mitigate the impact of these tariffs," says Reynolds.

For full-year fiscal 2019, Cree still targets a 40/20/20 business model (40% gross margin, 20% OpEx and 20% operating margin). Targeted capital spending is $220m, driven primarily by expanding Wolfspeed's production capacity to support forecasted long-term customer demand. Free cash flow should be –$10m, due to the timing of Wolfspeed's capacity investments to alleviate current constraints and support the substantial growth opportunity forecasted over the next several years. "As we continue to ramp this new capacity, we could have some variability in our initial production yields and factory utilization that may reduce our near-term Wolfspeed gross margins," cautions Reynolds.

"The Wolfspeed sales funnel is growing rapidly for power devices, materials and RF," says Lowe. For example, Cree has just signed another strategic long-term agreement worth more than $85m to produce and supply 150mm silicon carbide substrates and epiwafers to "one of the world's leading power device companies". "In power devices alone, we are engaged with dozens of partners working on projects with a total opportunity well in excess of $1bn. These projects, which span the time frame of our long-range plan, include segments such as electric vehicle drivetrain, on-board charging, DC-to-DC conversion and charging infrastructure," Lowe adds. "The number of customers that we're working with that are committed to silicon carbide is significantly higher than it was a year ago."

"We plan to double our materials and power device capacity again over the next couple of years [quadrupling capacity from 18 months ago] to meet growing demand for our products and to expand our leadership position in these technologies," Lowe concludes.

www.cree.com

Cree has made changes to its board of directors following its 2018 annual meeting of shareholders):

- John C. Hodge and Duy-Loan T. Le have been elected to the board;
- Darren R. Jackson was appointed as chairman; and
- Robert A. Ingram and C. Howard Nye retired from their positions on the board, upon expiration of their terms.

Hodge and Le will "assist the leadership in shaping our vision to create a world-class semiconductor company," says Darren Jackson, newly appointed chairman of the board. "Their breadth of industry experience will be invaluable as we drive market expansion for SiC- and GaN-based innovations focused on a variety of applications across diverse sectors such as automotive, telecommunications and energy," he adds.

Osram Opto joins ISELED Alliance

Osram Opto Semiconductors GmbH of Regensburg, Germany has joined the ISELED Alliance. The alliance was founded in 2016 to further develop and market the 'digital LED' (controller chip with three coloured LED chips) for an innovative LED lighting concept for vehicle interiors. In addition to Osram Opto Semiconductors, Inova Semiconductors, Dominant Opto Technologies, Lucie Labs, Melexis, OLSA Group, NXP, TE Connectivity, the University of Pforzheim and Valeo have already joined.

The alliance aims to install a complete ecosystem with the corresponding hardware and software for the ISELED concept. The key product is a 'smart' digital RGB LED in a very compact package. The focus is not on the individual products but on their interaction within the overall system. A special protocol ensures optimum coordination of the individual hardware and software components used by the system solution, guaranteeing optimum integration of the smart LED and the associated controller. Due to this approach, not only can the LED controller be greatly simplified but also the possibilities of in-car LED lighting systems can be significantly extended.

With the development towards more automated and autonomous driving, the use of car interiors changes fundamentally. The interior design acquires a particular significance not only due to the possibility of visual differentiation to the competition. On the other hand, the demands on the installed light sources, in particular on LEDs, are also increasing. The new generation of automotive interior or ambient lighting uses hundreds of LEDs, usually made up of flexible strips with a large number of RGB LEDs, which in turn have to be controlled individually to create dynamic lighting effects.

In the ISELED concept, each of the 'digital LEDs' consists of a red, green and blue LED chip, which are integrated together with a controller in a small package and can be daisy-chained. In total, up to 4079 of these digital LEDs can be arranged via a differential 2-wire bus with a data rate of 2Mbps and controlled by an external controller. With a data rate of 2Mbps and using the corresponding application software — also available from ISELED partners — fascinating lighting effects with video speed are possible.

Osram Opto will soon be introducing the first prototypes of smart RGB LEDs on the market. "A key customer advantage of these innovative smart LED components is that the complex calibration for adjusting colour location and brightness between the individual LEDs is no longer necessary," says Hermann Senninger, senior marketing manager Automotive Interior at Osram Opto. "In addition, this technology also opens up many other potential applications for our customers — first for the vehicle interior and later also for the exterior," he adds.

"The addition of Osram Opto Semiconductors — one of the world's leading providers of innovative LED products — underscores the growing acceptance of ISELED and its ecosystem as a highly innovative and forward-looking technology," says Robert Kraus, CEO of Inova Semiconductors and a founding member of the alliance. "With its extensive LED expertise and manufacturing know-how, Osram Opto Semiconductors will continue to strengthen the unique technology concept and enable new, previously unrealisable LED lighting capabilities for the next generation of vehicles."

https://iseled.com
www.osram-os.com

Rutronik & Osram expand distribution agreement to North America

Rutronik Inc (Europe's third largest electronic components distributor and the world's 11th largest, with annual sales of $1bn) has expanded its franchise agreement in North America with Osram Opto Semiconductors GmbH of Regensburg, Germany. Osram inventory is in stock in Rutronik's Texas warehouse, and also available via the e-commerce platform Rutronik24.

Osram provides LEDs in low-power, mid-power, high-power and ultra-high-power classes for general illumination, automotive, consumer, and industrial applications, as well as infrared emitters, lasers and optical sensors. Key markets include automotive, smartphones, general lighting, horticultural lighting, industrial, and projection.

The addition of the North American region marks the completion of a global franchise agreement between the two companies. Rutronik already serves as one of the most important distributors for Osram Opto Semiconductors in the Europe, Middle East & Africa (EMEA) market. Rutronik was also franchised for Osram in the Asian market in 2017.

"With Osram's extensive product line aligned with our field application engineers and field sales specialists, we look forward to serving our growing customer base in North America," says Sean Sisson, Rutronik's VP for North America.

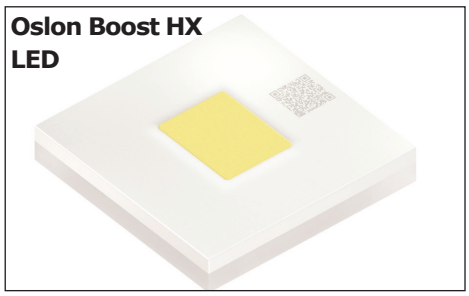
"Osram is well established in the region, and Rutronik is already a leading distributor of our LED products in Europe and China," comments Geoff Brown, VP of sales, North America, at Osram Opto Semiconductors. "Combining this regional and product expertise will enable us to quickly impact the North American market," he reckons.

www.rutronik.com
www.osram-os.com

Osram launches Oslon Boost HX LED for automotive forward lighting and information projection

Just like a normal projector can display pictures on a screen, a digital mirror device (DMD) system (with millions of micro-mirrors) in a car headlight can project light onto a road in the form of symbols. Osram Opto Semiconductors GmbH of Regensburg, Germany says that, due to components such as its new Oslon Boost HX LED, each headlight achieves a resolution of more than 1 million pixels, offering drivers not only classic illumination but also optional support from information projected onto the road. For example, future headlights may project two guide lines the width of a car apart, enabling the driver to negotiate roadworks more safely. Projections may also be used to tell drivers that they are too close to the vehicle in front, or warn them that they are approaching roadworks, icy patches or other hazards.

In developing Oslon Boost HX, Osram Opto made use of its



Oslon Boost HX LED

expertise in projection technology, in which high-current LEDs have been used for a long time and have been continually optimized. They have now been transferred to the automotive sector and adapted to meet the strict quality requirements. "This first product in the Oslon Boost family addresses the trend for special user experiences with added safety and emotional appeal," says Stefan Seidel, senior manager marketing Automotive Exterior at Osram Opto. "This LED is a good example that shows the enormous potential our products will have in automotive lighting."

Oslon Boost HX delivers luminance of more than 200cd/mm^2, taking light-based driver assistance systems and communication with the driver into new territory, it is claimed. Special chip technology with very high ampacity can be operated at 3A/mm^2, ensuring high luminous flux — and most importantly for this application — high luminance. Its 2mm^2 chip emits at least 1400lm at a current of 6A.

The package has been optimized to exploit the high current capability of the chips. An electrically insulated thermal pad and special internal design structures ensure that heat is reliably removed from the device. The 4mm x 4mm ceramic package is very robust so it is easy to handle.

Passive DMD solutions herald the start of a broad range of applications, says Osram Opto. More efficient active solutions for glare-free high beam and projection as well as other Oslon Boost derivatives will follow.

Prototype of RGB-LED Osire E4633i provides dynamic in-car lighting

Osram Opto Semiconductors GmbH of Regensburg, Germany says that previously static light, which could only be switched on and off, has now been given a dynamic dimension with the prototype of its Osire E4633i LED, offering countless design options for car makers. The more autonomous a car becomes, the more the ways in which it is used will change, says the firm. As developments progress towards autonomous driving, more attention is being focused on the passenger cell, in which light will become an integral part, taking on functional and design-specific tasks.

"In the future, the interior of vehicles will be more than simply a cabin for the driver and passengers. It will be an extension of our living space in which we will be able to work and relax," believes Stephan Pawlik, marketing manager Automotive Interior at Osram Opto: "Light sources in car interiors will provide ambient lighting and perform a number of additional functions. For example, they could use dynamic and color effects to draw the driver's attention back to the traffic in good time."

To make it easier to provide such new functions in vehicles, Osram has installed a serial control driver from Inova Semiconductors in the new E4633i product from the Osire family in addition to the three color chips (red, blue and green). It is now possible for a large number of separate LEDs to be controlled via a serial bus system either individually or in groups, providing simple implementation of uniform color rendering across the entire color space as well as dynamic light cases. Control of the desired color and brightness has been simplified because the E4633i is precalibrated and can automatically correct color shifts in the red range caused by fluctuations in temperature. The LED has a pre-mold SMT package with a footprint of just 4.6mm x 3.3mm x 0.7mm. The compact package and the link to the serial bus now allow implementations with more LEDs in a much smaller space.

Since September, Osram Opto has been a member of the ISELED Alliance (Integrated Serial/Smart Embedded Light Emitting Diode) and aims to drive forward development in this field. The prototype of the Osire E4633i is being presented for the first time in booth 155 (Hall B4) at the electronica 2018 trade fair in Munich, Germany (13–16 November).

https://iseled.com
www.osram-os.com

NTT DOCOMO Ventures invests in QD Laser

Quantum dot technology targeted at retinal scanning laser eyewear and augmented reality applications

Tokyo-based NTT DOCOMO Ventures Inc has invested in QD Laser Inc of Kawasaki City, Kanagawa, Japan, which develops and manufactures semiconductor lasers, retinal scanning laser eyewear, and other products based on quantum dot laser technology.

QD Laser was founded in 2006 as an offshoot of Fujitsu Ltd with funding from Mitsui Ventures. By leveraging its nanocrystal technology, it achieved mass production of quantum dot lasers capable of operating stably even at high temperature.

In 2018, QD Laser applied its technology to incorporate a compact laser projector with extremely small output into a spectacle-type device, and commercialized what was claimed to be the first retinal scanning laser eyewear that directly projects an image onto the user's retina for image display. The technology for projecting a direct image onto the retina using a laser does not require the user to focus their eyes to see an image, so it is expected to improve the quality of life of patients with ametropia or corneal opacity and weak-sighted individuals.

The technology can also be applied to realizing natural-looking augmented reality (AR) that people with normal vision can experience.

NTT Group says that it has high expectations for the potential of the retinal scanning laser eyewear developed by QD Laser for resolving various social issues and contributing to creating new services through AR.

www.qdlaser.com
www.nttdocomo-v.com

EPIC and COBO sign memorandum of understanding

In conjunction with its VIP Party at the European Conference on Optical Communication (ECOC 2018) in Rome, Italy, the European Photonics Industry Consortium (EPIC) signed a memorandum of understanding (MoU) with the Consortium for On-Board Optics (COBO), targeting cooperative activities involving industry endorsement of standards and technology roadmaps.

The partnership will encourage direct contact and cooperation between the consortiums and its members, including participation at events, writing joint articles, collaboration in information exchange and promotion, and advisory mandates with an aim of bringing cooperation and, ultimately, support the development of an efficient and sustainable industry.

EPIC is a not-for-profit industry association that promotes the sustainable development of organizations working in photonics. It is owned and operated by its members, who range from start-ups and SMEs to large corporates, as well as including research organizations, universities and other stakeholders connected to the photonics industry.

COBO is membership-driven, non-profit corporation developing specifications for embedded optical modules in the manufacturing of networking equipment (i.e. switches, servers). It references industry specifications where possible and develops specifications, where required, with attention to electrical interfaces, pin-outs, connectors, thermals and materials for the development of interchangeable and interoperable optical modules that can be mounted onto motherboards and daughtercards.

COBO's president Brad Booth and EPIC's chief technology officer Dr Jose Pozo, who signed a collaboration agreement at the EPIC VIP Party during ECOC.

COBO consists of about 63 companies in telecoms, semiconductors, IT and software. This complements the interests of most of the 385 members of EPIC, which span the entire value chain from photonics fields such as lighting, photovoltaics, photonics integrated circuits (PICs), optical components, lasers, sensors, imaging, displays, optic fiber and other photonics-related technologies.

"EPIC members include key actors in the value chains on photonic packaging, silicon photonics, indium phosphide devices and vertical-cavity surface-emitting lasers (VCSELs)," says EPIC's chief technology officer Dr Jose Pozo. "This additional collaboration with COBO will bring EPIC members in contact with the main players in standardization of on-board optical interfaces, to enable a turning point for accelerating the time to market for novel optical modules," he adds.

"As the importance of optics grows as technology advances, it is important that organizations like EPIC and COBO collaborate to eliminate barriers and smooth the adoption of innovative photonic developments," states COBO's president Brad Booth.

www.epic-assoc.com
www.onboardoptics.org

VueReal announces $8.5m in SDTC funding

Micro- and nano-device technology developer VueReal Inc of Waterloo, ON, Canada has announced $8.5m in funding from Sustainable Development Technology Canada (SDTC) to support a total project investment of over $26m. SDTC is a foundation created by the Government of Canada to help small- and medium-sized enterprises in Canada to accelerate the development and deployment of globally competitive clean technology solutions. VueReal will use the funding to further develop innovative micro-LED technologies by expanding its Waterloo team and launching an Advanced Nano-Technology Center fabrication facility.

Micro-LED displays use screens built from tiny versions of the same type of chip used in LED lights. They have many significant advantages over today's OLED and LCD screens, including being much brighter (a requirement for displays that must compete with ambient daylight), supporting higher frame-rates, delivering denser pixels per inch (PPI), providing better contrast, being more flexible, and doing it all at double or triple the power efficiency and with significantly longer lifetimes.

Together with the SDTC support, VueReal will leverage key industry partnerships with Angstrom, a Canadian manufacturer of industry-leading thin film deposition systems for PVD and CVD processes, and a large Asian electronics company.

"We are proud to have the support of this federal program, and collaborations with industry partners. The next steps include building an integrated pilot production system, engineering the equipment needed to enable VueReal's proprietary Solid Printing process at commercial volumes, and enhancing the performance of micro-LEDs even further," says VueReal's CEO & founder Reza Chaji, Ph.D. "I'm extremely proud of our world-class multi-disciplinary team. We've achieved some important milestones — and the industry has taken notice — but our journey is really just beginning," he adds.

"We are excited to support VueReal in developing innovative solutions by providing engineering support for the deposition equipment required to create the micro-LED devices," comments David Pitts, president, Angstrom Engineering Inc.

"SDTC is proud to support the steps that VueReal is taking to reduce the carbon footprint of micro- and nano-technology production processes, demonstrating that small actions can create big change," says SDTC's president & CEO Leah Lawrence.

www.vuereal.com

AIM Photonics unveils support for datacom and telecom optical bands with new silicon photonics PDK

New Analog Photonics and SUNY PDK enables partnering companies to gain technological capabilities in O+C+L optical bands

The Rochester-based consortium AIM Photonics (American Institute for Manufacturing Photonics) — an industry-driven public–private partnership advancing the USA's photonics manufacturing capabilities — and Analog Photonics of Boston, MA, USA (which has expertise in the design and verification of silicon photonics components and systems) have announced the release of the AP SUNY Process Design Kit v2.5a (APSUNY_PDKv2.5a).

Analog Photonics (AP) has expanded the comprehensive set of silicon photonics integrated circuit (PIC) component libraries within SUNY Poly's process capabilities to address the needs for O+C+L-band applications. Combined with multi-project wafer (MPW) runs, this updated PDK will give AIM Photonics' members access to silicon photonics components for the development of optical transceivers or systems used in all levels within data centers and high-performance computers.

The silicon photonics PDK includes design guide, design rule check deck, technology files, active and passive component documentation, abstracts, schematics and compact models for the development of PICs.

The key features of the APSUNY_PDKv2.5a are:

- O-band modulation, detection and coupling support;
- C+L-band modulation, detection, filtering, switching, monitoring and coupling support;
- single-level and multi-level modulation format support at 50Gbps, namely NRZ and PAM-4; and
- continued multi-vendor electronics-photonics-design-automation (EPDA) support with integrated EPDA PDK flow for hierarchical design and system-level simulation.

"We are thrilled to continue to expand the offerings of our state-of-the-art PDK to meet the needs of our more than 100 signed partners and other interested collaborators who can gain access to our unique capabilities," says Dr Michael Liehr, AIM Photonics CEO and SUNY Poly executive VP for Innovation and Technology. "This also dovetails perfectly with our effort to efficiently process our multi-project wafers in the fab, with processing time decreasing from 130 days in 2016 to fewer than 90 days as we simultaneously add additional mask levels and functionality and continue to achieve world-class quality," he adds.

The combined APSUNY_PDKv2.5a and MPW offering provides access to PIC systems for companies that desire a reduction in the time to market, product development risk and investment. By incorporating the design, verification and process development within the PDK, interested organizations can rapidly modify their designs while reducing cost.

"The IEEE standards and multi-source-agreements (MSAs) for communications compatibility are key for our PDK component library," says Dr Erman Timurdogan, director of PDK Development at Analog Photonics. "These standards require optical components to operate at O band (1260–1360nm), C band (1530–1565nm) and L band (1565–1625nm)," he adds. "With the PDKv2.5a component library, we are enabling components that cover all these bands in a single fabrication flow, and we look forward to the advancement of this library while innovating to meet industry needs."

In the near future, the PDK will be empowered by laser and CMOS integration with an interposer, a capability that will be made possible at AIM Photonics' Test, Assembly and Packaging (TAP) facility in Rochester, NY. Additional releases of the AP SUNY Process Design Kit are planned over the next several years each quarter, with improved statistical models, optical components, and PIC systems.

"We are seeing customers take advantage of our repeatedly characterized and proven devices in the APSUNY PDK," says AIM Photonics Design Center offering director Barton Bergman. "With this valuable resource, which is validated on our 300mm advanced semiconductor toolset, customers are able to rapidly address global standards, shrink their design sizes, and most importantly, reduce their time to market."

AIM Photonics is leveraging SUNY Poly's facilities for three total full-build/passive MPW runs that incorporate the PDK updates, with an interposer MPW run anticipated later in 2018. To ensure space for all interested parties, AIM Photonics is accepting reservations for these MPW runs. Those interested in participating in any of the AIM Photonics 2018 MPW silicon photonics runs should contact Chandra Cotter at ccotter@aimphotonics.com to guarantee a spot on the new silicon photonics offerings. Interested parties can also sign up for the 2018 runs by visiting www.aimphotonics.com/mpw-schedule.

PDK and MPW fab access is solely available through the AIM Photonics MPW aggregator, MOSIS. Contact MOSIS for access to the most current PDK version release at www.mosis.com/vendors/view/AIM.

www.aimphotonics.com/mpw-schedule

www.analogphotonics.com/pdk

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Source Photonics calls for potential of 5G to be matched by optical fronthaul and backhaul network infrastructure

There may be a vast number of opportunities for mobile fronthaul and backhaul on the horizon but improvements in protocols, standards and technology will also need to be made, said Supriyo Dey, senior director product line management at Source Photonics Inc of West Hills, CA, USA (which provides optical connectivity products for data centers, metro and access networks), at the European Conference on Optical Communication (ECOC 2018) in Rome, Italy (24–26 September).

"While an exciting era of unprecedented opportunity is almost here in the shape of 5G, it comes with a set of challenges for the whole industry," says Dey. "The advent of this technology is undeniably huge, but there's a real challenge for those who are hungry to develop its capabilities to match their expectations in terms of performance. Applications such as 3D video, augmented reality, UHD screens, self-driving cars and smart cities, to name a few, will need to be supported by mobile front and backhaul," he adds.

"With these advances in capabilities come new requirements — up to 10Gb/s data rate to support high-quality video, ultra-reliable and low latency communication for autonomous vehicles, and massive node communications for the Internet of Things," notes Dey. "The current 4G optical fronthaul and backhaul architecture will not be adequate to support these new applications. While several optical fronthaul and backhaul solutions have been proposed, we have yet to see a clear winner."

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Dey's observations were delivered at the ECOC18 Exhibition's Market Focus, as part of an agenda that tackled topics ranging from FTTX evolution and next-generation data centers to optics as an enabler for 5G.

At ECOC, Source Photonics also showcased some of its latest products in the form of live demos. This included a demonstration (with equipment testing firm Ixia) of its 400G QSFP-DD LR8 transceiver. It also demonstrated its 25G SFP28 LR Lite transceiver, which supports CPRI wireless and 25GBASE-LR applications.

In addition, Source Photonics demonstrated interoperability of its 50G and 400G modules into the Huawei router alongside other participating companies in the Ethernet Alliance interoperability demo.

www.sourcephotonics.com

Source Photonics partners with Huawei in showcasing 50G and 400G PAM4-based optical transceivers

Source Photonics partnered with telecom equipment maker Huawei in showcasing 50G and 400G optical transceivers based on PAM4 (4-level pulse amplitude modulation) technology by joining the Ethernet Alliance interoperability demonstration at ECOC, consisting of multiple 400G and 50G links among participating network and test equipment manufacturers.

Demand for bandwidth is rising continuously as new technologies such as AI, virtual reality, Internet of Things (IoT) and 5G drive the need for faster transmission speeds in the network, says Source Photonics. Moreover, the rapid growth of network traffic increases the challenges brought by heat dissipation and power supply in the equipment rooms. This leads to more expensive construction costs, making network migration and expansion impractical.

Source Photonics is working with Huawei to provide operators an environmentally friendly and energy-efficient technology. The firms took the initiative this year in driving the development of optical modules based on 50G PAM4 technology. Coupled with faster Baud Rates and higher-density transceiver types, PAM4 is enabling 400G, which is key to migrating to higher-speed networks.

"We successfully demonstrated interoperability of the first 400G QSFP-DD LR8 and 400G CFP8 LR8 transceivers at OFC 2018 in March," says product line manager Andy Xiao. "Source Photonics continues to take initiative as it collaborates with Huawei in developing IEEE optical standards for 50G PAM4 technology."

Source Photonics' 400G CFP8 supports the IEEE 400GBASE-LR8 optical standard and 400GAUI-16 electrical interface. The module operates from 0°C to 70°C and complies with the CFP8 MSA and allows connections of up to 10km. The 50G LR QSFP28 uses a directly modulated laser (DML) with mature TO package as a cost-effective solution for network migration. This product will be available for purchase in September and will also be key in enabling 5G commercialization and other services requiring higher network bandwidth.

www.ecocexhibition.com
www.huawei.com

Oclaro demos 100G single-lambda interoperability; will begin sampling 400G QSFP56-DD FR4 2km transceivers

As part of the plug fest organized by the 100G Single-Lambda Multi-Source Agreement (MSA) at the European Conference on Optical Communication (ECOC 2018) in Rome, Italy (24–26 September), Oclaro Inc of San Jose, CA, USA demonstrated interoperability of its 100G 4-level pulse amplitude modulation (PAM4) electro-absorption modulated laser (EML) technology integrated into the 100G QSFP28 form factor of transceiver.

Oclaro also announced that sampling will begin later this year of its new high-density QSFP-DD solution, which uses this same 100G PAM4 EML technology in four lanes to enable an aggregated data rate of 425Gbps.

"The breakthrough demonstration of the 100G single-lambda optical link was made possible through the use of Oclaro's world-class integrated indium phosphide (InP) 100G PAM4 EML technology," claims chief strategy officer Yves LeMaitre. "When combined with the latest-generation DSPs [digital signal processors], our high-bandwidth EMLs enable new transceiver designs for 100G per wavelength and 400G," he adds. "Products such as Oclaro's QSFP-DD are critical to hyperscale data-center operators to leverage a new generation of switching ASICs and allow for a faster migration to 400G."

The 400G QSFP56-DD FR4 transceiver significantly reduces system cost per port by enabling 36 ports of 400G per 1RU compared with only 18 ports of 400G with CFP8 (first-generation 400G modules). To ensure interoperability, Oclaro has been actively involved in the 100G Lambda MSA and QSFP-DD MSA. In August, Oclaro interfaced the transceiver's mechanical housing with leading QSFP-DD connector and cage vendors at the QSFP-DD MSA mechanical plug fest. Earlier this September, Oclaro also participated with its 100G QSFP28-FR and 400G QSFP-DD FR4 transceivers in an interoperability test organized by the 100G Lambda MSA.

Enabled by Oclaro's 100G EMLs, the new 400G QSFP56-DD FR4 transceiver represents a new generation of optical transceiver solutions for hyper-scale datacenter applications. Key features include:

- 400 Gigabit Ethernet (400GbE) transceiver operating at a data rate of 425Gbps;
- compliant to the 400G-FR4 optical interface specification of the 100G Lambda MSA and the 400GAUI-8 electrical interface specification of the IEEE;
- transmission distance up to 2km (supporting 95% of links inside data centers);
- compliant to QSFP-DD MSA hardware specification;
- optical transmitter with 4 EMLs in the 1.3μm wavelength band aligned to the CWDM grid;
- optical receiver with 4-channel PIN photodetector;
- low power consumption of 12W (key to lowering operating expense);
- operating case temperature of 0–70°C; and
- hot Z-pluggable to 76-pad QSFP-DD electrical connector so that transceivers can be installed or removed without affecting the rest of the network (enabling a 'pay as you grow' model for 400G capacity increases).

The 100G PAM4 EMLs are fully qualified and in volume production. Oclaro will ship initial samples of the 400G QSFP56-DD FR4 in fourth-quarter 2018, with volume production planned for Q2/2019.

www.ecocexhibition.com
www.oclaro.com

Emcore raises quarterly revenue guidance from $21–$23m to $24.2–25.2m

Higher-than-expected revenue driven by increased L-EML sales and higher Navigation product shipments

Emcore Corp of Alhambra, CA, USA — which provides indium phosphide -based optical chips, components, subsystems and systems for the broadband and specialty fiber-optics markets — has reported preliminary revenue for fiscal fourth-quarter 2018 (to end September) of $24.2–25.2m, up on prior guidance of $21–$23m.

Principal factors contributing to the higher-than-expected revenue include:

- higher L-EML (linear externally modulated laser) transmitter sales;
- completion of a long-term agreement with a major defense prime contractor (resulting in higher Navigation product shipments).

"We saw a sharper rebound in CATV sales during the quarter than anticipated along with strength in our Navigation business," says president & CEO Jeffrey Rittichier. "We shipped record volumes of L-EML transmitters in Q4, including production shipments of all of the L-EML design wins that we recently announced," he adds.

Preliminary results are based on the most current information available following an initial review of operations for the quarter, and remain subject to completion of Emcore's customary closing procedures, including external auditor review.

www.emcore.com

First Solar's 58MW Cove Mountain Solar Project to support Facebook's Prineville Data Center via power purchase agreement with PacifiCorp

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA is to develop and build the 58MW$_{AC}$ Cove Mountain Solar Project near Enterprise, Utah (comprising Series 6 thin-film modules mounted on single-axis trackers), which — through a power purchase agreement (PPA) with PacifiCorp — will support Facebook's Prineville Data Center in Oregon. The agreement is part of a larger deal structure that will support the data center with 100% renewable energy.

"This is an exciting example of how utilities and corporations are collaborating to achieve economic benefits for their stakeholders and also advance renewable energy objectives," says Eran Mahrer, First Solar's vice president of markets, origination & government affairs. "We are proud to offer First Solar's project development expertise to help enable this strategic relationship between PacifiCorp and Facebook," he adds.

"We appreciate First Solar's efforts to help us provide solar energy on the same grid as our data center," comments Facebook's energy strategy manager Peter Freed.

As clean, renewable solar energy has become one of the cheapest sources of new energy generation available in the USA, companies like Facebook are able to meet their environmental commitments while making smart economic decisions, says Karl Brutsaert, First Solar's senior director of corporate renewables. "First Solar has been on the leading edge of this trend, and we are well-positioned to work with corporations globally as they develop smart renewable energy strategies that leverage efficient and reliable large-scale offsite generation facilities," he believes.

This is an exciting example of how utilities and corporations are collaborating to achieve economic benefits for their stakeholders and also advance renewable energy objectives

"This project exemplifies an exciting opportunity for solar development to support economic development in both rural Utah and Oregon," comments Kathryn Arbeit, First Solar's VP of project development. "As a US manufacturer, we are thrilled to facilitate this type of regional development, which helps create good-paying construction and manufacturing jobs," he adds.

First Solar expects to begin construction on the project in late 2019, and estimates an average of about 200 construction jobs with potential peak construction jobs of nearly 500. Commissioning is expected in late 2020. First Solar Energy Services expects to provide Operations & Maintenance services when the project is commissioned.

www.firstsolar.com

First Solar sells 100MW Willow Springs project to DESRI

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA says that its 100MW$_{AC}$ Willow Springs Solar Project in Kern County, California, has been acquired by an affiliate of D. E. Shaw Renewable Investments LLC (DESRI), which acquires, owns and manages long-term contracted renewable energy assets in North America.

Currently under construction (for completion at the end of 2018), the project will supply power to Southern California Edison Company through a long-term Renewable Power Purchase and Sale Agreement.

When in operation, the plant is expected to annually provide enough electricity to power about 41,000 typical California homes and displace more than 77,000 metric tons of CO_2 greenhouse-gas emissions each year (equivalent to taking almost 15,000 cars off the road).

"This project is a testament to the strong partnership that our firms have built over many years," comments DESRI's CEO Bryan Martin. "We are looking forward to using First Solar's leading Series 6 module technology to deliver clean energy to the Kern County community for years to come," he adds.

"We are grateful for the opportunity to build on our strong relationship with DESRI as they grow their solar portfolio," says First Solar's chief commercial officer Georges Antoun.

Antoun also notes the importance of the positive business environment provided by Kern County as a factor in realizing the benefits of solar as a fundamental power generation source.

Willow Springs is the fourth renewable energy project that DESRI has acquired from First Solar. In 2017 a DESRI affiliate acquired the 40MWac Cuyama Solar Project in Santa Barbara County, and in 2016 DESRI affiliates acquired the 31MWac Portal Ridge Solar Project in Los Angeles County and the 11MWac Rancho Seco Solar Project in Sacramento County.

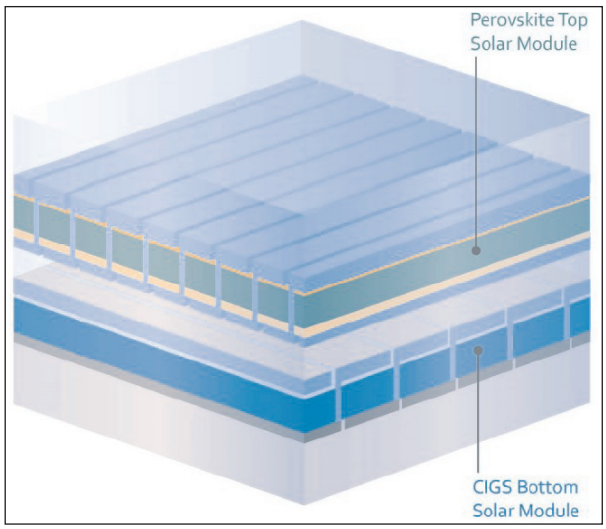
www.deshaw.com
www.firstsolar.com

Imec combines different solar cells to target efficiencies above 30%

Nanoelectronics research centre imec of Leuven, Belgium has unveiled its new tandem solar cell technologies, paving the way to higher cell efficiencies of photovoltaic (PV) panels on roofs as well as on vehicles or building-integrated photovoltaic (BIPV) applications such as solar cells in windows or facades.

Tandem cells combine two types of solar cells applied on top of each other. Because each cell uses a different part of the sunlight spectrum, very high efficiencies beyond 30% can be achieved.

In its tandem cells, imec combines copper indium gallium selenide (CIGS) or silicon solar cells with perovskite, a material that enables thin, transparent and cheap solar cells. As perovskite solar cells utilize the visible part of the light spectrum, they are suitable for combining with CIGS or silicon solar cells, which utilize more the near-IR light portion of the spectrum instead. Tandem cells are therefore able to convert sunlight more efficiently.



Imec's perovskite/silicon cell combines its 0.13cm^2 perovskite cell, developed within the Solliance collaboration, with a 4cm^2 silicon solar cell. The tandem cell achieves a conversion efficiency of 27.1%, which is higher than the best silicon solar cell (26.6%). Imec's perovskite/CIGS cell combines the 0.13cm^2 perovskite cell with a 3.8cm^2 CIGS module developed by ZSW (Zentrum für Sonnenenergie- und Wasserstoff-Forschung — or Center for Solar Energy and Hydrogen Research — Baden-Württemberg) in Stuttgart, Germany. This tandem cell achieves 24.6% efficiency, which is also higher than the leading CIGS solar cells (22.9%).

"According to the International Technology Roadmap for PV (ITRPV), tandem solar cells are expected to appear in the market in 2021," says Tom Aernouts, group leader thin-film PV at imec/Energyville. "At imec, we work on perovskite/silicon as well as on perovskite/CIGS tandems because each technology is directed towards different applications," he adds. "For instance, silicon solar cells are especially suited for roofs and in solar cell parks, while CIGS thin-film solar cells can be produced on foils that could, in the future, be applied for building-integrated PV, turning facades and windows into electricity producers."

www.zsw-bw.de
www.imec.be

Midsummer named one of Sweden's fastest-growing firms

Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines as well as flexible, lightweight copper indium gallium diselenide (CIGS) thin-film solar panels for building-integrated photovoltaics (BIPV) — has been named as one of Sweden's 50 fastest-growing technology companies in 2018, according to Deloitte's Technology Sweden Fast 50.

Audit and consulting firm Deloitte lists the 50 fastest-growing technology companies in Sweden each year. Midsummer topped the Fast 50 list in 2012, when it was also named the fastest-growing cleantech company in the EMEA (Europe, Middle East, Africa) region.

The Fast 50 is based on criteria such as rapid growth, ownership of patented technology, major investments in technology research, and certain minimum levels of revenue and the number of years during which the business has been operating.

Also, Sweden's biggest daily financial newspaper Dagens Industri has included Midsummer in its 2018 list of 'Gasells' (Gazelles) for being one of Sweden's fastest-growing companies. To be appointed a Gasell company, the firm must meet certain financial and growth criteria. Also, the Gazelle jury does an overall valuation of the company and weighs in additional parameters that indicate a healthy business.

The exact ranking on each of the two lists are only disclosed by the organizers later this autumn.

"Being included on these prestigious lists shows that our investment in research and development is on the right track," says CEO Sven Lindström. "Our goal is for our technology to remain market leading in the segment of lightweight, flexible solar panels, and for the company to grow at least as fast at the entire rapidly expanding segment."

Midsummer claims that its DUO system is the world's most widely distributed manufacturing tool for flexible CIGS solar cells.

www.deloitte.com

Bragg reflector structures combined within graded buffer for lower-cost, higher-efficiency multi-junction solar cells

Thin, high-reflectivity GBBR structure may also be useful in VCSELs.

The US National Renewable Energy Laboratory (NREL) of Golden, CO, USA has combined two structures of III–V materials into one to provide significant cost savings. The combination has already enabled novel, potentially record-setting, multi-junction solar cells, consisting of several thin subcells of absorbing materials with differing physical, electrical and optical characteristics stacked atop each other (to generate electricity more efficiently than single-junction devices such as silicon solar cells).

The two structures — a graded buffer and a Bragg reflector — are both already used independently in solar cells and lasers. Integrating them into one, dual-purpose structure allows devices to gain functionality without extra cost, but it requires some design work.

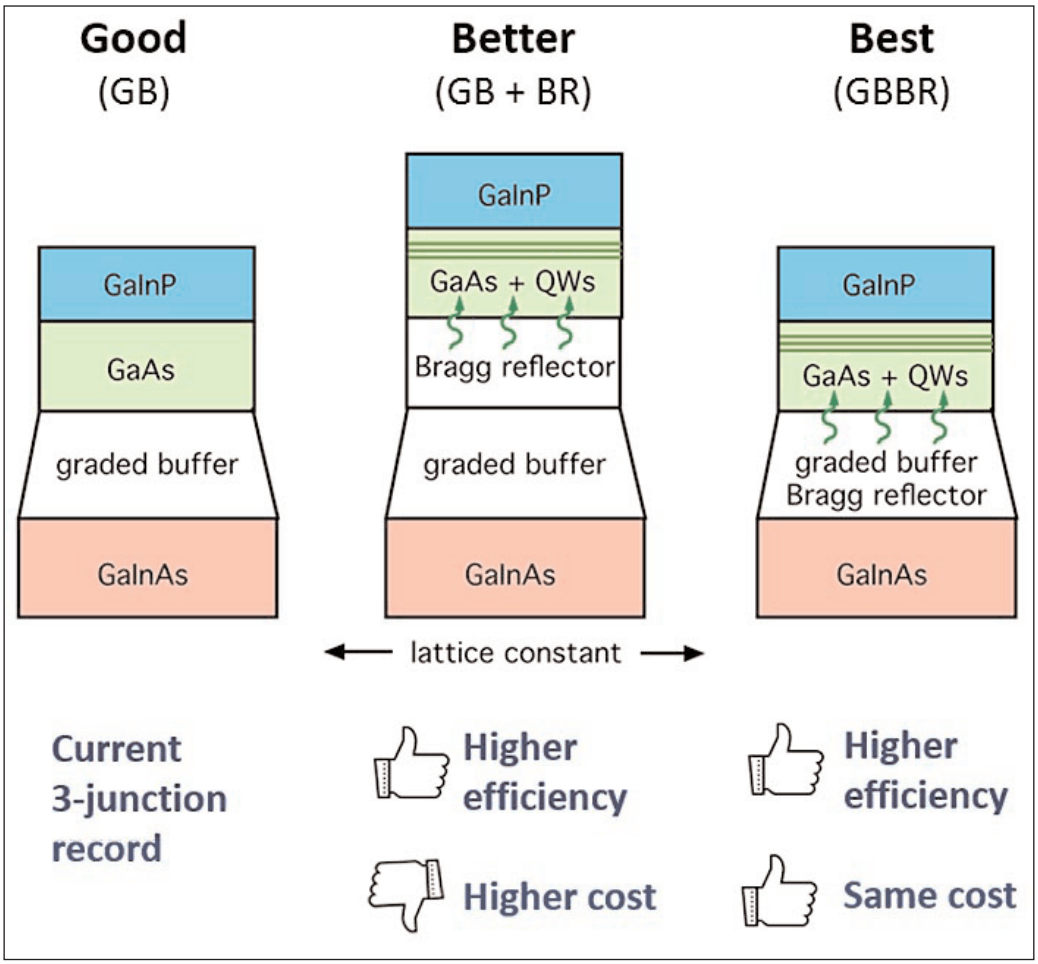


Figure 1. The graded buffer Bragg reflector (GBBR), which combines two complex structures (GB and BR) into one thinner unit, enabling novel multi-junction devices that may surpass existing efficiency records with similar cost.

Better designs through innovation

Graded buffers (GBs) are used to match up different-sized crystal lattice constants within a III–V device, which allows designers to access materials with a whole host of diverse properties, such as a material's bandgap — determining the wavelength of light emitted by a light-emitting diode (LED) or laser and the wavelengths most efficiently absorbed by solar cells and detectors. Integrating materials with different lattice constants and bandgaps into a single III–V multi-junction solar cell has enabled many previous record devices, such as a three-junction inverted metamorphic device with 37.9% efficiency under the 1-sun global spectrum (shown in the left side of Figure 1).

Bragg reflectors (BRs) allow selected wavelengths of light to be reflected and are commonly used in laser devices to create an optical cavity. In multi-junction solar cells, Bragg reflectors reflect light back into an adjacent subcell, which is particularly useful for materials that do not fully absorb the incoming light, such as

very thin subcells or thin quantum-well layers (absorbing layers with a low bandgap). In theory, higher efficiency is possible with the structure in Figure 1 (middle figure), involving quantum wells to lower the middle-cell bandgap, a BR to increase absorption, and a GB to access lattice-mismatched GaInAs. However, both BRs and GBs are relatively thick layers of the device and are expensive to make. So, these structures come with the drawback of additional cost.

In recent work, Ryan M. France, Harvey Guthrey, Myles A. Steiner and John F. Geisz of NREL; Pilar Espinet-González of Applied Physics and Materials Science, California Institute of Technology (Caltech); and Nicholas J. Ekins-Daukes of the School of Photovoltaic & Renewable Energy Engineering, University of New South Wales (UNSW) in Australia, combined a GB and BR into one structure — a graded-buffer Bragg reflector (GBBR). The GBBR is thinner than an independent GB and BR and enables a multi-junction structure with higher potential efficiency than the existing record device, but without an increase in cost (shown in the right side of Figure 1).

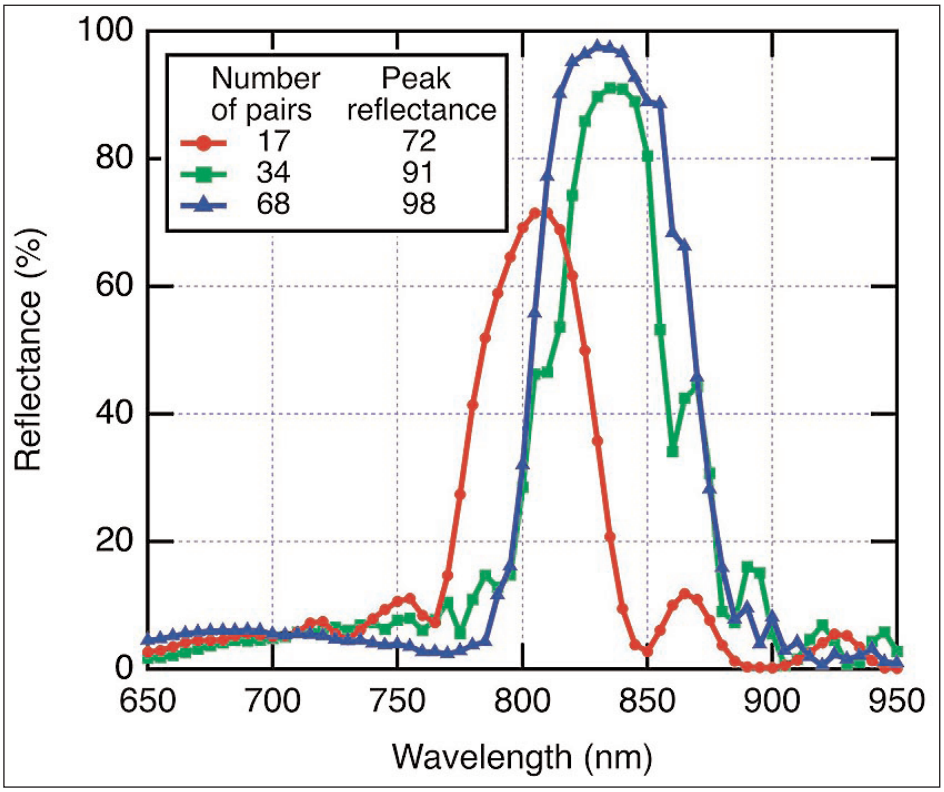


Figure 2. Reflectance from three graded buffer Bragg reflectors with a varied number of contrasting refractive-index pairs.

"III–V materials have been studied and used for solar purposes for a long time—for at least 50 years. So as a materials scientist, I'm excited that we are still innovating new III–V materials and concepts that enable novel device structures," says NREL's Ryan France, lead author of 'Multijunction Solar Cells with Graded Buffer Bragg Reflectors' (IEEE Journal of Photovoltaics; DOI: 10.1109/JPHOTOV.2018.2869550).

The team studied the performance of the GBBR and integrated it into this novel multi-junction structure. Initial three-junction devices already achieve 36.5% efficiency under the AM1.5 global spectrum and 32.4% efficiency under the AM0 space spectrum, which is one of the highest reported efficiencies for a three-junction device under the 1-sun AM0 spectrum.

"Our upcoming plans use a similar device to target the development of a three-junction cell that will reach 40% power conversion efficiency under the global spectrum — which is about 2% absolute better than the current record efficiency," says co-author Myles Steiner.

Branching into other applications

Over its more than 40-year history, NREL has amassed experience in designing, fabricating, characterizing and testing III–V multi-junction solar cells. Applying this new GBBR to such solar cells has been a natural strategy.

But, as often happens, innovations in one field can directly benefit other fields. GBs access materials with a variety of bandgaps, enabling LEDs and lasers with a variety of emission wavelengths. Using a GBBR instead of a GB adds a reflector directly behind an LED or laser, which could enhance the power output or reduce the cost of these emitting devices.

In their study targeting multi-junction solar cells, the team developed a GBBR with 98% reflectance by increasing the refractive-index contrasting pairs, which provide the reflection in a BR (shown in Figure 2). This reflectance may also be useful in vertical-cavity surface-emitting lasers (VCSELs), where it is difficult to place a metal reflector next to the optical cavity. BRs in these laser structures currently provide super-high-reflectivity (99.9%) alternatives to metals, and the GBBR may be useful in longer-wavelength metamorphic lasers if such a high reflectivity can be achieved.

In other solar-related applications, GBs and BRs are being considered as a means to mitigate radiation damage on solar devices in outer space. The advances by NREL, UNSW and Caltech in combining GB and BR functions into a GBBR will therefore likely be of interest for enhancing the operational performance of space solar cells. Currently, NREL has a patent pending on the GBBR technology and hopes to make the technology available for licensing in the near future. ■

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Argon-ion-enhanced room-temperature bonding with low resistance

Researchers bond gallium arsenide to silicon and gallium nitride, giving an ohmic junction.

A research team based in Japan and China has been developing room-temperature bonding enabled by argon ion exposure of gallium arsenide (GaAs) and silicon (Si) along with gallium arsenide and gallium nitride (GaN) [Yoshiaki Ajima et al, Appl. Phys. Express, vol11, p106501, 2018].

The scientists from Chiba Institute of Technology in Japan and Suzhou Institute of Nano-tech and Nano-bionics (SINANO) in China were particularly keen to produce bonds with low resistance. The GaN//GaAs bond achieved an interface resistance of 2.7Ω-cm^2 — "the first reported instance of a bonded GaN//GaAs wafer with a low electrical resistance," according to the researchers.

The team sees applications for "artificial photosynthesis", using III–V materials to generate hydrogen and oxygen, while decomposing carbon dioxide. The decomposition of greenhouse gases and generation of energy-rich molecules has obvious economic and environmental benefits. Panasonic has demonstrated the use of GaN/pn-Si and InGaN/pn-Si multi-junction structures with potassium bicarbonate electrolyte, giving almost 1% solar energy conversion efficiency, much higher than the 0.2% of biological photosynthesis. The GaN or InGaN materials were not bonded to the pn-Si, but rather there was an airgap and the connection was via wires.

The Chiba/SINANO group hopes that their low-resistance bonded materials could help towards better efficiency. In particular, the room-temperature process avoids problems from thermal expansion mismatches between the materials. At the same time, bonding rather than epitaxial processing also avoids the defects introduced by lattice-constant mismatching.

Direct bonding of p-GaAs with n-Si was first compared with bonding through sputtered indium tin oxide (ITO) interlayers on both samples. The surfaces of the

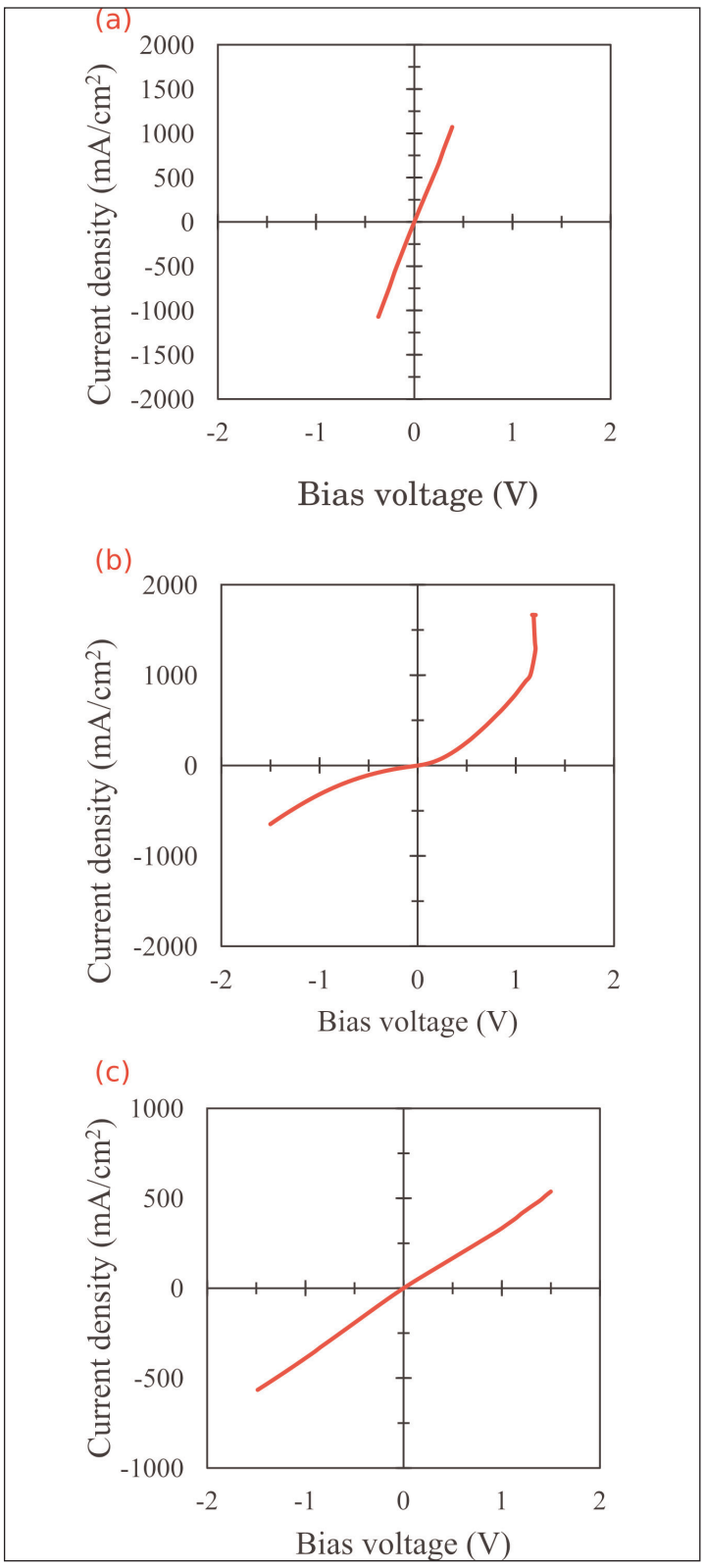

Figure 1. Current-voltage characteristics of (a) p-GaAs//n-Si; (b) p-GaAs/ITO//ITO/n-Si; and (c) p-GaAs//n-GaN bonded materials.

directly bonded samples were prepared with alkaline and hydrochloric acid cleaning processes. The metal contacts for electrical testing were applied before bonding: unannealed titanium/platinum/gold for the p-GaAs, and annealed titanium/platinum/silver for the n-Si.

Also, the researchers bonded n-GaN with p-GaAs. The p-GaAs had the same preparation and metal electrodes as above. The n-GaN had an annealed titanium/aluminium electrode.

The bonding was carried out in a chamber from Mitsubishi Heavy Industries Machine Tool capable of containing vacuums less than 10^{-5}Pa. The room-temperature bonding was enabled with exposure to argon ions with kinetic energies in the range 60–80eV and a bonding force of 20MPa.

The directly bonded p-GaAs//n-Si junction exhibited an ohmic-like current–voltage (I–V) characteristic, in contrast with the Schottky junction behavior of the p-GaAs/ITO//ITO/n-Si bond (Figure 1).

The interface resistance of the p-GaAs//n-Si sample was estimated to be 0.32Ω-cm^2. Although a lower 0.079Ω-cm^2 resistance has been achieved with bonding of n-GaAs on ITO/p-Si (n-GaAs//ITO/Si), the structure is seen as being unsuitable for photovoltaic applications due to the refractive index difference between ITO and silicon leading to the reflection of incoming radiation, reducing the absorption of light in silicon subcells.

The team comments: "The interface resistance for the p-GaAs//n-Si sample without ITO was low enough for the unit to operate under relatively low irradiation conditions, ranging from 1 to 5 suns. Furthermore, this configuration should reduce the degree of interface light reflection."

The n-GaN//p-GaAs bonded interface also demonstrated ohmic behavior with a resistance of 2.7Ω-cm^2. The team claims this is "the first report of a conductive GaN//GaAs bond with linear I–V characteristics".

The researchers also investigated the high resistance of n-GaN//p-GaAs relative to the p-GaAs//n-Si bond. They found increased levels of iron and chromium from the chamber walls incorporated into the interface, as detected by energy-dispersive x-ray (EDX) analysis. This was attributed to the low-energy argon ion treatment. Iron doping is used to create semi-insulating GaN. There was also an increased oxygen EDX signal, presumably due to surface oxidation.

Transmission electron microscopy (TEM) revealed a 2–5nm amorphous layer between the materials. The high resistance, it is suggested, is due to the large difference in bandgap between GaN (3.39eV) and Si (1.42eV). Using narrower-bandgap InGaN as an interlayer could reduce the interface resistance, the team believes. ■

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Author: Mike Cooke

Mid-to-long wavelength IR emitters and detectors

Mike Cooke reports on attempts to improve quantum cascade emission and van der Waals semiconductor detection of MWIR and LWIR wavelengths.

The creation and detection of longer-wavelength infrared is challenging due to thermal effects. The mid-wavelength infrared (MWIR, 3–8μm) region corresponds to black-body temperatures of the order 362–966K, i.e. from 89°C up to 693°C. This range is useful for detecting jet engine exhausts in missile guidance systems, for example, since there is an atmospheric window for this range of wavelengths with relatively low absorption.

The long-wavelength infrared range (LWIR, 8–15μm) can be used for thermal imaging with black-body temperatures of the order 193–362K (–80°C–+89°C) covering the normal range that humans expect to encounter and more.

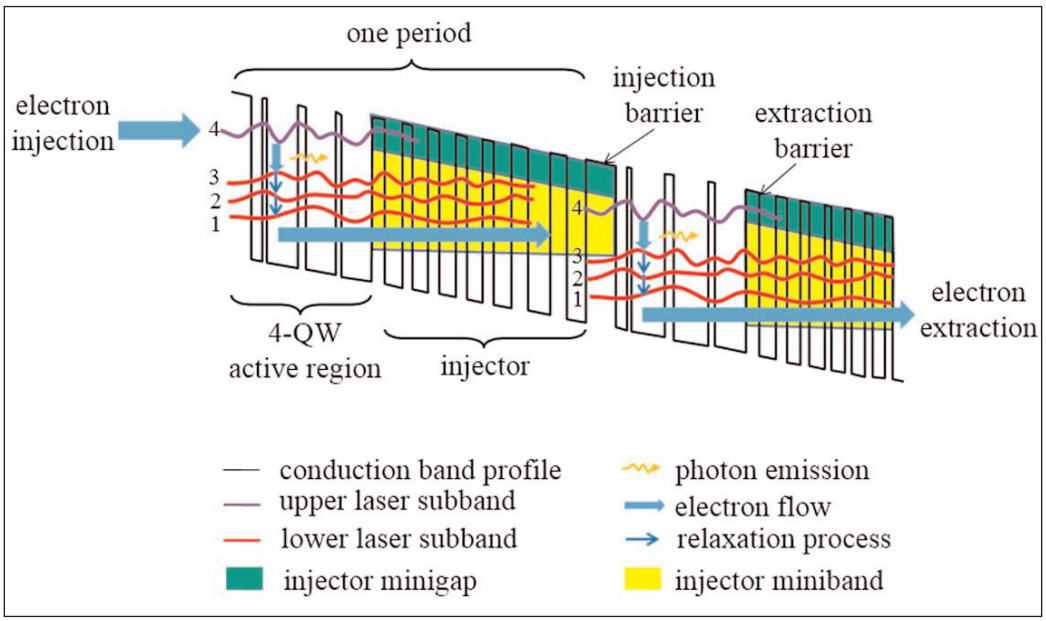

Figure 1. Band structure of four-QW coupling and two-phonon-resonance-based QC energy level.

Of course, if the equipment is expected to operate at 'room temperature', there will be problems separating useful signals from background noise. Usually this is accomplished by cooling the equipment relative to the surroundings. Alternatively one can reduce the relative importance of ambient noise by using additional appropriate illumination.

Here we look at some recent research in improving semiconductor-based mid-to-long wavelength infrared illumination and detection.

Quantum cascade superluminescent arrays

Researchers based in China have developed ~5μm-wavelength mid-infrared quantum cascade superluminescent emitters (QCSLE), in single and array formats [Jialin Sun et al, Optics Letters, vol43, p5150, 2018]. The team from Suzhou Institute of Nano-Tech and Nano-Bionics (SINANO), Institute of Semiconductors, and University of Science and Technology of China, sees potential for biomedical imaging, security inspection and gas detection from using QCSLEs as broadband light sources.

A particular application could be optical coherence tomography (OCT), which is widely used for human tissue imaging. In the near-infrared (NIR) such techniques have achieved high resolution in a non-invasive, non-contact manner. The team comments: "It is noteworthy that most biological tissues absorb much more photons within the mid-infrared (MIR) spectral range compared to the NIR range, indicating that a MIR-OCT could contain strong overtone and combination vibrational absorption bands of the spectral response to molecular species."

The paper reports "for the first time, to the best of our knowledge" a compact light-emitter array with a very high room-temperature continuous wave (RT-CW) light output power of 2.4mW. Such RT-CW operation is seen as a crucial requirement for MIR-OCT.

Superluminescent devices use amplified spontaneous emission to give high-power, low-coherence light. SLEs use a single-pass structure so spontaneous photons are amplified, but lasing does not occur. To ensure single-pass behavior, it is necessary that the waveguide structure transmits light out, rather than the photons being trapped in multiple reflections, as in lasers.

The active layers of the QC structure were grown by solid-source molecular beam epitaxy (SS-MBE) on indium phosphide. The active region of the cascade

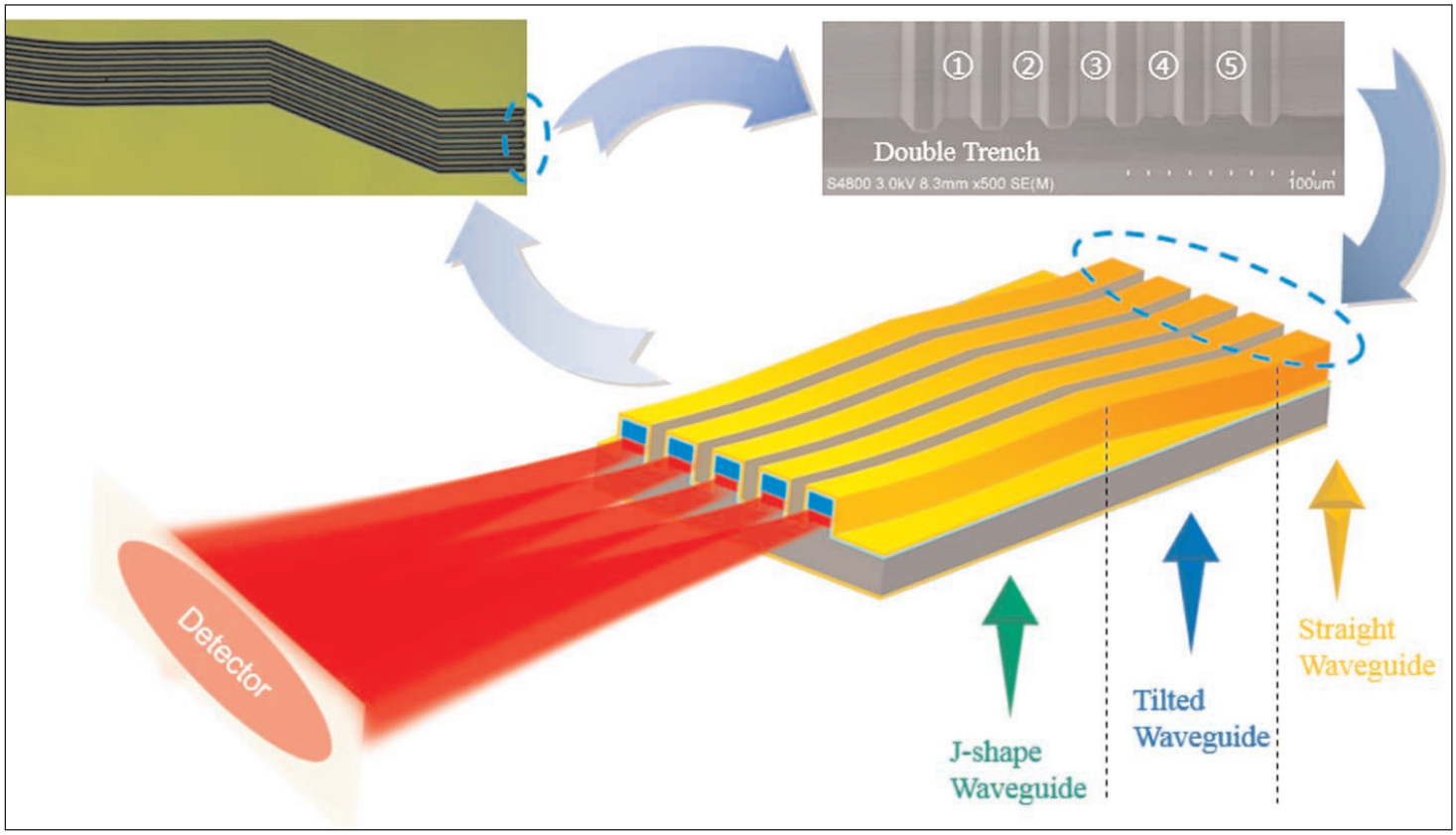

Figure 2. Bottom: schematic diagram of array device. Top-left: microscope image of 5-array. Top-right: corresponding scanning electron microscope image of rear end.

section (Figure 1) was four coupled strain-compensated quantum wells (QWs) of indium gallium arsenide in indium aluminium arsenide ($In_{0.678}Ga_{0.322}As/In_{0.365}Al_{0.635}As$). The structure used a two-phonon resonance structure to improve depopulation of the lower state, enabling increased amplification from stimulated emission. At the same time, the four wells enhanced spontaneous emission. The device material consisted of 30 repetitions of the cascade section design separated by low-doped n-InGaAs. The target emission wavelength was ~5μm.

The material was fabricated into double-trench narrow-ridge 'W'-shaped waveguide structures 7μm deep. The ridge width was 10μm and the trench widths were 20μm. Plasma-enhanced chemical vapor deposition (PECVD) silicon dioxide, 200nm thick, was used as insulation. Contact windows, 3μm wide, were etched in a reactive-ion process. The top contact metals were titanium/gold. The bottom contact consisted of germanium/gold/nickel/gold. The devices were mounted epitaxial-side down on copper heat-sinks.

The waveguide was shaped with a 1mm-long tilted section connected to 0.5mm-long straight and 2mm-long 'J' sections (Figure 2, SLE 1). The researchers comment: "This design can create two mutations of refractive index in the waveguide to achieve a rather low reflectivity with a fairly small geometry, and hence provide an opportunity to fabricate array devices."

Two further devices (SLE 2 and SLE 3) were produced giving a shorter 'J' section of 1.5mm. This reduced the angle between the tangent to the end of the 'J'-section and the output facet normal from 9° to 4°. One of these latter devices also included a high-reflection coating on the rear facet (SLE 3).

The maximum output powers for three different structures were 1.6mW (at 1.75A, SLE 1), 2.2mW (at 1.85A, SLE 2) and 3mW (at 1.9A, SLE 3). The slope efficiency of SLE 3 was 0.0028W/A, about twice that of SLE 1.

Compact SLE arrays with up to 7 devices were based on the SLE 3 structure. The arrays were characterized in 'quasi-continuous wave' mode — 5μs pulses with 20kHz repetition (10% duty cycle) — at room temperature. The best performances were delivered by 3-SLE and 5-SLE arrays: 8.5mW output at 5.5A and 12mW output at 7A, respectively. The 7-array suffered from "excess thermal generation and low current density". The turn-on voltage of the 7-array was ~12V, compared with ~9V for a single SLE 3 device.

Continuous-wave operation of the 5-array gave an output power of 2.4mW at 3A with 199/cm full-width at half maximum (FWHM) — see Figure 3. The researchers comment: "The high output power can increase the penetrating depth of light, the broad spectral width can enhance the axial resolution of the images, and the high-quality output beam can be effectively coupled into fiber, so the QC array device has been demonstrated as an ideal broadband light source for realizing the MIR-OCT system."

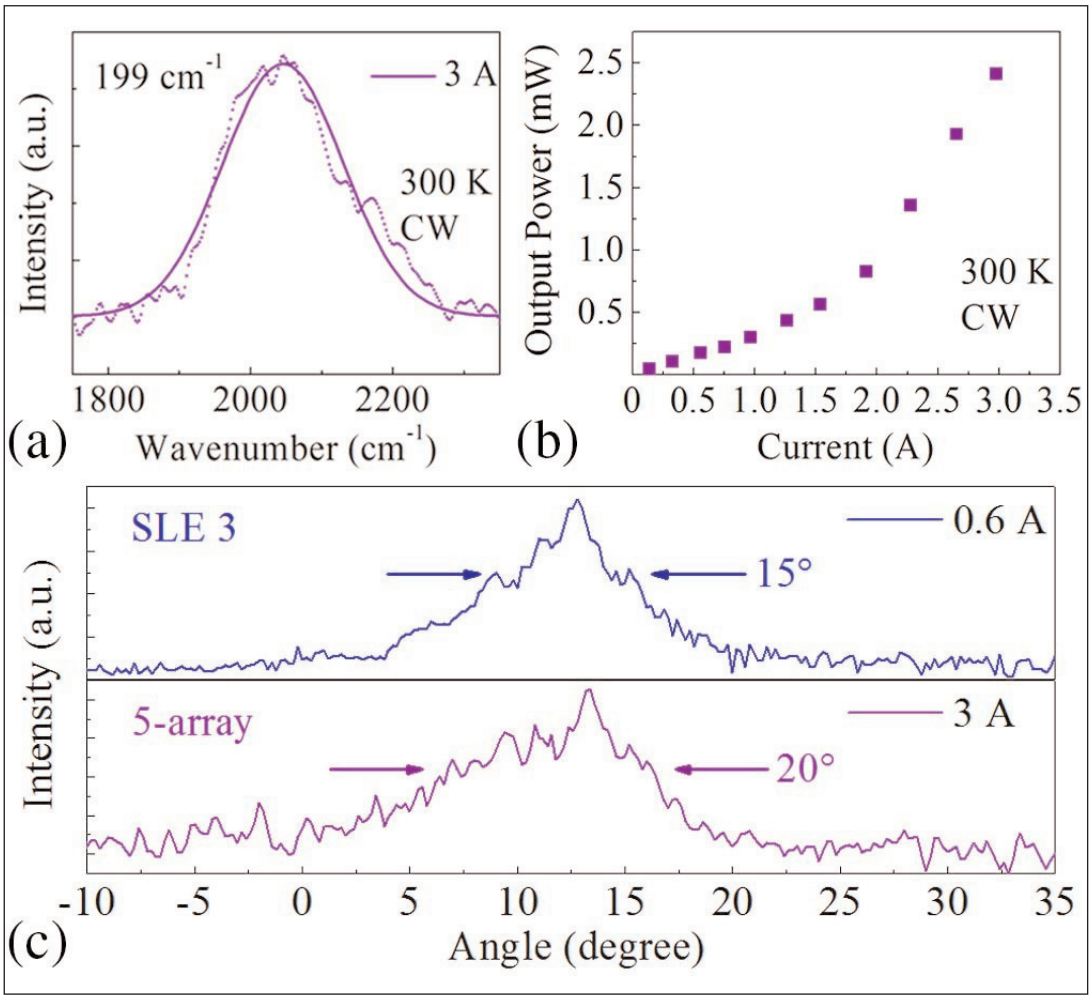

Figure 3. (a) Emission spectrum and (b) light–current curve measured from 5-array under CW mode at 300K. Lines corresponding to Gaussian fitting to spectra. (c) Comparisons between far-field profiles of SLE 3-array and 5-array.

Reorienting quantum cascade lasers

Humboldt University Berlin and Paul-Drude-Institut für Festkörperelektronik in Germany have used (411)A-oriented indium phosphide (InP) to improve the power efficiency, threshold current and slope efficiency of quantum cascade lasers (QCLs) [M. P. Semtsiv et al, Appl. Phys. Lett., vol113, p121110, 2018]. Targeted at 9μm-wavelength emission, the material used combinations of indium gallium arsenide (InGaAs) and indium aluminium arsenide (InAlAs) layers.

The researchers attribute the improvements to reduced interface roughness (IFR) scattering enabled by growth on (411)A material, compared with conventional on-axis (100) substrates. "Reduced IFR scattering results in better inversion, longer upper laser state lifetime, smaller non-radiative recombination, and less leakage current during injection," the team reports.

The improvements are thought to result from the change in average lateral extent of the roughness, rather than the height/amplitude. The lateral extent for the conventional (100) orientation is around 6nm, which gives expect peak expected IFR scattering in devices aimed at 9–20μm-wavelength emission.

The researchers report that, although off-cut substrates like (411)A InP are commonly used to achieve almost atomically flat epitaxial growth fronts, they had not been previously applied in QCL work. The team explains: "The off-cut substrates introduce monolayer-high steps into the growth front, but these steps are more regular than the random monolayer-high islands on the exact (100) surface, and are characterized by a different lateral size Λ. Growth proceeds in the step-flow mode, reducing fluctuations with random lateral extent."

The (411)A orientation is tilted 19.5° relative to the convention (100) surface plane in the [011] direction. The flat surface morphology during epitaxy has typically 1.8nm-long terraces in the [$\bar{1}$22] direction, much shorter than the 6nm 'lateral extent' seen for the (100) orientation. Previous work characterizing such material confirmed improved qualities such as higher electron mobility and a narrower photoluminescence peak.

The epitaxial wafers were produced on InP substrates with conventional (100) and with (411)A surface orientations. The QCL epitaxial structure, based on a design by Hamamatsu Photonics K.K. researchers, was an InGaAs/InAlAs heterosystem lattice-matched to InP, giving a dual-upper-state to multiple-lower-state active regions. The growth temperature was 500°C.

The material was fabricated into lasers with ~30μm-wide ridges. For the (411)A, the ridge was oriented along the [1$\bar{1}$0] crystal direction, allowing cleavage along the perpendicular direction to give mirror facets. The ridge sidewalls were insulated with silicon dioxide. The top and bottom electrodes were annealed chromium/gold and gold-germanium/chromium/gold, respectively. The devices were soldered onto copper-tungsten submounts.

Although the devices operated at room temperature and above, the reported measurements were restricted to the stable 60–280K range of the team's cryostat equipment. The team believes, however, that

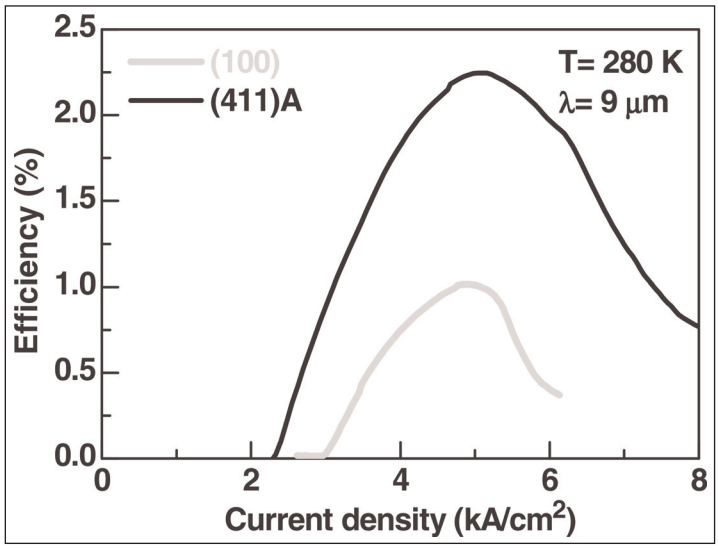

Figure 4. Power (wall plug) efficiency as a function of current density with the same QCL structures grown on (411)A- and (100)-oriented InP. Both lasers were 4mm long. Lasers grown on (411)A and (100) substrates had 24.4μm- and 32.7μm-wide ridges, respectively.

the efficiency improvements enabled by growth on (411)A InP could result in higher maximum operation temperatures.

The (411)A device demonstrated more than twice the maximum 'wall-plug' power efficiency at 280K under 150ns pulsed operation with 10kHz repetition, compared with the reference (100) QCL (Figure 4). The improvement is credited to reduced interface roughness scattering. The threshold currents of the (411)A devices were also lower (Figure 5). However, the lower characteristic temperature for the threshold (T_0) for the (411)A QCL does mean that the threshold does approach that of the conventional (100) laser at higher temperatures. The researchers attribute this to "an increasing influence of phonon scattering".

Above 150K the slope efficiency of the (411)A device was about 50% higher than that of the (100) structure. The saturation of the (411)A QCL's slope efficiency below 150K was probably due to freeze-out of carriers as a result of the low doping used in the design, the researchers suggest. A (411)A QCL with a wider 33.2μm ridge had similar temperature characteristics: 217K for T_0, and 234K for the slope efficiency (T_1).

The researchers suggest that these efficiency improvements could result in higher maximum operation temperatures also for longer-wavelength 'terahertz' long-wavelength and far-infrared devices.

Black phosphorus photodiode

Researchers based in the USA, Taiwan and Australia have improved the performance of mid-wavelength infrared (MWIR, 3–8μm) photodiodes using black

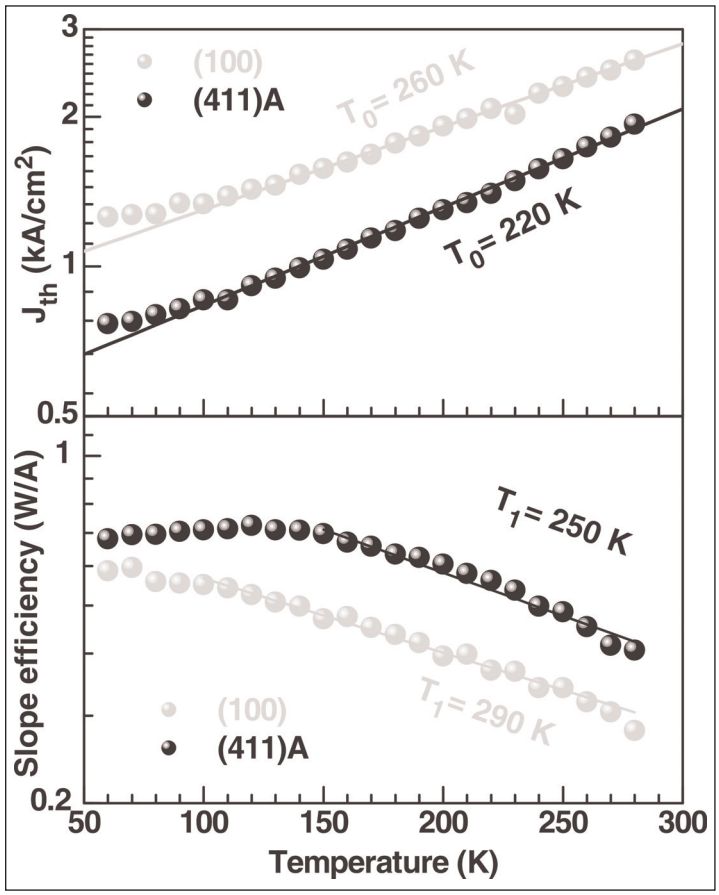

Figure 5. Top: threshold current densities as functions of temperature for QCLs on (411)A and (100) InP. Bottom: slope efficiency functions of temperature. In both panels, bullets are experimental data and lines are simple exponential fits.

phosphorus (bP) as absorbing material and a molybdenum disulfide (MoS_2) electrode [James Bullock et al, Nature Photonics, published online 27 August 2018].

The team from University of California Berkeley and Lawrence Berkeley National Laboratory (LBNL) in the USA, Taiwan's National Tsing Hua University and Australia's University of Melbourne claim that their devices can be competitive with conventional MWIR detectors. Further, the team used the anisotropic optical response of black phosphorus to "demonstrate the first bias-selectable polarization-resolved photodetector that operates without the need for external optics," with potential for astronomy, polarization-division multiplexing and remote sensing.

'Van der Waals' materials such as black phosphorus and MoS_2 have many interesting properties due to their two-dimensional (2D) nature of strong in-plane bonds but weaker between-plane bonds. The Van der Waals forces between planes avoid problems with 'dangling bonds' at the surface that can cause difficulties with devices based on conventional 3D bulk semiconductor materials. The 2D materials can be used to create thin absorbing layers with reduced noise from thermal electron-hole generation-recombination. Bulk

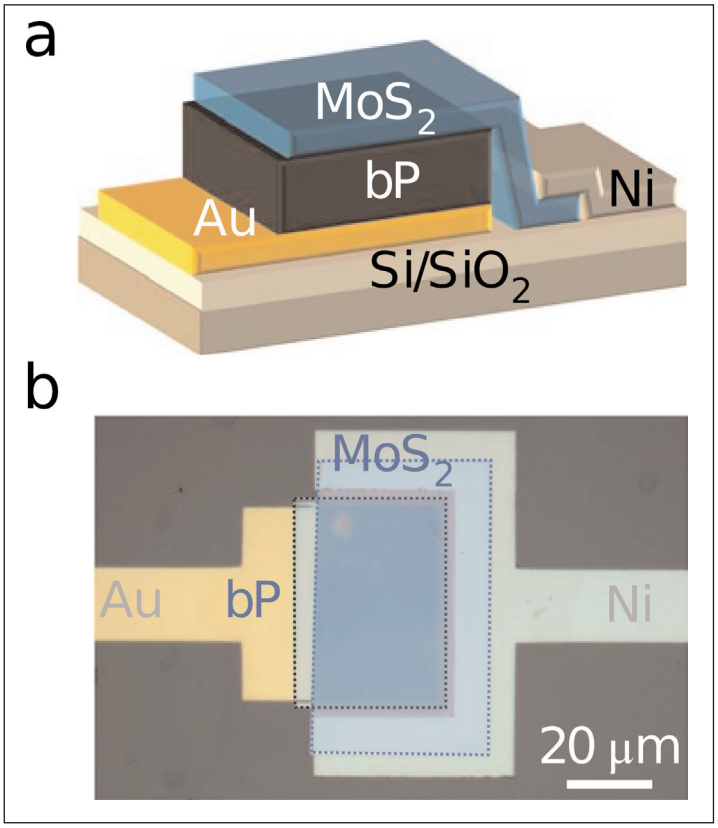

Figure 6. bP/MoS_2 heterojunction photodiode concept. a, Schematic of device configuration, showing the heterojunction and contact configuration. b, Optical micrograph of a completed device; regions containing black phosphorus and MoS_2 are outlined for clarity.

semiconductor layers need to be thicker to reduce the effect of surface recombination at their problematic dangling bonds.

The bandgap of black phosphorus ranges from 1.5eV for monolayers shifting down to 0.3eV as the thickness increases, putting longer and longer wavelengths into the detectable range (~830nm out to ~4.1μm). At the same time, MoS_2 is also a 2D Van der Waals material from the transition-metal dichalcogenide family.

The researchers are looking to MWIR applications in the medical, scientific, communication, automation and surveillance fields. They hope that the use of black phosphorus as absorber could overcome problems with other technologies such as expensive processing and the need for costly active cooling to reduce thermal noise.

The devices consisted of a back pad/reflector of gold, black phosphorus, and a top window/contact of 10–20nm n-type MoS_2 (Figure 6). The band offset between the black phosphorus and n-MoS_2 enables electron flow into the contact material, but blocks holes. The monolayer thicknesses of black phosphorus and MoS_2 were 5.5Å and 6Å, respectively. Electron microscope analysis suggested some amorphous material at the bP/MoS_2 interface, which was attributed

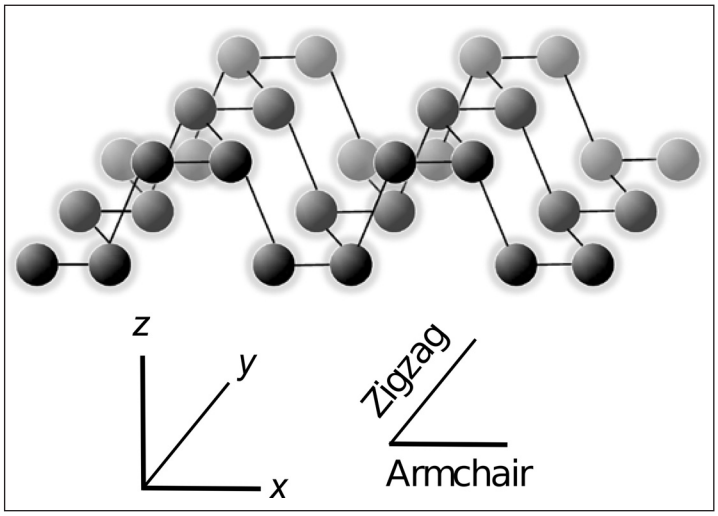

Figure 7. Schematic diagram of black phosphorus crystal structure.

to oxidation of the phosphorus due to air exposure during fabrication. The design of the device was optimized using simulations.

The optimum structure was expected to be 150nm black phosphorus and 15nm MoS_2, giving a predicted ~80% absorption of polarized light at 3μm wavelength. The optimum polarization was along the 'x' or 'armchair' direction of the black phosphorus atomic structure (Figure 7). The moderately thin black phosphorus layer should reduce noise while still permitting high absorption in the narrow MWIR target spectral range.

A fabricated device demonstrated a peak external quantum efficiency (ε_e) between 30% and 35% for radiation wavelengths between 2.5μm and 3.5μm (Figure 8). The researchers comment: "These are the highest ε_e values reported for black phosphorus in this range at room temperature and correspond to current-responsivity values of ~0.9AW^{-1}." Previous work has only managed ee values less than 5% in the near-infrared and short-wavelength infrared regions.

The device design targeted a quarter-wavelength interference peak at just below 3μm. The internal quantum efficiency (ε_i) was estimated to be 40–50%. Moving the polarization of the incident radiation from the x to y ('zig-zag') directions reduced ε_e from more than 30% down to less than 1%. Reducing the operating temperature to 78K increased ε_e to 63% for 3μm infrared.

The detectivity (D*) peaked at 3.8μm with a value of $1.1x10^{10}cmHz^{1/2}/W$, according to an estimate based on the zero-bias resistance area product. Unlike many more established technologies, the device was not biased to improve performance. A measurement based on noise equivalent power measurements under flood illumination from a black-body source (from 100°C up to 400°C) gave a D* value of $7x10^{9}cmHz^{1/2}/W$. The researchers consider the agreement between the two methods to be 'good'.

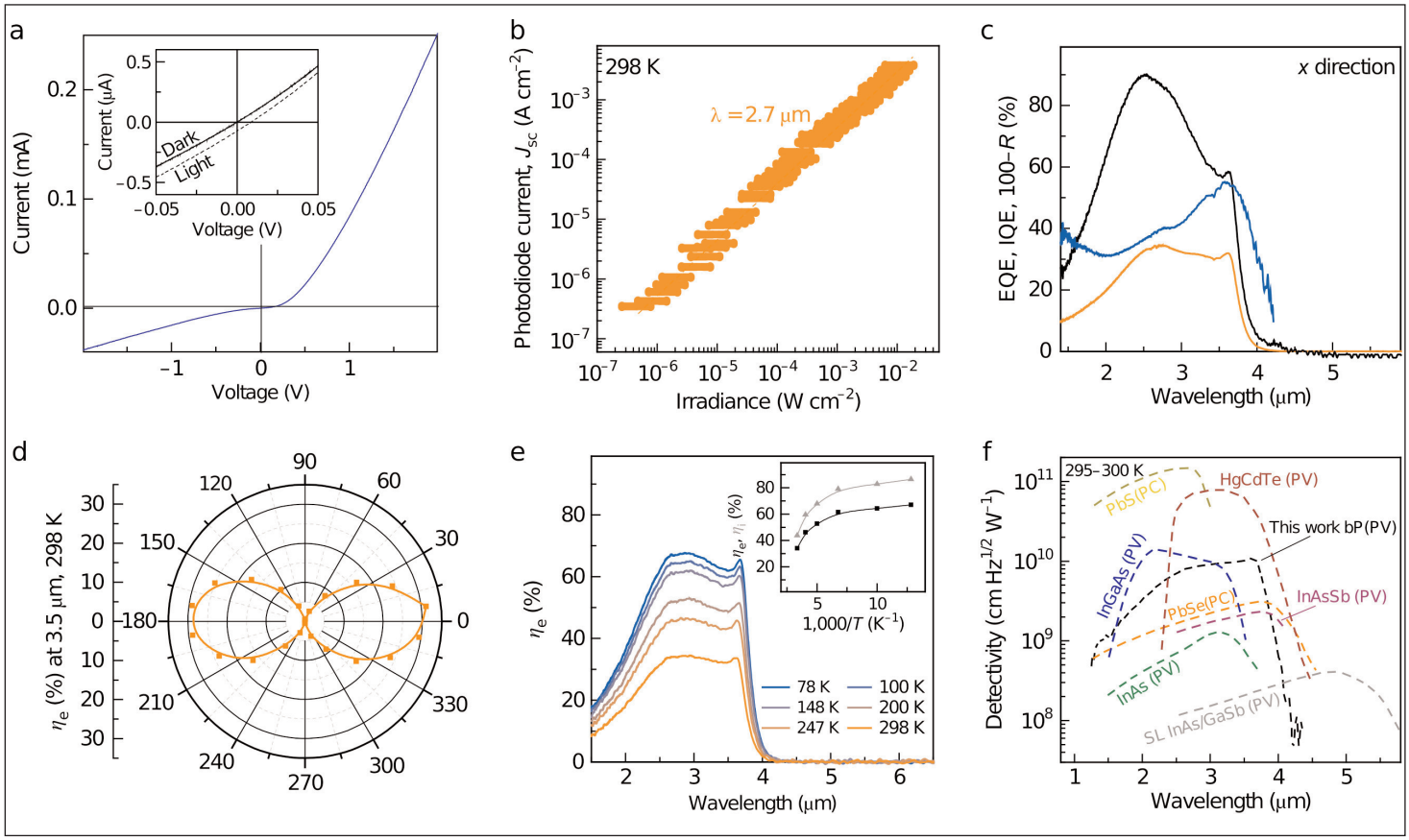

Figure 8. Photoresponse and detectivity characterization performed at zero bias. a, Current–voltage curve with inset measurements in dark and under illumination by 1000K black-body source. b, Measured photocurrent as function of incident illumination intensity with2.7μm laser diode source. Error bars represent uncertainty in spot size. c, Spectrally dependent ε_e, ε_i and 100%-reflectivity (R). d, Variation of ε_e with polarization angle at 3.5μm wavelength. e, Spectral ε_e as a function of temperature with inset ε_e and ε_i variation at 3μm. f, Specific detectivity versus wavelength at room temperature as well as various commercially available and reported MWIR photovoltaic (PV) and photoconductive (PC) detectors.

The rise-time and fall-time responses to 2.7μm infrared were 3.7μs and 4.0μs, respectively, "among the fastest reported for bP-based photoconductors and photodiodes," according to the team. However, commercial devices have faster response, and the researchers hope that improvements could come from reducing the bP bulk trap concentration and eliminating defective interfacial layers with oxidant-free fabrication.

A more complex device was developed for polarization resolution. Two layers of black phosphorus with perpendicular crystal alignments were separated by a MoS_2 electrode (Figure 9). The bottom black phosphorus had a gold contact, while the top black phosphorus layer used a stack of molybdenum oxide and palladium (MoO_x/Pd) to collect holes. The arrangement allowed discrimination between radiation polarized in the two different directions. ■

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

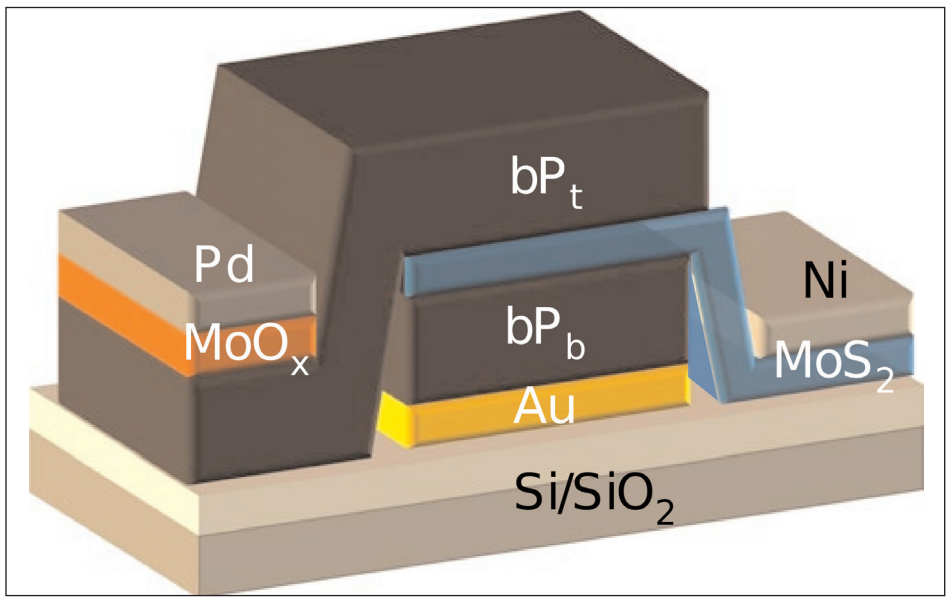


Figure 9. Polarization-resolved bP/MoS_2 heterojunction photodiode.

IR light source market to grow at 29% CAGR from $1.8bn in 2018 to $6.5bn in 2023

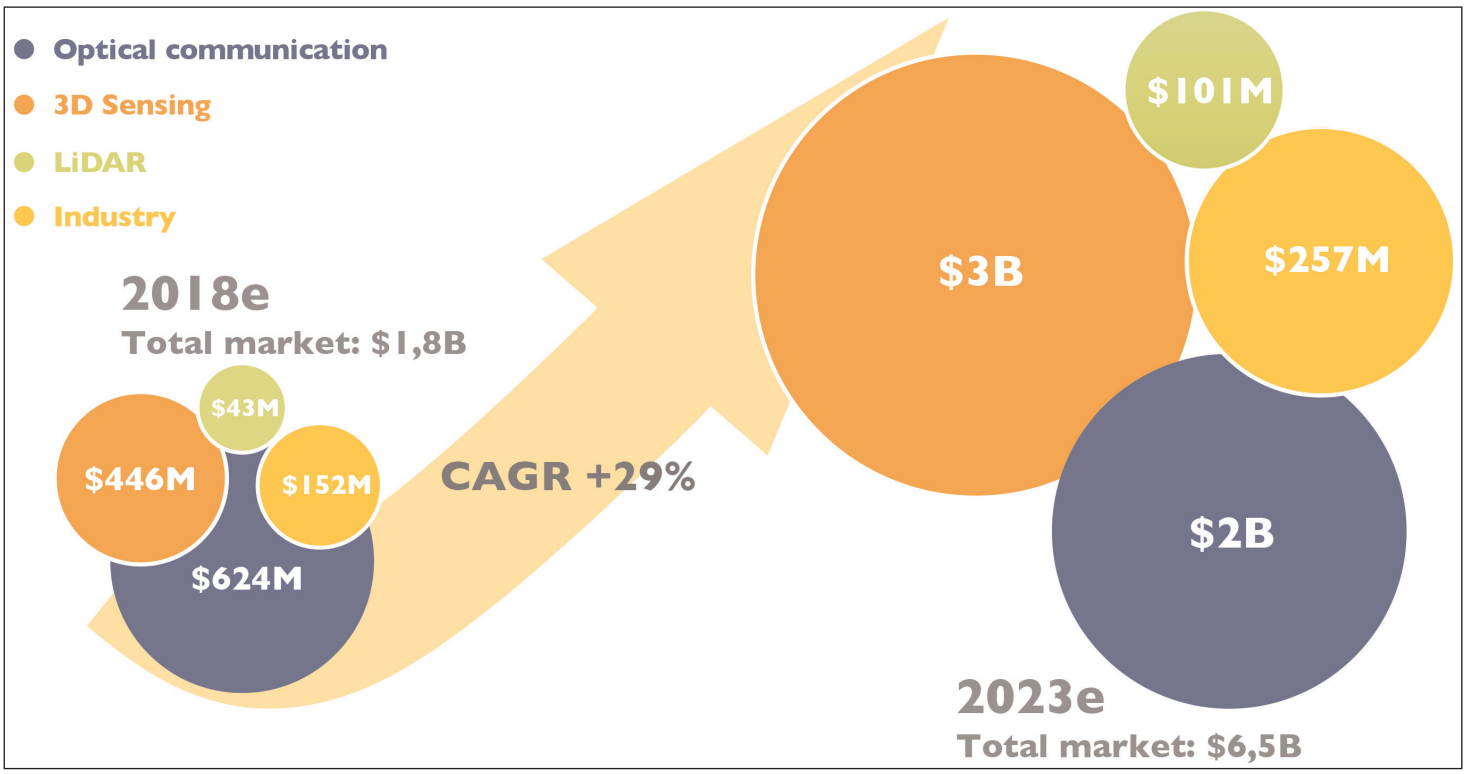
Application proliferation and technology diversity are reshaping the infrared light source industry, says Yole Développement.

The infrared (IR) light source market will rise at a compound annual growth rate (CAGR) of 29% from $1.8bn in 2018 to $6.5bn in 2023, forecasts Yole Développement in 'IR LEDs & Laser Diodes — Technology, Applications, And Industry Trends report'. The development of new and smart functionalities in smartphone, medical and automotive applications as well as the development of breakthrough devices and functions such as wearables and virtual reality are driving growth in the infrared light-emitting diode (LED) and laser diode (LD) industry, the report notes.

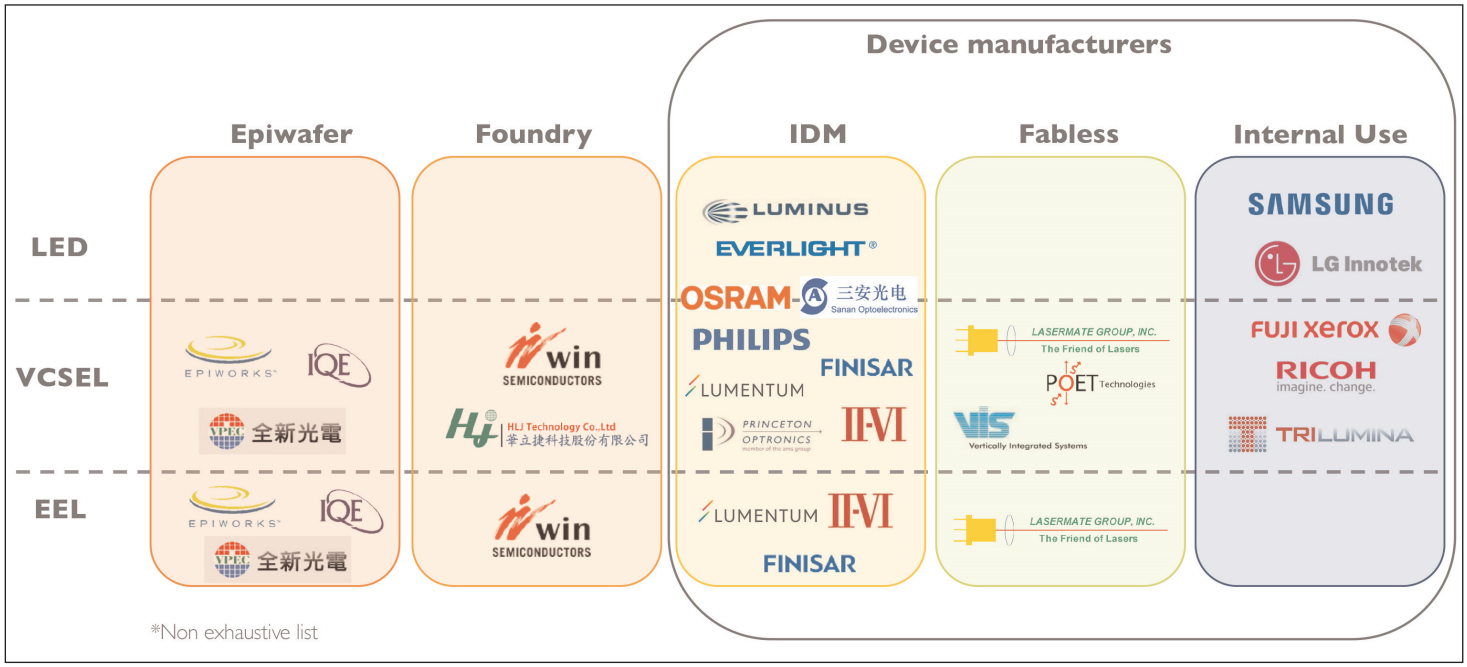
IR light source technologies

Initially developed for optical communication applications, IR LEDs and laser diodes are now integrated into high-value functions for datacom/telecom, industrial, automotive and consumer applications. These technologies are part of a revolution, with each one finding its own path:

- Initially focused on low-end applications (photo-interrupters, remote controls, etc), IR LEDs are now increasingly implemented into smartphones for proximity sensing; automotive for gesture recognition; and VR/AR (virtual reality/augmented reality) headsets for eye tracking.
- For edge-emitting lasers (EELs), the market has historically been driven by optical communication applications. This is likely to continue, given the always-increasing amount of data exchanged with optical fiber networks. However, in the mid-term the technology may also find strong growth relays in new applications, such as. LiDAR. Yole had the opportunity to discuss with Dr Joerg Strauss, head of the Emitter Laser & Sensor Segment at Osram Opto Semiconductors to share their vision of the industry and get a deep understanding of the development of EEL-based solutions: "Within Osram, that EEL laser will continue to be beneficial compared to VCSELs [vertical-cavity



Infrared light source market forecast — by key segment.



2018 infrared lighting players' ecosystem.

surface-emitting lasers] in LiDAR [light detection and ranging] applications," Strauss believes. "The primary reason is the required laser power for LiDAR, which is hard to achieve with a reasonable light emission area by VCSEL technology," he adds.

● Today, vertical cavity surface-emitting lasers might be the fastest-growing technology. Having originally found its sweet spot in short-distance data communication, Apple's 2017 release of the iPhone X (which has a 3D sensing function based on VCSEL technology) has completely changed the business landscape.

Within Osram, that EEL laser will continue to be beneficial compared to VCSELs in LiDAR applications. The primary reason is the required laser power for LiDAR, which is hard to achieve with a reasonable light emission area by VCSEL technology

Each of these infrared SSL sources have different semiconductor structures (i.e. epitaxy, front-end, back-end), emit at different wavelengths/power outputs, and provide different light-emission profiles/shapes, creating a large variety of possible specifications as well as applications.

Different industry structures and maturity levels for LEDs, EELs and VCSELs

Fueled by visible lighting applications, the LED industry is quite mature. Almost all players are vertically integrated, from epitaxy to packaging. More than 40 IR LED suppliers have been established, mostly in Asia. The manufacturing process is well controlled and there are few remaining challenges, except for high-power and long/multi-wavelength IR LED devices.

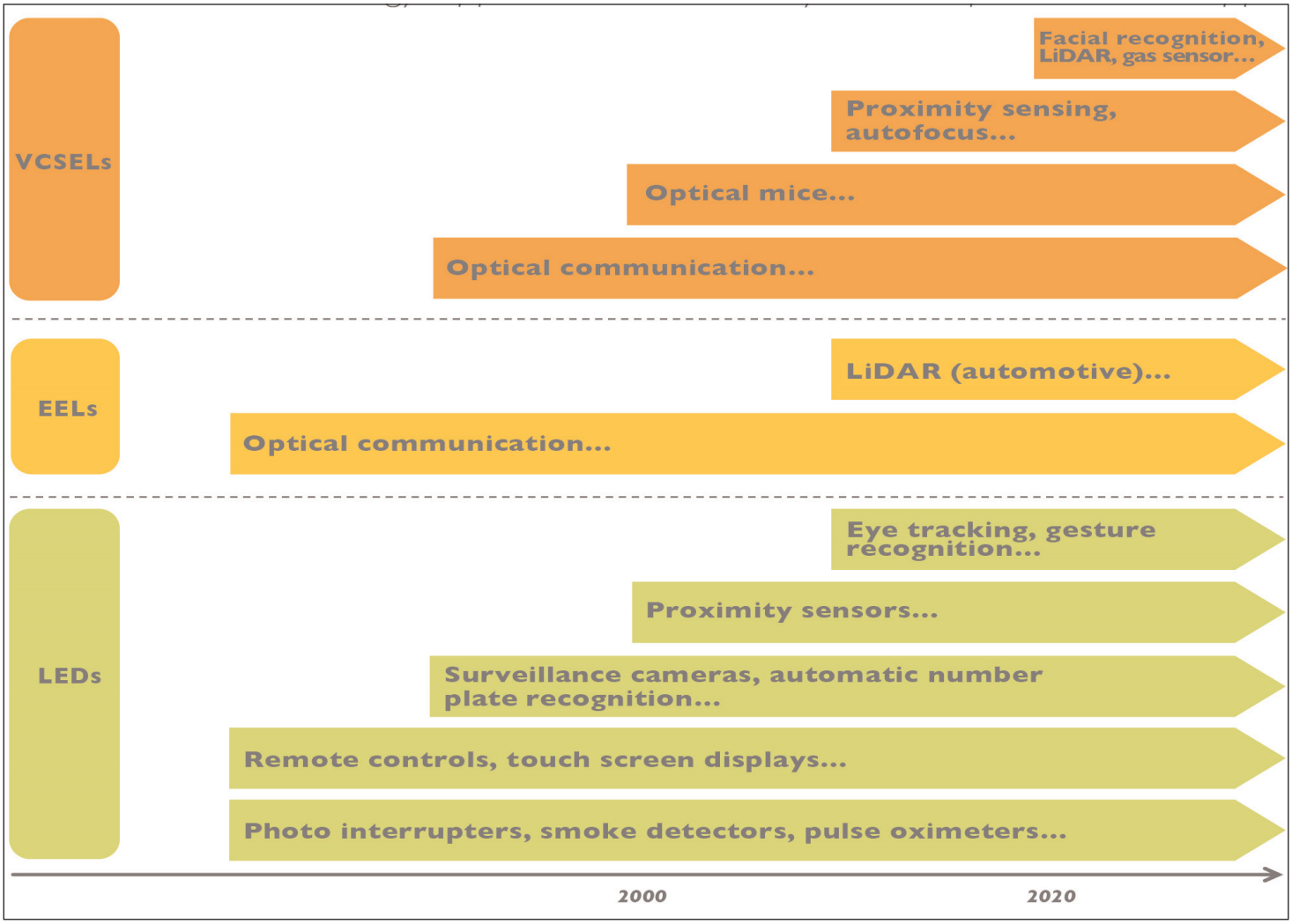
The landscape is different for edge-emitting lasers and vertical-cavity surface-emitting lasers, where most of the identified players are in the USA and Europe. The manufacturing process is much more complex and there is still a need for R&D and engineering to increase device performance and production yields. There is hence a variety of players with different positioning along the supply chain, including epi houses, foundries, IDMs and fabless players.

Since EELs and VCSELs will drive the bulk of future IR lighting revenue, there is still a large business opportunity for specialized players (epi houses and foundries primarily, but also designers). This is related to the manufacturing process (which still must be optimized) and also to the challenges of integrating light sources into packages and/or systems. Indeed, VCSELs and EELs can be combined with complex optics: for example, the dot projector used in facial recognition; or integrated into packages for optical communications and its future evolution, silicon photonics.

IR light source applications

"More than 40 different applications have been identified as integrating IR SSL [solid-state lighting] sources," says technology & market analyst Pierrick Boulay. "Among these, some are expected to make the IR LED and laser diode markets boom in the next five years," he adds.

Optical communication (one of the oldest IR light-source applications) is still expected to be one of the major drivers in the coming years. Indeed, the amount of data exchanged on the internet is exploding, and will continue to do so with the emergence of the



Timeline for major infrared lighting applications, by technology: LED versus EELs versus VCSELs.

Internet of Things (IoT), cloud-based services, autonomous cars, and more.

Driven by additive manufacturing, industrial applications are also expected to generate much revenue in the coming years. Traditional IR light sources that emit light in all directions and consume large amounts of energy are starting to be replaced by vertical-cavity surface-emitting lasers (VCSELs) that can be individually controlled, resulting in lower energy consumption.

Finally, 3D sensing is expected to be the killer application for IR light sources. The integration of VCSELs in Apple's iPhone X for facial recognition has generated much interest in 3D sensing. "In 2017 Apple released the iPhone X, with a 3D sensing function based on this technology," notes Yole's Pierrick Boulay. "It integrates three different VCSEL dies for the proximity sensor and the Face ID module, and made the VCSEL market explode in 2017, propelling overall revenue to about $330m," he adds. After Apple, some key Android-based smartphone manufacturers are following a similar strategy and starting to release new products.

3D sensing is not limited to smartphones. It also has potential for automotive LiDAR (light detection and ranging), which is necessary for the development of ADAS (advanced driver assistance systems). Not surprisingly, many start-ups in this field have entered the market in order to develop this technology and join the coming revolution

"3D sensing is not limited to smartphones. It also has potential for automotive LiDAR [light detection and ranging], which is necessary for the development of ADAS [advanced driver assistance systems]," says Pars Mukish, business unit manager Solid-State Lighting & Display at Yole. "Not surprisingly, many start-ups in this field have entered the market in order to develop this technology and join the coming revolution."

With increasing interest from the automotive and consumer industries in photonic technologies, IR lighting has a bright future ahead, concludes Yole. ■

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Magnetic sensing with GaN high-electron-mobility transistors

Split drain devices on silicon achieve greater sensitivity than pure silicon equivalents.

Researchers at Swansea University in the UK and the University of Nis in Serbia claim the first fabrication of gallium nitride (GaN) magnetic high-electron-mobility transistors (MagHEMTs) [S Faramehr et al, Semicond. Sci. Technol., vol33, p095015, 2018].

The devices featured a split drain (Figure 1) that allowed the deviation of electron paths due to interaction with magnetic fields to be assessed. The relative sensitivity of such devices is given by the current difference between the drain terminals relative to the total drain current over the magnetic field in Teslas (T).

Magnetic sensors are widely used for control in engineering systems covering aeronautical, automotive and industrial applications.

The devices were fabricated on HEMT heteroepitaxial structures with $Al_{0.25}Ga_{0.75}N$ barrier layer. Step-graded AlGaN was used to transition from the silicon substrate. The length (L) and width (W) of the device were 35μm and 20μm, respectively. The lengths of the source (L_S), and drain (L_D) were both 5.5μm. The gate length (L_G) was 1.0μm. The gate–source distance (L_{GS}) was 1μm. The widths of the two drain contacts (W_D) were 7.5μm each. The device was passivated with 10nm silicon nitride.

With the gate at zero and the drain bias at 0.5V, the sensitivity was found to be 11.98%/T — higher than previously reported values for silicon dual-drain split-current magnetic sensors.

The researchers used the experimental results to calibrate a series of simulations aimed at optimizing performance. The model suggested that improved sensitivity of 23.29%/T, at zero gate potential and 0.5V drain bias, could be achieved in a device with altered parameters - L=65μm, W=20μm, L_S =5.5μm, W_S =5.0μm, W_{DD}=5μm, L_G =5.0μm and L_{GD}=10μm

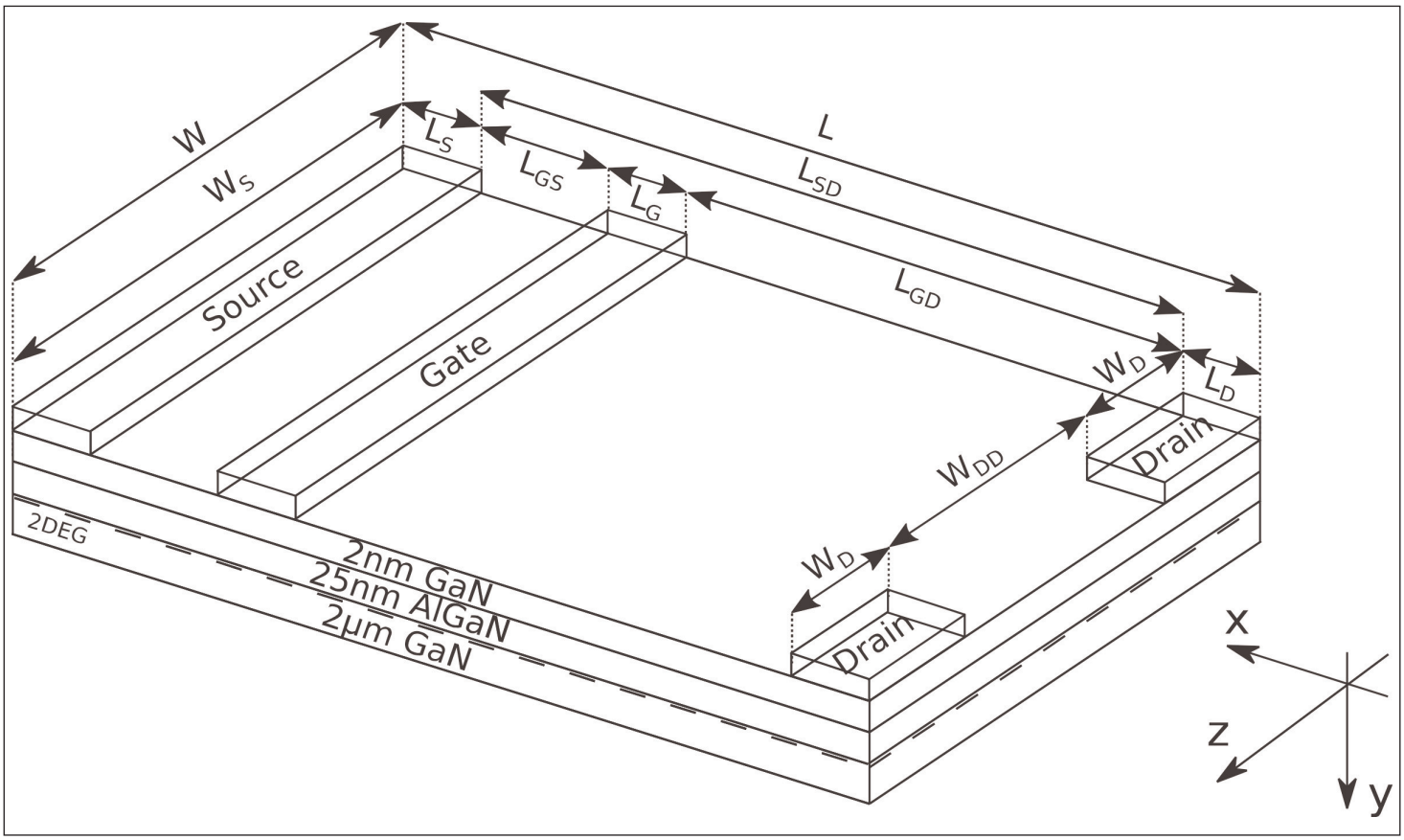

Figure 1. GaN MagHEMT (split-current sensor) schematic showing geometrical parameters used for relative sensitivity optimization.

(Figure 2).

The important changes seem to be a much longer total length of 65μm and reduced source width of 5μm. The reduced source contact decreases the total current flow and increases sensitivity to current deflection effects. The longer length also increases source to drain resistance, again reducing total current. The simulations also suggest an order-of-magnitude enhanced sensitivity at around –4V gate potential.

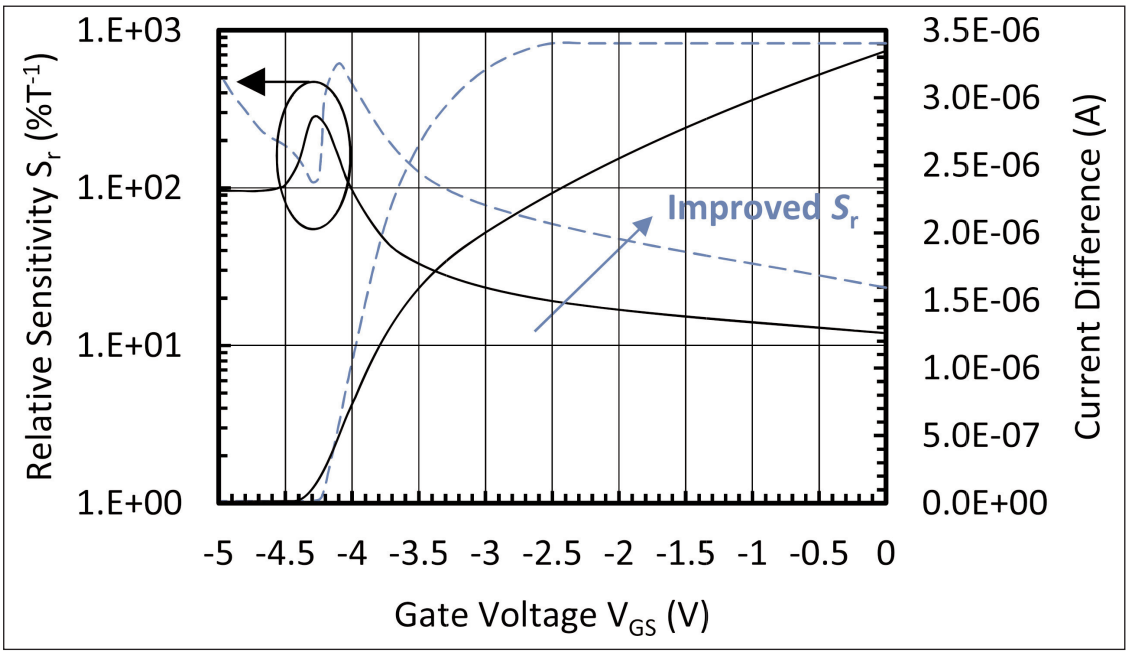

Figure 2. Simulated relative sensitivity (dash) and current difference (dash) of optimized GaN MagHEMT against simulated original GaN MagHEMT.

The researchers further studied the simulations at a raised temperature of up to 500K, showing "promising operation of GaN magnetic sensors under harsh environments". However, there was a decrease in sensitivity to 4.91%/T for the original device structure. ■

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Author: Mike Cooke

Silicon monoxide gate dielectric for gallium nitride transistors

A thermal evaporation process avoids the need for high-temperature, reactive-gas and ion-bombardment processes that can impact interface quality.

Researchers based in China and the UK have explored thermally evaporated silicon monoxide (SiO) as a gate dielectric for gallium nitride (GaN) metal-oxide-semiconductor high-electron-mobility transistors (MOS-HEMTs) [Gengchang Zhu et al, Semicond. Sci. Technol., vol33, p095023, 2018].

The hope of the team from Shandong University and University of Manchester was that improved interfaces would reduce performance impacts from charge trapping states and so on. Dielectrics are often deposited using interface-damaging processes involving ion bombardment and reactive gases, often at high temperature, that are avoided with thermal evaporation.

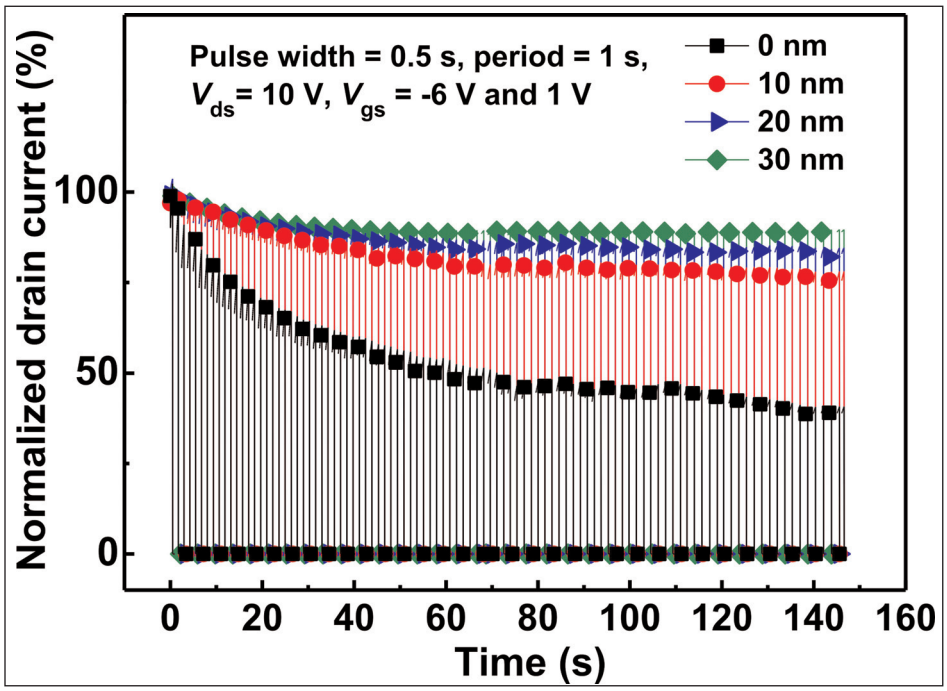

Figure 1. Transient on–off characteristics of MES-HEMTs and MOS-HEMTs with different SiO thicknesses.

GaN transistors are being developed for high frequency and high power handling for radio-frequency amplification, and power-switched power supplies and AC/DC, DC/AC conversion. The electronic properties that make GaN suitable for these applications include high breakdown field strength, high electron velocity, and thermal stability.

There are some barriers to progress towards commercial application such as gate leakage and current collapse when moving from DC to switched operation. Gate leakage is suppressed by inserting insulating dielectrics between the metal gate and semiconductor material. Current collapse is connected with charge-trapping states that introduce delay and hysteresis effects in performance.

The III–N heterostructure with aluminium gallium nitride (AlGaN) barrier layer consisted of 25nm/1nm/1.8μm $Al_{0.22}Ga_{0.78}N$/AlN/GaN grown by metal-organic chemical vapor deposition (MOCVD) on 2" 6H silicon carbide (SiC) with 100nm AlN nucleation. The GaN buffer layer was doped to be semi-insulating.

The material was used to fabricate mesa-isolated MES-HEMTs and MOS-HEMTs with titanium/aluminium/nickel/gold ohmic source–drain electrodes. For the MES-HEMT, the gate stack was nickel/gold. The MOS-HEMT included SiO in the gate stack from 99.99%-pure powder thermally evaporated from a tungsten boat and deposited at room temperature on the AlGaN barrier surface with a 0.55nm root-mean-square roughness for a 30nm layer, according to atomic force microscopy.

The devices featured a 2μmx100μm gate (width)x(length). The source-drain and gate–drain spacings were 14μm and 6μm, respectively.

One effect of the SiO gate insulation was to increase the maximum drain current to 452mA/mm for 30nm thickness, compared with 317mA/mm for the MES-HEMT ('0nm' SiO). The researchers suggest that the improved current may be due to the suppression of surface trapping effects by SiO passivation and/or passivation induced stress in the AlGaN layer.

Another related effect is an increase in carrier density in the channel region to $1.21x10^{13}/cm^2$ from $8.1x10^{12}/cm^2$, as determined by the 1MHz capacitance–voltage response, reducing sheet resistance and hence boosting current flow. The increased carrier density is tentatively attributed to the reduction in surface traps. There may also be a piezoelectric enhancement due to the SiO layer inducing stress in the underlying AlGaN.

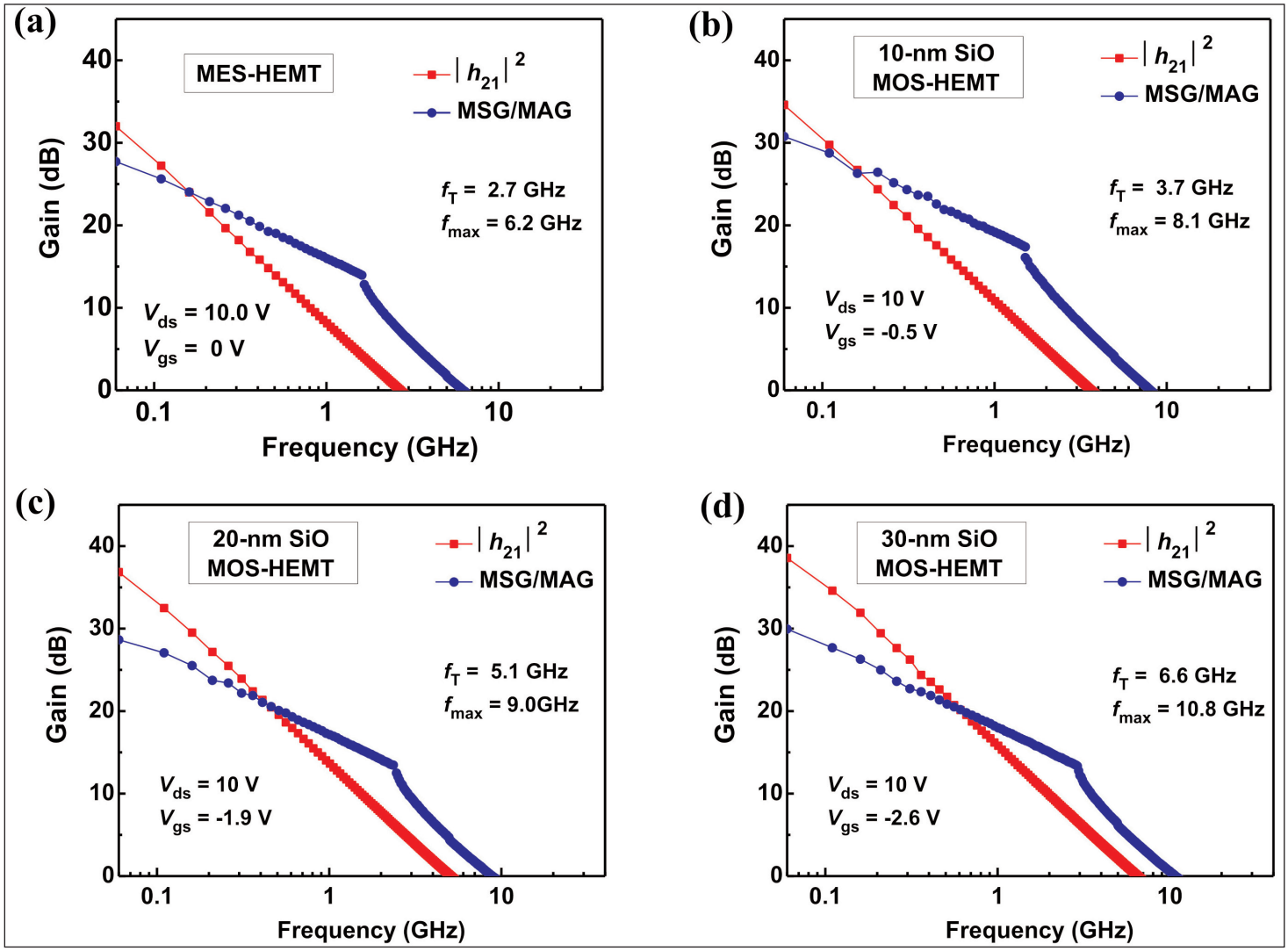

Figure 2. Small-signal characteristics of (a) MES-HEMTs and MOS-HEMTs with (b) 10nm, (c) 20nm, and (d) 30nm SiO. Drain bias 10V, gate potential set for maximum transconductance at 0V, –0.5V, –1.9V and –2.6V, respectively.

The increase in carrier density more than compensated for a slight decrease in mobility — 10^{10}cm^2/V-s for 30nm SIO, compared with 1240cm^2/V-s for the MES-HEMT.

The off current was reduced by more than two orders of magnitude in the MOS-HEMTs, increasing the on/off ratio, compared with the MES-HEMT — 1.4×10^8 versus 3.2×10^5, respectively. In pulsed operation (0.5s width, 1s period), current collapse was 12% for 30nm SiO MOS-HEMTs, while the MES-HEMT suffered a significantly greater 51% impact on performance (Figure 1). The reduction in collapse is attributed to a much lower interface charge trap density in the MOS-HEMT — 9.3×10^{11}/cm^2-eV, compared with 2.37×10^{12}/cm^2-eV for the MES-HEMT structure.

The off-state breakdown (–10V gate potential, 1mA/mm leakage drain current compliance threshold) occurred at 236V with 30nm SiO, a 100V increase from 136V for the MES-HEMT. The breakdown strength (breakdown voltage divided by gate–drain spacing) was 39V/μm for 30nm SiO and 23V/μm for the MES-HEMT.

The researchers comment: "The breakdown mechanism has been found to be caused by impact ionization, which can be triggered by gate leakage injection into the channel at high electric fields. The breakdown voltage is enhanced in our MOS-HEMTs due to the suppression of gate leakage by the SiO gate dielectric."

Frequency-dependent measurements up to 20GHz gave current gain cut-off and maximum oscillation frequencies of 6.6GHz and 10.8GHz, respectively, for the MOS-HEMT with 30nm SiO (Figure 2). The comparable figures for the MES-HEMT were 2.7GHz and 6.2GHz. The improvement in the SiO device is suggested to be due to a lower gate capacitance, compared with the MES-HEMT. The (cut-off)x(gate-length) product was 13.2GHz-μm, higher than other values for scaled GaN HEMTs, according to the researchers. It is to be hoped that scaling the SiO MOS-HEMT structure will therefore lead to promising high-frequency performance. ■

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Author:
Mike Cooke

Thin gallium nitride on silicon carbide high-power and high-frequency electronics

High-quality 60nm grain-boundary-free aluminium nitride nucleation layer avoids extended defects over large areas

Researchers based in Sweden have developed thinner III-nitride structures on silicon carbide (SiC) with a view to high-power and high-frequency thin high-electron-mobility transistors (T-HEMTs) and other devices [Jr-Tai Chen et al, Appl. Phys. Lett., vol113, p041605, 2018]. Rather than having a ~1–2μm-thick gallium nitride (GaN) buffer layer, the new structure uses a high-quality 60nm grain-boundary-free aluminium nitride (AlN) nucleation layer to avoid extended defects over large areas (Figure 1). The nucleation layer allows high-quality GaN to be grown within 0.2μm.

The normally thick buffer layers are used to transition and reduce defects arising from the 3.5% lattice mismatch between GaN and SiC — the mismatch is much higher for other substrates such as sapphire and silicon. These thick layers create problems for high-power and high-frequency devices. These layers are often doped with carbon or iron to increase resistance with the aim of confining current flow to the channel region, avoiding leakage effects from parasitic conduction. The doping creates charge-trapping states that can cause their own negative impacts on performance such as current collapse in radio-frequency operation.

Thinner devices should also have lower thermal resistance, improving thermal management. The team from SweGaN AB, Chalmers University of Technology, and Linkoping University, comments: "Structural defects like voids and dislocations generated at the interfaces of GaN/AlN/SiC introduce a thermal boundary resistance (TBR) that results in an additional 30–40% channel temperature rise in HEMTs."

The reduced amount of expensive materials needed is a further attraction of the work. The researchers estimate a 90% reduction in raw materials including precursors and gases, along with reduced processing cost from the decreased growth time needed.

The new AlN nucleation process avoids the usual grain-like morphology that tends to result in column-like growth where defects are carried up into the overlying GaN. The usual graininess is due to the low mobility of aluminium atoms on the growth surface.

The III-nitride material was grown on silicon-face 4H silicon carbide. Hot-wall metal-organic chemical vapor deposition (MOCVD) was used to create epitaxial structures with 60nm AlN nucleation, a 200nm GaN channel,

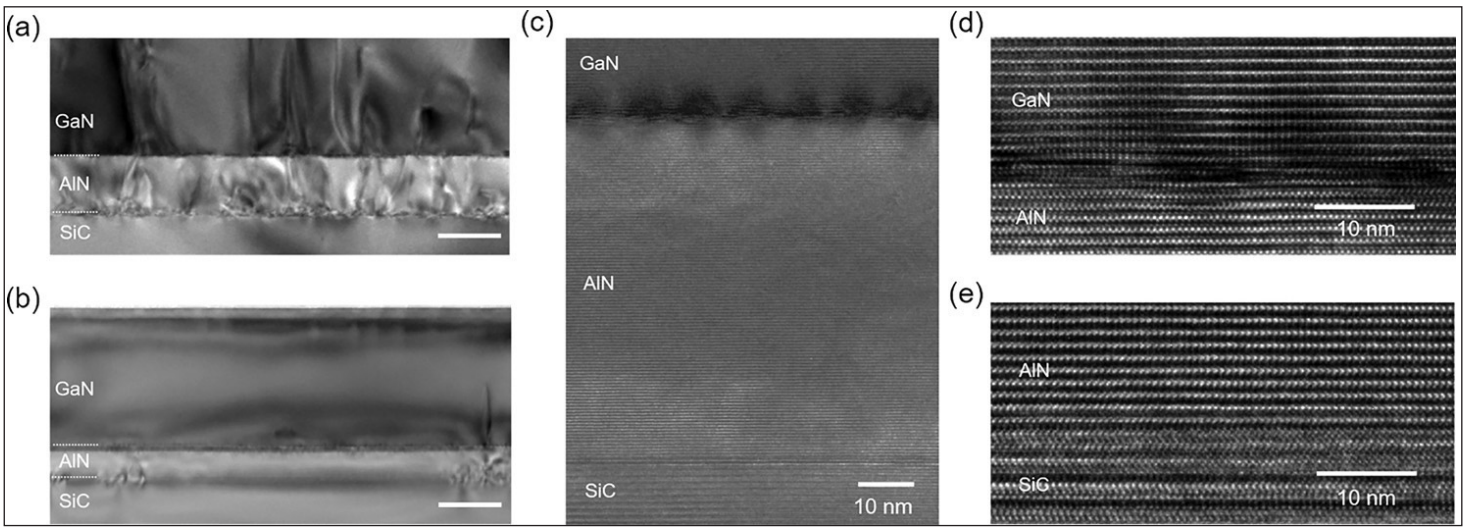

Figure 1. Cross-sectional transmission electron micrograph (TEM) images along the [11$\bar{2}$0] direction at the GaN/AlN/SiC interface using (a) conventional and (b) low-TBR AlN nucleation. (c) High-magnification image of GaN/low-TBR AlN NL/SiC. (d) High-resolution image at the interface of the GaN/low-TBR AlN NL. (e) High-resolution image at the interface of the low-TBR AlN NL/SiC. Scale bar is 100nm in (a) and (b).

an AlN interlayer of up to 1.5nm, a 10–14nm AlGaN barrier (~30% Al), and a 2nm GaN cap. The 60nm AlN was produced using a low thermal-boundary-resistance (low-TBR) technique enabled by the hot-wall growth.

Despite the thinness of the structure, threading dislocations densities in the low 10^8/cm^2 range was estimated, "two orders of magnitude less than that of the typical GaN layers with the same thickness," according to the researchers. Contactless Hall measurements on a structure with a 2nm GaN cap and a 14nm $Al_{0.29}Ga_{0.71}N$ barrier gave a $9.8x10^{12}$/cm^2 two-dimensional electron gas (2DEG) density and a 2050cm^2/V-s mobility. The sheet resistance was 315Ω/square.

Test T-HEMTs were produced on material with a 2nm GaN cap, a 10nm $Al_{0.3}Ga_{0.7}N$ barrier and a 1nm AlN interlayer. Tantalum-based contacts were used for the source/drain, giving a contact resistance of 0.3Ω-mm.

The device achieved a high on-current density of 1.1A/mm with low normalized on-resistance of 1.3Ω-mm (Figure 2). The saturation current was maintained up to 30V drain bias. With 10V drain bias, the pinch-off was sharp, with transconductance reaching 500mS/mm. The subthreshold swing depended on gate length: 250mV/decade for 0.1μm and 130mV/decade for 0.2μm. The breakdown voltages were 70V and 140V for the 0.1μm and 0.2μm gates, respectively.

The researchers comment: "The linear relationship between the breakdown voltage and the gate length suggests that the breakdown was taking place laterally due to the limited dimension of the gate length and the gate-to-drain spacing."

The gate-drain spacing was 2μm, far short of the usual 10–20μm normally used in GaN HEMTs aimed at power performance. Also, conventional GaN power HEMTs have micron-scaled gate lengths.

Load-pull measurements at 30GHz gave a peak radio-frequency power density of 5.8W/mm at 40V drain-to-source quiescent bias (V_{DSQ}).

Breakdown measurements on an epitaxial stack without the upper AlN/AlGaN layers gave breakdown voltages up to 1.5kV in both lateral and vertical directions.

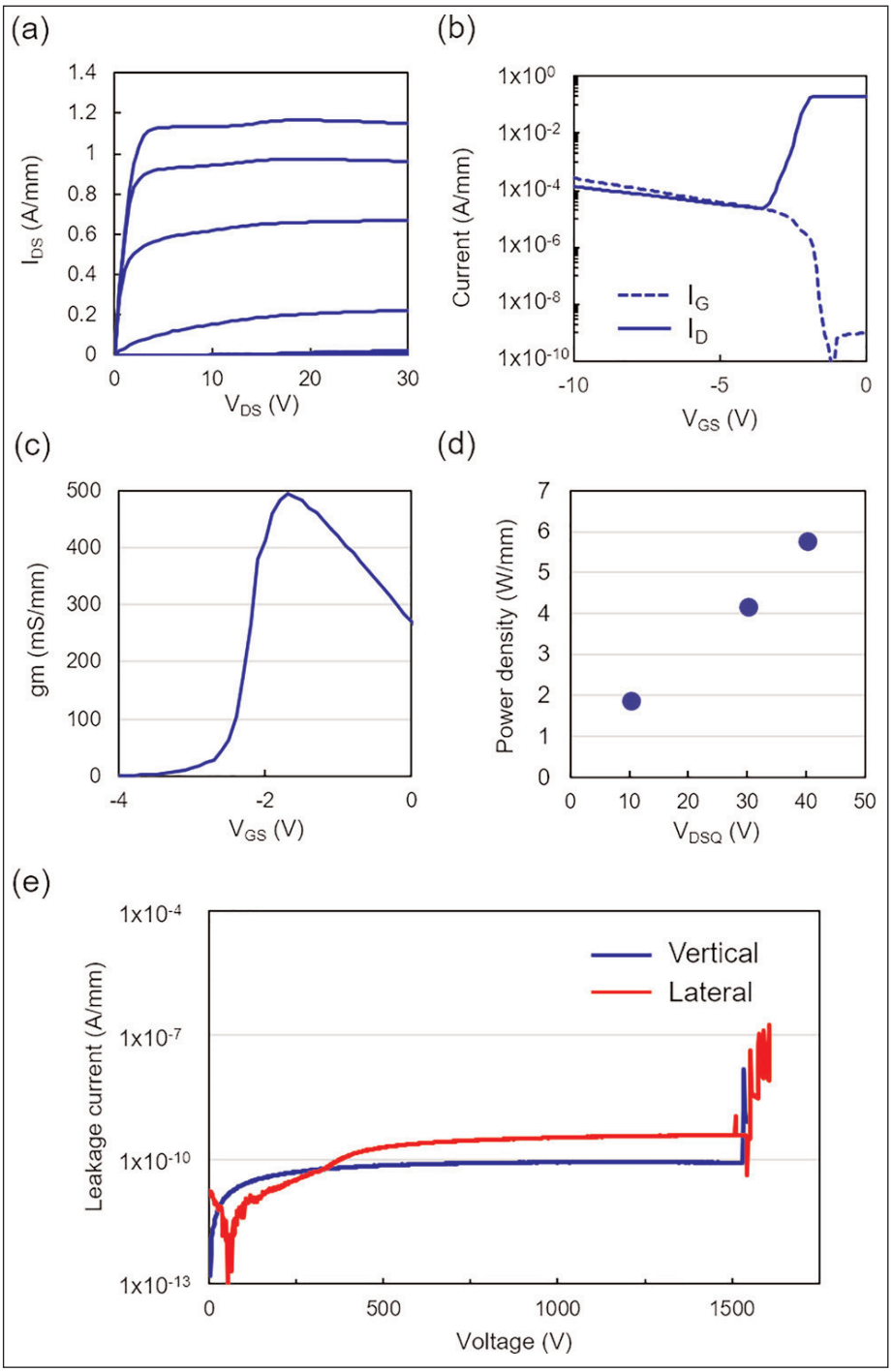

Figure 2. (a) DC drain current-voltage (I_{DS}–V_{DS}) characteristics, (b) transfer characteristics and gate and drain current at 10V drain bias (V_{DS}) as a function of gate voltage (V_{GS}), (c) transconductance (g_m) as a function of gate potential, and (d) radio-frequency output power density as a function of V_{DSQ} of T-HEMT. (e) Vertical and lateral breakdown characteristics of heterostructure without top active layers.

The team comments: "In both cases, the breakdown was due to the bad delineation of the contacts. Therefore, the real breakdown voltage of the stack is expected to be higher. In other words, the breakdown has been limited by the surface and it confirms that there are no interface carriers." ■

https://doi.org/10.1063/1.5042049

Author: Mike Cooke

Activating buried p-type GaN for power electronics

Researchers use reverse breakdown for assessing p-GaN activation as a "sensitive probe pertinent to power electronic applications".

Cornell University, IQE RF LLC and Qorvo Inc in the USA have been working out ways to better activate buried p-type layers of gallium nitride (p-GaN) [Wenshen Li et al, Appl. Phys. Lett., vol113, p062105, p2018]. In most GaN/III–N growth processes the p-type layers are left until last because of the difficulty of activation, which usually involves heating the sample in an attempt to drive out hydrogen that passivates the magnesium doping used to create mobile hole charge carriers.

This p-GaN-last constraint limits the sort of structures that can be explored for power electronics and other applications. Examples of buried-structure devices include heterojunction bipolar transistors (HBTs), trench metal-oxide-semiconductor field-effect transistors (MOSFETs), current-aperture vertical electron transistors (CAVETs), and laterally diffused MOSFETs (LDMOSFETs).

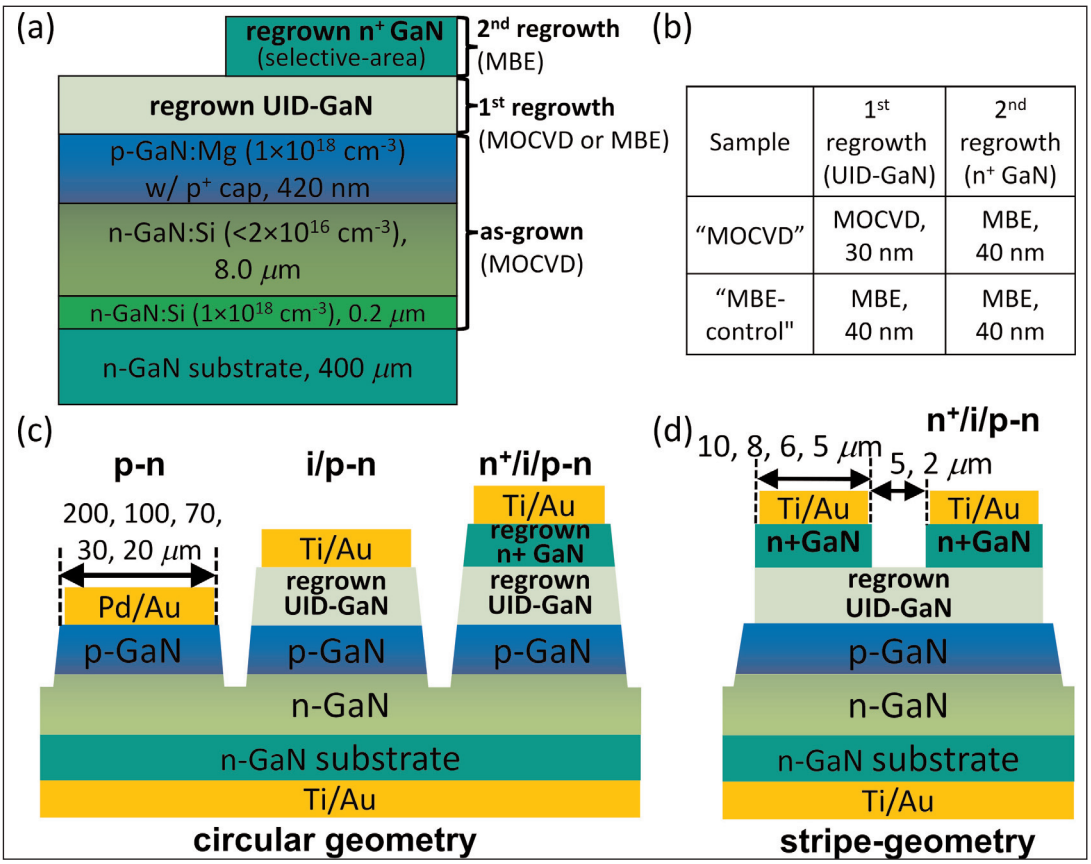

Figure 1. (a) Schematic layer structure of as-grown in-situ activated p-n diode structure and two re-grown layers. (b) Information on two re-grown layers on MOCVD and MBE control samples. (c) Schematic cross sections of three types of circular diode: p-n, i/p-n and n^+/i/p-n diodes fabricated on both samples. (d) Schematic cross section of n^+/i/p-n diodes with stripe geometry. Stripes all have a finger length of 50μm.

The team used the reverse breakdown measurements for assessing p-GaN activation as "a sensitive probe pertinent to power electronic applications".

Metal-organic chemical vapor deposition (MOCVD) produced epitaxial layers on bulk GaN (Figure 1). The top p-GaN layers were activated in-situ. The researchers report that the contact resistance (~$4x10^{-5}\Omega$-cm^2) and Hall measurement (hole density ~7% magnesium concentration, mobility 24cm^2/V-s) results for this material with a top p-GaN layer were "among the best in the literature".

The p-GaN was then buried using re-growth via blanket MOCVD or molecular beam epitaxy (MBE) of undoped GaN. For the MOCVD sample, the p-GaN was passivated with 900°C annealing in ammonia for 30 minutes in the reaction chamber. The MOCVD sample was also prepared by ultraviolet-ozone and hydrofluoric acid treatments to reduce silicon residues. For the MBE sample, the buried p-GaN was unpassivated. A final n^+-GaN layer was grown selectively by MBE on the two samples.

The material was used to create a series of buried p-GaN structures for electrical testing with contacts using various stacks of palladium (Pd), titanium (Ti) and gold (Au). Various dry etch recipes were used to remove the undoped GaN re-grown top layer and for mesa isolation. The buried p-GaN was activated by

annealing at 725°C for 30 minutes in dry air, driving hydrogen out through the mesa sidewalls. The metal contacts were applied after annealing.

Probing unmetalized MOCVD-sample structures without buried p-GaN activation showed high leakage currents under reverse bias. The leakage was suppressed by activation.

The reverse-bias breakdown occurred in the range 1100–1200V for annealed circular p–n and i/p–n diodes, independent of diameter (Figure 2). Breakdown damage was observed as a burnt region at the mesa edge, typical for devices without field plates or other edge termination structure. The researchers estimate more than 28% activation of the magnesium acceptors in the p-GaN layers, as calculated from the field distribution at punch-through. The team sees this as a lower bound on activation as "breakdown is limited by edge field crowding but not punch through".

The n^+/i/p–n-diodes had much higher leakage, and current-dependent soft breakdown occurred at 300V. MBE-sample devices had much lower leakage, attributed to the absence of hydrogen in the re-growth.

The high leakage in n^+/i/p–n diodes is attributed to the n^+-GaN layer blocking the diffusion of hydrogen out of the buried p-GaN layers. For the i/p–n devices, magnesium diffusion into the undoped (UID) GaN cap converts it into a p-GaN layer, allowing hydrogen diffusion upward during activation. Even with 20μm-diameter circular devices, diffusion of hydrogen through the mesa sidewalls is not sufficient for effective p-GaN activation.

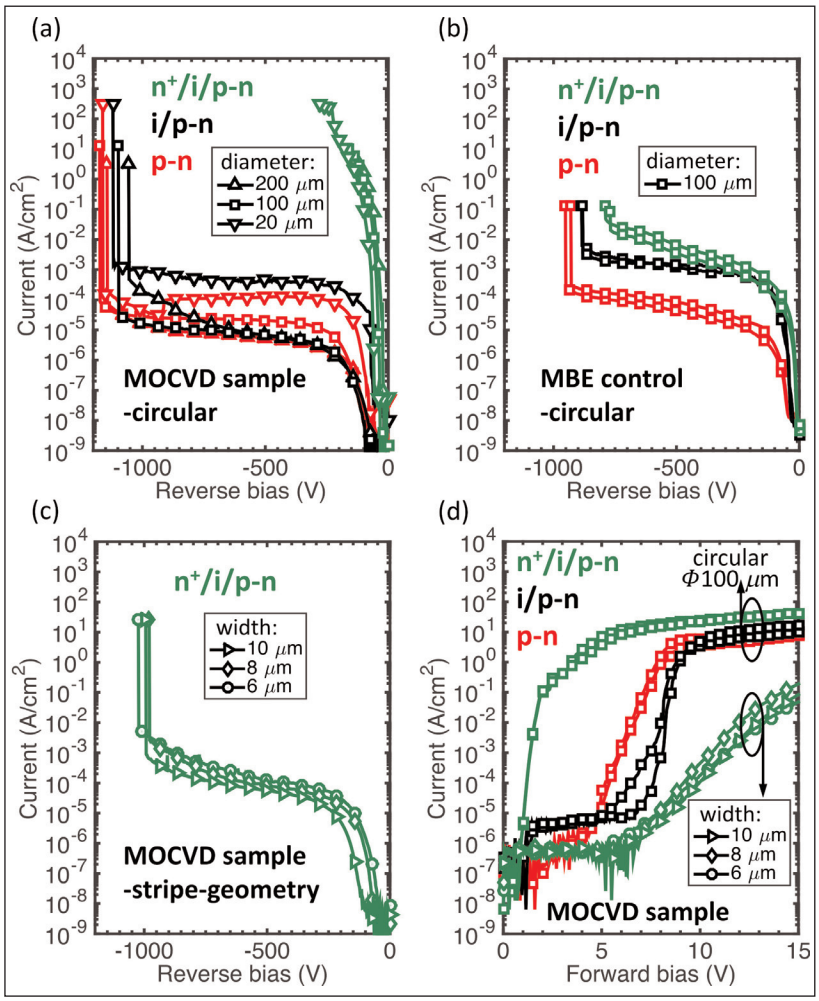

Figure 2. Reverse and forward current density versus voltage characteristics of diodes. (a) Reverse-bias characteristics of circular diodes on MOCVD and (b) on MBE control samples. (c) Reverse-bias characteristics of n^+/i/p-n diodes with stripe geometry on MOCVD sample. (d) Forward-bias characteristics of various diodes on MOCVD sample.

Narrower-stripe-geometry devices with widths between 10μm and 5μm reduced the leakage current and enable breakdown to reach comparable values to the circular p–n and i/p–n diodes. The researchers comment: "These data indicate sufficient activation of the buried p-GaN, and thus a lateral hydrogen diffusion length of >5μm (half of the stripe width) under the annealing conditions used in this work. The observed activation should be attributed to the lateral diffusion of hydrogen out of the etched mesa sidewall as well as the exposed UID-GaN surface between fingers."

The forward bias characteristics of the p–n and i/p–n circular devices are similar — the turn-on voltage is rather high, and the on-current low, due to poor ohmic contact with p-type GaN.

The n^+/i/p–n devices were back-to-back diodes and hence should not have a high current in the 'forward' bias region. The high current of the circular n^+/i/p–n diodes demonstrates high leakage and hence poor p-GaN activation. By contrast, the leakage is suppressed in the stripe devices.

The researchers see 10–20μm as the critical lateral dimension range for effective activation of buried p-GaN through annealing. This range allows the escape of hydrogen out of p-GaN surfaces with a diffusion length of 5–10μm.

The researchers comment: "The reverse breakdown measurement is a much stricter test of the acceptor activation of buried p-GaN than light emission. Any insufficient activation of buried p-GaN leads to drastically higher leakage current due to premature punch-through."

The team also suggests that activation of magnesium near the surface creates an electric field that attracts hydrogen ions (mainly protons), enhancing out-diffusion. However, the effect of concentration gradient and electric field is reduced when the lateral dimension through which the hydrogen is required to diffuse increases. ■

https://doi.org/10.1063/1.5041879

Author: Mike Cooke

Photo-electro-chemical deep trench etching in GaN

Researcher hope for new device structures for power electronics, achieving trenches with 7.3 aspect ratio and 24.3μm depth.

SCIOCS Co Ltd and Hosei University, both of Japan, have reported progress in using photo-electro-chemical (PEC) etching for deep high-aspect-ratio trenches in gallium nitride (GaN) [Fumimasa Horikiri et al, Appl. Phys. Express, vol11, p091001, 2018]. The team hopes that the technique will open up new device structures for power electronics, using GaN's high breakdown field and high electron drift velocity in high fields.

Deep etching is needed to create 'superjunction' structures with columns of p- and n-type material that, when incorporated into lateral field-effect transistors, enable breakdown voltages of more than 10kV. Vertical devices can also benefit from superjunction drift regions and other deep-etched structures. High-quality fast etch-rate processes are also desired for ridge fabrication of laser diodes, wafer-dicing applications, and micro-electro-mechanical systems (MEMS). PEC has already been applied to mesa, gate-recess, and vertical-cavity surface-emitting laser (VCSEL) fabrication processes.

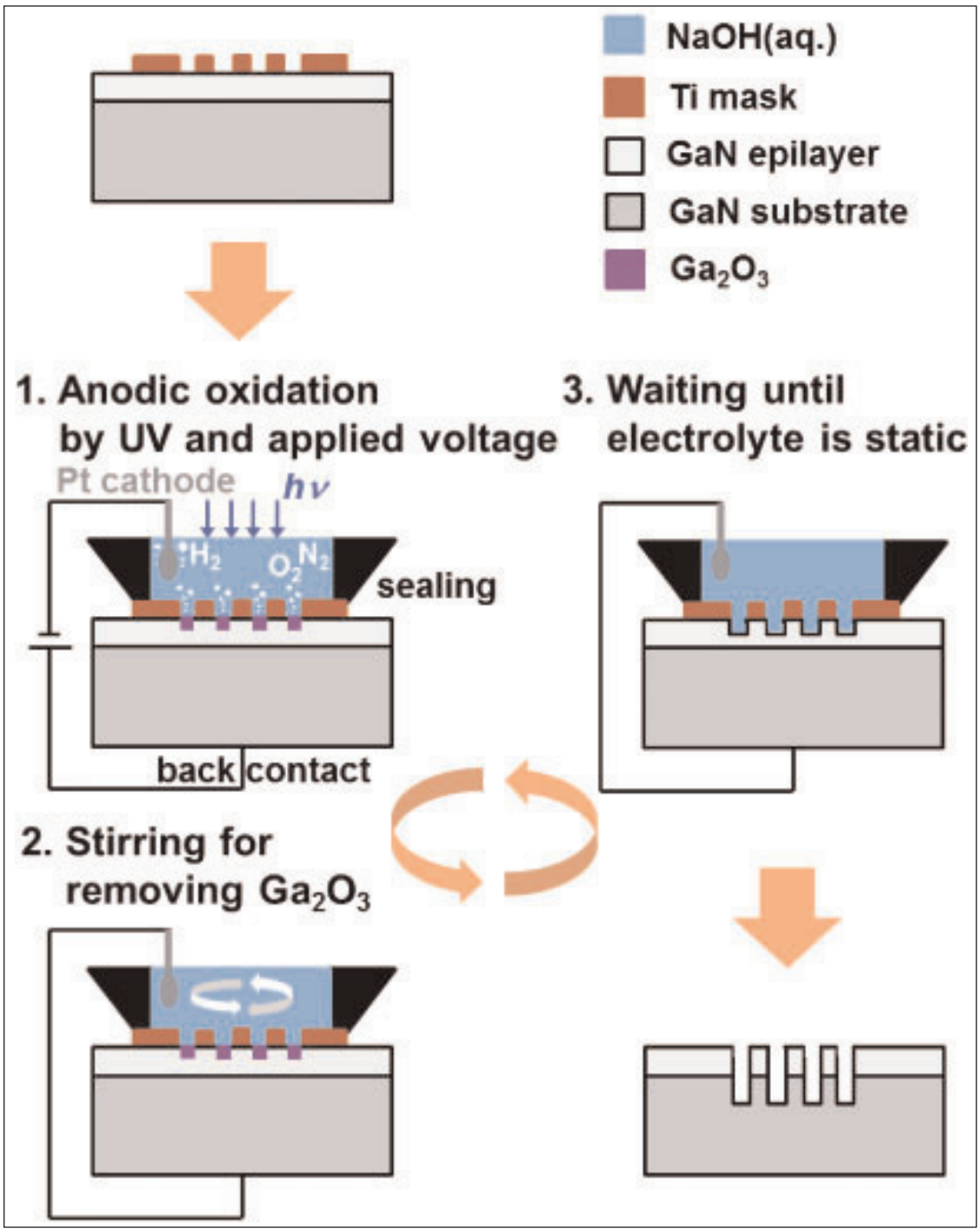

Figure 1. PEC etch scheme.

According to Horikiri, the work was supported by a big budget from Japan's Ministry of the Environment.

The team comments: "We commit to sharing this convenient PEC etching technology with the GaN community as part of our responsibility as a supplier of GaN substrates."

Normally, deep etching is achieved with dry plasma etching such as inductively coupled plasma reactive-ion etch (ICP-RIE), which suffers from high surface damage. Further problems arise from low dry-etch selectivity between GaN and mask materials. High-quality etch techniques tend to be slow, reducing the scope for deep structures.

The researchers prepared 2-inch free-standing GaN substrates by void-assisted separation of n-type hydride vapor phase epitaxy (HVPE) material from sapphire [Mike Cooke, Semiconductor Today, p80, June/July 2018] — a technique developed by SCIOCS. The dislocation density in the wafer was in the range $2x10^6/cm^2$ to $5x10^6/cm^2$.

Further diode layers were grown by metal-organic vapor phase epitaxy — 5.8μm n-GaN for Schottky barrier diodes and 2μm n^+-GaN, 10μm n^--GaN, 500nm p-GaN and 20nm p^+-GaN for pn diodes. The pn diode material was annealed at 850°C for 30 minutes in nitrogen to activate the magnesium acceptors of the p-type layers. The effect of annealing was to drive out the hydrogen atoms that passivate the acceptors.

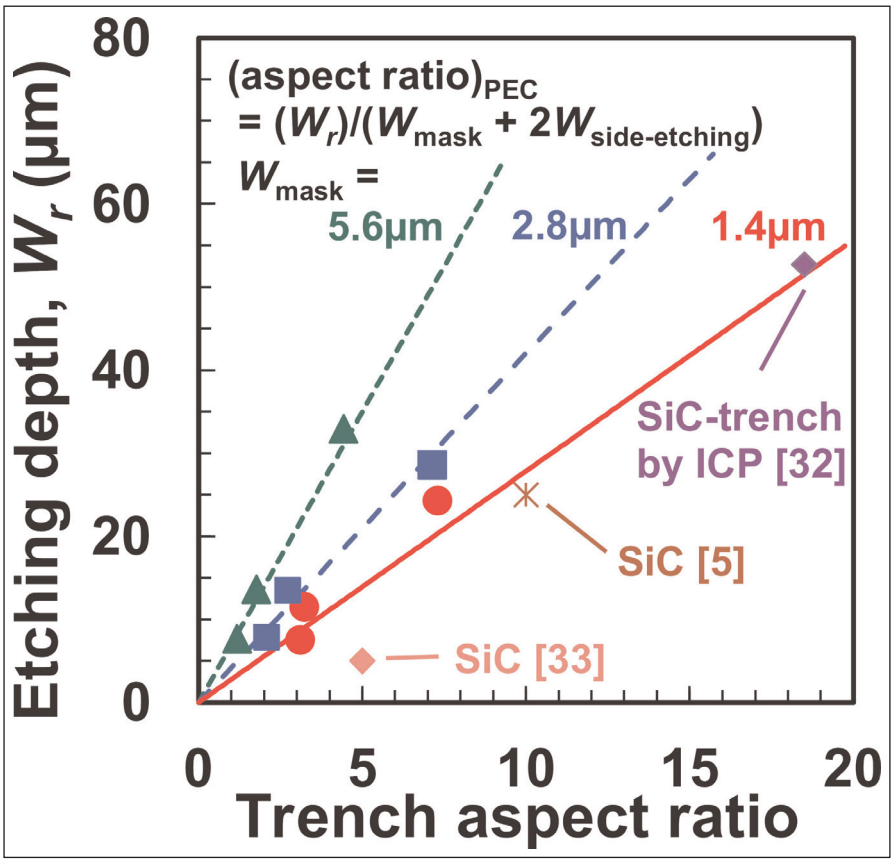

Figure 2. Relationship between PEC etching depth and trench aspect ratio. Solid, dashed and dotted lines correspond to estimates based on aspect ratio of PEC with trench width that includes side-etching of the order 0.7μm into both walls. Filled symbols show experimental results.

The mask material for the PEC etch (Figure 1) was titanium. PEC etching uses 'photo-assisted anodic oxidation' to etch GaN. The process releases Ga^{3+} from GaN with the positive charge coming from holes generated by ultraviolet (UV) light at the GaN/electrolyte anodic interface. The electrons are removed by the electrical circuit of the PEC set up between an ohmic contact on the back-side of the GaN wafer and a platinum counter-electrode as cathode. The etch potential was 1V. The UV radiation was provided by a mercury–xenon lamp, giving $9.0mW/cm^2$ at vertical incidence. The radiation and etch potential were operated in pulse mode with 0.6 duty cycle on the potential.

The electrolyte contained OH- hydroxide ions that react with the Ga^{3+}, forming Ga_2O_3. The electrolyte solution contained 0.01M sodium hydroxide and 1% Triton X-100 [C14H22O(C2H4O)n ; 4-(1,1,3,3-tetramethylbutyl)phenyl–polyethylene glycol] as wetting agent, reducing surface tension and assisting in bubble removal.

The PEC process achieved a smooth surface rate of 24.9nm/minute, comparable with damage-free dry etching. Increasing the PEC rate to 175.5nm/minute resulted in a rough surface. Higher-speed PEC could find uses in wafer dicing.

With a 50nm-thick titanium mask consisting of 90μm-diameter circular dots, PEC etching to a depth of 20μm gave a selectivity of greater than 400 (20μm/50nm). Side etching was less than 1μm.

In experiments on trench etching, the depth reached was controlled by current density rather than mask orientation along the m- or a-axes of the GaN lattice. The trench etch rate of short-width aperture masks slowed at about 30μm depth. The researchers suggest that this was due to the difficulty for the UV radiation to reach the etch front at the bottom of the trench. They add that a coherent UV source might help in deep trench etching.

The maximum trench aspect ratio achieved was 7.3 with 3.3μm width and 24.3μm depth (Figure 2). The team comments: "This aspect ratio and the etching depth are comparable to the best results for SiC trenches fabricated by ICP-RIE, and they indicate the excellent potential of PEC etching not only in the fabrication of optical and electronic devices, but also in fabricating GaN-MEMS such as the through-via of wafers, diaphragms, microfluidic channels, and optical gratings." ■

https://doi.org/10.7567/APEX.11.091001

Author: Mike Cooke

suppliers' directory

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13–15 November 2018
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www.apec-conf.org

16–18 April 2019
23rd Annual Components for Military & Space Electronics Conference & Exhibition (CMSE)
Four Points by Sheraton (LAX), Los Angeles, CA, USA
Abstract deadline: 7 December 2018
E-mail: terlizzi@tjgreenllc.com
www.tjgreenllc.com/cmse

29 April – 2 May 2019
2019 International Conference on Compound Semiconductor Manufacturing (CS MANTECH)
Hyatt, Regency, Minneapolis, MN, USA
E-mail: chairman@csmantech.org
www.csmantech.org

7–9 May 2019
PCIM Europe (Power conversion and Intelligent Motion) 2019
Nuremberg Messe, Germany
E-mail: daniela.kaeser@mesago.com
www.mesago.de/en/PCIM/main.htm

15–17 May 2019
Intersolar Europe 2019
Munich, Germany
E-mail: info@intersolar.de
www.intersolar.de

27–31 May 2019
10th International Conference on Power Electronics (ICPE 2019 – ECCE Asia)
BEXCO, Busan, South Korea
E-mail: icpe2019@icpe2019.org
www.icpe2019.org

24–28 June 2019
PVSC 2019: IEEE 46th Photovoltaic Specialists Conference
Chicago, IL, USA
E-mail: info@ieee-pvsc.org
www.ieee-pvsc.org

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

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

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

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

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