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COMPOUNDS & ADVANCED SILICON

Vol. 14 • Issue 5 • June/July 2019

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Wide-bandgap power electronics developments

Hamamatsu's Shingai plant gets 2nd building • Rockley raises $52m
Light Communications Alliance formed • Emcore cuts guidance

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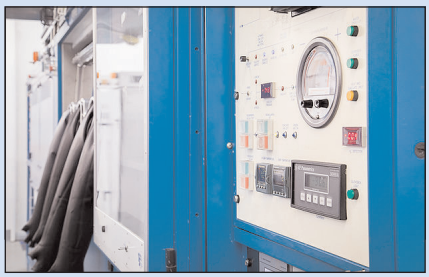


p32 BluGlass has brought online its BLG-300II upgraded RPCVD system, boosting development and foundry capacity by over 30%.

p39 Hamamatsu is to construct a second building at its Shingai Factory, for opto device production from October 2020.

p48 Toyota is to begin public road trials of a Prius PHV electric vehicle that generates 860W using 34%-efficient triple-junction cells, versus 180W using 22.5%-efficient cells in the commercial model.

Cover: Germany's Fraunhofer ISE has inaugurated its Center for Power Electronics and Sustainable Grids. With a propriety connection to the 110kV high-voltage grid and 40MVA transformer, it offers research infra-structure to meet the growing demands on power electronics. **p14**

editorial

Wide-bandgap boost from auto sector

With the penetration of electronics into both the industrial and consumer domains, power semiconductor devices are becoming ubiquitous. And, with energy saving becoming a priority, wide-bandgap silicon carbide (SiC) and gallium nitride (GaN) are increasingly being adopted in preference to the less energy-efficient and lower-performing incumbent silicon.

According to Global Market Insights, the GaN and SiC power semiconductor market will grow from over $400m to more than $3bn by 2025, driven by applications in areas such as photovoltaic (PV) inverters, hybrid & electric vehicles (HEV/EV) and uninterruptible power supplies (UPS) — see page 8.

Specifically, with demand for power electronic components forecast to account for over 55% of the total semiconductor demand from HEV/EV powertrains by 2026, wide-bandgap semiconductor revenues are rising at a compound annual growth rate (CAGR) of 60% through 2026, so that GaN and SiC will collectively account for almost 20% of the HEV/EV automotive power semiconductor market in 2026, according to Strategy Analytics (see page 6). "SiC is the more mature of the two technologies, with 650V and 1200V parts starting to compete with silicon-based components for the main inverter as well as getting some traction into the DC–DC converter and the OBC (on-board charger)," it notes.

According to Yole Développement, the overall silicon carbide power device market is growing at CAGR of 29% to $1.93bn in 2024, driven by the EV market, so that the automotive sector will rise from 27% of the SiC power device market in 2018 to 49% in 2024 (see article on page 70).

With such demand in prospect, R&D on silicon carbide and gallium nitride materials and devices is attracting greater attention and funding.

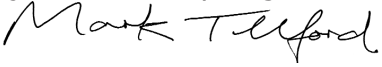
For example, State University of New York (SUNY) Polytechnic Institute is receiving $1.5m in funding from the US Department of Energy's Vehicle Technology Office (VTO) for developing 1200V SiC MOSFETs and for reliability studies on AlGaN-based high-electron-mobility transistors (HEMTs), as superior switch components than their silicon-based counterparts in areas such as cost, performance and reliability (page 16), targeting highly efficient and reliable power electronics for drive trains in applications including improved EVs. The VTO award supports research through the new 'Electric Drive Technologies Consortium' (supported by the Vehicle Technology Office and DOE), of which SUNY Poly is one of the 10 founding university members.

Meanwhile, Sweden's Ascatron (spun out of research institute Acreo in 2011) — which supplies bare SiC dies for both power modules and discrete components — has sold shares in a joint venture company in China, securing €3.5m funding to continue development of power semiconductor devices using its proprietary 3DSiC technology (page 17).

Also, in the industrial area in northern Freiburg, Germany, the Fraunhofer Institute for Solar Energy Systems (ISE) has inaugurated its new Center for Power Electronics and Sustainable Grids which, with a connection to the 110kV high-voltage grid and 40MVA transformer, provides the research infrastructure to meet growing demands on power electronics (page 14).

Due to the accelerating switch away from fossil fuels (particularly diesel) to electric power (in regions with a manufacturing focus on both vehicles and electronics, such as Germany, Japan etc), investment in wide-bandgap semiconductors like SiC is still just at the early stage.

Mark Telford, Editor



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

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SiC- and GaN-based power electronics to boost automotive semiconductor efficiencies and profitability

Wide-bandgap semiconductors to grow at 60% CAGR through 2026

As hybrid electric vehicle/electric vehicle (HEV/EV) platforms become a greater proportion of the global vehicle manufacturing mix, the demand for power electronic components will account for over 55% of the total semiconductor demand from HEV/EV powertrains by 2026, predicts Strategy Analytics. Specifically, the Strategy Analytics Powertrain Body Chassis & Safety (PBCS) service report 'HEV-EV Semiconductor Technology Outlook: What Role will SiC and GaN Play?' finds that the emphasis on improving system efficiencies will dictate a move towards the use of higher-value silicon carbide (SiC) and gallium nitride (GaN)-based components, creating a window of opportunity for the automotive semiconductor industry for higher margins and greater profitability.

Silicon-based insulated-gate bipolar transistors (IGBTs), metal-oxide-semiconductor field-effect transistors (MOSFETs) and Schottky barrier diodes (SBDs) will continue to dominate the power electronics landscape, but SiC and GaN are starting to make in-roads, and will collectively account for almost 20% of the HEV/EV automotive power semiconductor market in 2026, it is forecasted.

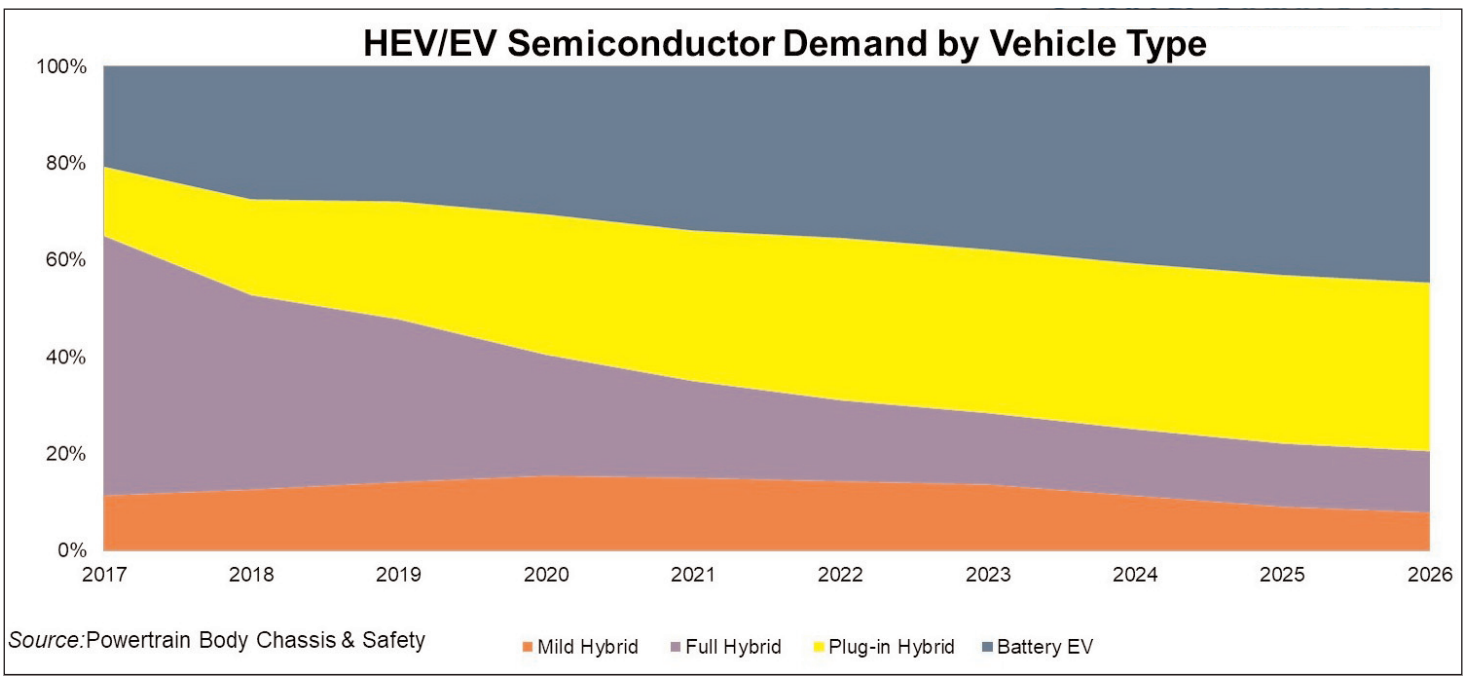
"SiC is the more mature of the two technologies, with 650V and 1200V parts starting to compete with Si-based components for the main inverter as well as getting some traction into the DC–DC converter and the OBC (on-board charger)," notes Chris Webber, senior VP of the Global Automotive Practice at Strategy Analytics. "However, we remain concerned that surety of material supply constraints as well as associated costs and yield issues could slow the implementation of SiC-based systems in the volume segments of the HEV/EV market," he adds.

Surety of material supply constraints as well as associated costs and yield issues could slow the implementation

"Efficiency is key in choosing the future power semiconductor architectures for HEV/EV platforms, and SiC and GaN technologies certainly offer significant advantages," observes report author Asif Anwar, associate director of the PBCS service. "However, silicon technology still has some performance overhead that it can tap into to improve switching losses and efficiencies, and this can be coupled with advances in packaging technology… Companies able to offer the full suite of technologies will be best positioned to take advantage of this growing power electronics semiconductor opportunity," he believes.

The report concludes that the power electronics market for wide-band semiconductors is at an early stage but offers significant upside potential for companies that are able to leverage the growing opportunity from the HEV/EV sector.

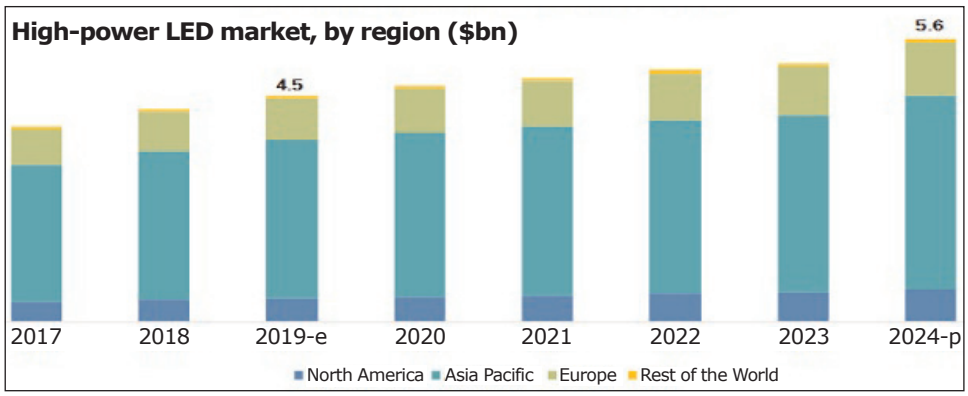
www.strategyanalytics.com



Hybrid electric vehicle/electric vehicle (HEV/EV) semiconductor trends, 2017-2026.

High-power LED market to grow at 4.5% CAGR from $4.5bn in 2019 to $5.6bn in 2024

The high-power LED market will rise at a compound annual growth rate (CAGR) of 4.5% from $4.5bn in 2019 to $5.6bn by 2024, according to a report 'High Power LED Market by Packaging Type (Flip Chip, Mesa, and Vertical), Application (General Lighting, Automotive, Flash Lighting, Backlighting,) and Geography (APAC, North America, Europe, Rest of the World) — Global Forecast to 2024' from MarketsandMarkets. The main factors fueling growth are the long life and continuous usage, small size, less power consumption and low voltage, as well as increasing high-brightness applications.



Mesa LED packaging leading the market

Mesa packaging (i.e. traditional horizontal packaging) is the standard chip design for lighting applications. Such LEDs do not require electrical conduction for the die bonding materials but require two wires electrically connected to the two electrodes on different sides of a substrate. Both the substrate and the die bonding materials must be electrically conductive. Despite currently leading the high-power LED sector, the use of this traditional horizontal LED packaging technology is likely to be limited in the near future due to its disadvantages compared with other packaging types.

High-power LED with vertical packaging to grow at considerable CAGR to lead market

Consisting of a conductive substrate at the bottom (forming a bottom electrode) so that current flows vertically, the vertical packaging structure is used predominantly for high- and superhigh-power applications. These advantages will help the market to grow at a higher CAGR than the mesa packaging, reckons the report.

General lighting to lead applications

Residential, commercial, industrial, outdoor and architectural lighting are the major segments in general lighting applications of high-power LEDs, with tremendous growth potential expected in the industrial, corporate and residential sectors due to their high efficiency and smarter lighting capability. As lighting applications comprise about 10% of global electricity consumption, improving the effectiveness of these light sources becomes essential to help reduce global carbon emissions. The use of high-power LEDs will improve energy efficiency and also provide high brightness, driving market growth.

Flash lighting applications to see high growth

Demand from mobile phone users for cameras providing high-quality image capture in dim light environments (such as night clubs and restaurants) has compelled smartphone makers to include high-power LEDs in a flash lighting module. Often the light available for taking photographs from mobile phones is insufficient, so the use of flashlight units as an additional light source is essential. Conventional LEDs produce 6–7lm, whereas high-power LEDs can deliver more than 80lm. The increased demand for smartphone applications will drive the high-power LEDs in a flash lighting application.

North America to be fastest-growing region

The USA is expected to be the main contributor to the high-power LED market in North America, based on its well-established economy; the presence of some leading high-power LED suppliers; and large demand from leading suppliers of smartphones, televisions, smart wearables, automotive lightings, and general lighting. Rapid adoption of the latest technologies, along with the growing number of applications, is another major factor contributing to the projected prominence of North America in the high-power LED market in the coming years. Many leading companies, such as HP, Dell and Apple, are headquartered in the USA, and are expected to play a key role in the growth of the high-power LED market for display backlighting application in North America. Cree and American Bright Optoelectronics are among the major high-power LED companies based in North America.

Europe to account for substantial share of market

With significant technological innovations taking place there, Europe is an important region in the high-power LED market, with the UK, Germany and France being key European countries that have been contributing significantly via key high-power LED manufacturing companies such as Osram, Lumileds and Plessey Semiconductors. Germany, UK, and France together are expected to hold a significant share of the high-power LED market, with general lighting and automotive lighting applications offering numerous growth opportunities.

www.marketsandmarkets.com/Market-Reports/high-power-led-market-199455057.html

GaN and SiC power semiconductor market to grow from $400m to $3bn by 2025

The gallium nitride (GaN) and silicon carbide (SiC) power semiconductor market will grow from over $400m to more than $3bn by 2025, according to the latest report by Global Market Insights Inc.

Power semiconductor devices are seeing rapid adoption for various power applications, fueling growth in the GaN and SiC power semiconductor market. As conventional silicon-based devices are approaching their material limits, silicon carbide and gallium nitride are becoming more popular and are being adopted across various industry verticals due to their higher dielectric field strength than silicon, notes the firm. Moreover, wider bandgap and thermal energy allows the material to withstand higher temperatures and voltages, making it a suitable substitute for silicon. The market has emerged significantly as the devices find applications in areas such as photovoltaic (PV) inverters, hybrid & electric vehicles (HEV), uninterruptible power supplies (UPS) and other power applications.

Various power industries are affected by energy loss, particularly during power conversion, so efficiency is a crucial factor to ensuring better performance. Limitations in achieving the required efficiency often lead to high costs. As a result, industry is focusing on adopting materials with more power-suitable characteristics, offering significant growth opportunities in the GaN and SiC power semiconductor market. These wide-band gap (WBG) devices have made it possible to make compact packaged electronic devices that have high power density. As the power semiconductor industry is aiming to develop devices with lower weight and low cost, this is creating opportunities for GaN and SiC power semiconductor markets.

Gallium nitride power devices have high growth potential for use in several power semiconductor applications, as the material can be used to enhance the electronic performance and power capacity. GaN offers several benefits over conventional silicon in transistors due to features such as high power density, system miniaturization and increased efficiency. While the power semiconductor industry has used mainly silicon for many years, companies are increasingly focusing on improving GaN device reliability for high-power systems. The exponential growth of GaN is expected to drive GaN and SiC power semiconductor market growth.

Semiconductor industry developments are one of the key factors influencing the market. By region, the USA comprises almost half of global semiconductor sales, at over $200bn in 2018, according to the Semiconductor Industry Association (SIA). Moreover, the US semiconductor industry spends one-fifth of its revenue on R&D activities, making it an important region for the market.

The GaN and SiC power semiconductor market is expected to gain traction in renewable energy applications. PV inverters are expected to adopt these devices to enable more efficient power conversion. Silicon carbide embedded PV inverters yield much lower switching losses and increase system efficiency. The use of SiC devices for PV inverters improves the power density by minimizing heat dissipation and can also reduce the size of passive components. The PV inverter applications for solar energy is expected to drive the GaN and SiC power semiconductor market in countries such as India and China. Efforts by several governments to increase the use of renewable energy are opening up new market opportunities for power devices, says the report. Countries like India are aggressively focusing on increasing their solar energy production capacity, targeting 175GW in 2022 according to India's Ministry of New and Renewable Energy. Moreover, the country saw the addition of 5.5GW energy based on wind capacity in year 2016–2017. This is expected to provide high market potential.

The rise in the application of insulated-gate bipolar transistor (IGBT) modules has become a prominent market driver, as they are being widely used in applications such as railway traction and propulsion, notes the report. Metros, electric & diesel-electric locomotives, tramways and high-speed trains are increasingly adopting IGBT modules. The capabilities of SiC to provide higher efficiency and lower losses are enabling its use in these modules. Automation companies such as ABB provide IGBT modules for railway applications.

The comparatively high device cost can be a restraining factor for the GaN and SiC power semiconductor market to some extent, comments the report. The conventional silicon materials for fabricating power devices have been used in the semiconductor industry for many years, and the market is not ready for an immediate switch to materials such as GaN, it adds. However, the benefits of the materials and their capabilities are expected to fuel market growth.

With many firms becoming inclined toward building more compact and highly efficient power semiconductor devices, Mitsubishi Electric Corp, Infineon Technologies AG, ROHM Semiconductor and NXP Semiconductors are some of the leading players in the GaN and SiC power semiconductor market. With companies focusing on R&D activities, the industry is seeing rapid technical advances. For example, Infineon spent 11% of its revenue on R&D in 2018. The firm is also expanding its production capacity for power semiconductors, including in May 2018 entering high-volume production of its silicon carbide MOSFETs.

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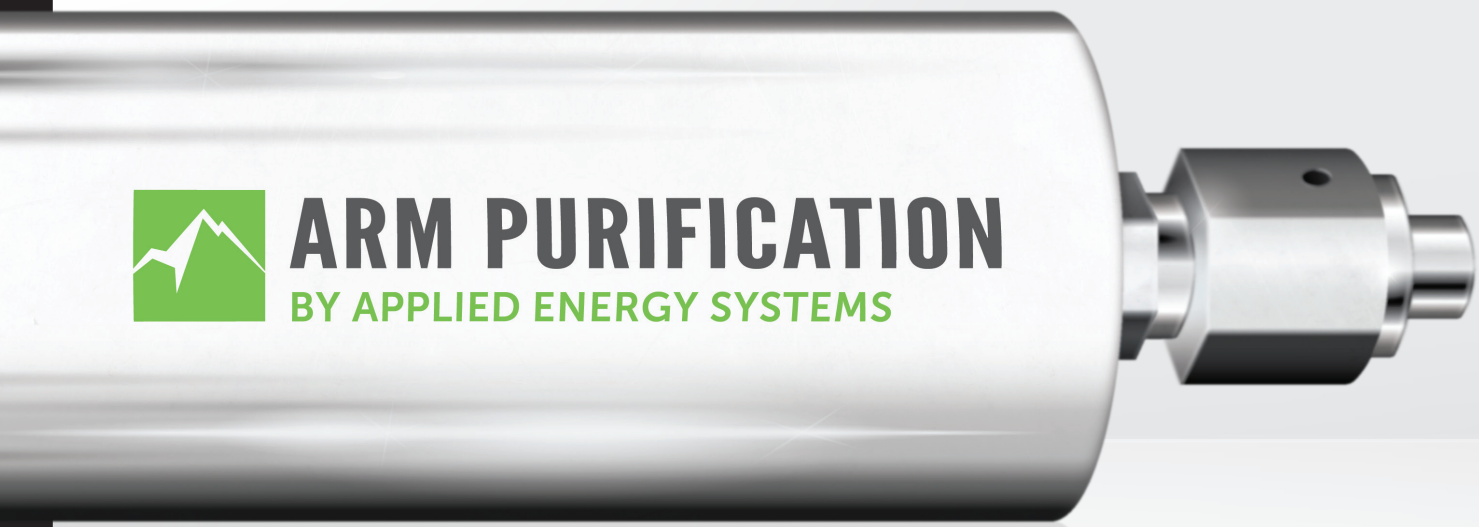

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Skyworks' sustainability report shows increased efficiencies across all major environmental categories

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) recently released its 2018 Sustainability Report, a voluntary, non-financial public document that provides a comprehensive self-assessment of the firm's sustainable business practices. The report highlights Skyworks' reductions in waste, energy and water usage, as well as progress across other areas including labor, ethics, health & safety, and management systems.

Skyworks says that, by utilizing well-established environmental management systems and setting aggressive targets, it has exceeded its internal goals, resulting in meaningful year-over-year improvements. Milestones in 2018 included:

- conserving 72,700 megawatt hours of energy (enough to power 6156 homes for one year);
- averting nearly 9300 tons of CO_2-equivalent emissions (comparable to removing 1974 passenger vehicles from the road for one year);
- saving 106 million gallons of water;
- avoiding the generation of 526,000 pounds of hazardous waste; and
- keeping 102,000 pounds of municipal waste from landfills.

"Skyworks is proud to have achieved significant efficiency improvements across all major environmental categories, particularly as we increased production and capacity," says Steven C. Machuga, VP of worldwide operations. "As an enabler of ubiquitous connectivity, we remain steadfast in our commitment to meet the growing demand for our wireless engines without compromising our sustainability initiatives."

www.skyworksinc.com/Sustainability

Skyworks launches front-end modules for Wi-Fi 6 applications

Skyworks Solutions has launched two front-end modules (FEMs), the 2.4GHz SKY85330-21 and the 5GHz SKY85748-11, suitable for enterprise 802.11ax (Wi-Fi 6) applications including, for example, access points, routers and gateways.

The fully integrated solutions feature a logarithmic power detector supporting wide dynamic ranges and low power consumption, enabling improved thermal management. They also deliver what is claimed to be industry-leading efficiency, suiting POE applications, and come in a compact 2.5 x 2.5 package for smaller footprint.

Both FEMs can be paired with leading enterprise 802.11ax reference designs.

www.skyworksinc.com/Category/109/Wi-Fi_Connectivity_Front-end_Modules

Skyworks expands 5G infrastructure portfolio

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has launched a broad range of proprietary solutions optimized for next-generation 5G wireless infrastructure applications. The firm's growing portfolio includes a family of high-efficiency amplifiers, switch low-noise amplifiers (LNAs), compact circulators and isolators, plus more fully integrated solutions for sub-6GHz and millimeter-wave frequencies — all designed to meet the high-performance requirements of 5G base stations.

Specifically, Skyworks' suite of miniature circulators is said to provide significant size advantages and leverages proprietary internal ferrite core procedures for improved isolation and reduced insertion loss.

The firm's high-power switches incorporate proven technology and patented design techniques to deliver products with fast switching speeds, increased power handling capabilities at extreme operating temperatures and low insertion loss. Given its vertically integrated supply chain — including diverse processes such as silicon, gallium arsenide and ceramics and high volume manufacturing and test facilities — Skyworks says that customers are further benefiting from highly integrated, customized architectures. As a result, it is delivering a breadth of infrastructure devices that are powering 4G LTE and emerging 5G NR networks for leading European equipment manufacturers.

Skyworks has strategically aligned our product development roadmap with 5G platforms. We are well positioned to capitalize on emerging opportunities

"Skyworks has strategically aligned our product development roadmap with 5G platforms," says David Stasey, VP & general manager of diversified analog solutions. "We are well positioned to capitalize on emerging opportunities and are leading the way in semiconductor integration as carriers upgrade their wireless networks," he reckons.

www.skyworksinc.com/Market/22/Wireless_Infrastructure

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pSemi announces new leadership structure

Murata company pSemi Corp of San Diego, CA, USA (formerly Peregrine Semiconductor Corp) — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has announced a new leadership structure. As reported in February, Sumit Tomar officially assumed the role of CEO on 1 July. In addition, Go Maruyama will be promoted to senior VP of administration, and two directors will transition into vice president positions.

Tomar has a track record of managing profit & loss, design-win strategy and revenue growth for wireless infrastructure, WLAN, industrial and automotive markets, says pSemi. He has driven strategic direction for numerous market-shaping products, including RF transceivers, RF synthesizers, power amplifiers (PAs) and RF multi-chip modules. Prior to joining pSemi, Tomar co-founded C-Ran Inc, where he designed and licensed a 5G RF system-solution prototype that solved issues of indoor coverage in 5G deployments. He has held high-level management positions at several prominent technology firms, including general manager at Qorvo, product line manager for High Speed Signal Path Solutions at Texas Instruments, and product line manager at Skyworks Solutions Inc.

Tomar (left) and Maruyama (right).

Tomar received a Master of Science in electrical engineering from Indian Institute of Technology (IIT), Roorkee and completed the Executive Management Program at Stanford University.

"Throughout Sumit's 20-plus year career, he has seamlessly brought numerous RF products to market, making him well-equipped to drive pSemi's growth trajectory," states chairman Jim Cable. "We recently celebrated the shipment of our 5 billionth chip... Sumit will be able to maintain this momentum in his new leadership role," he believes.

As senior VP of administration, Go Maruyama will have six direct reports, including VP of legal, intellectual property (IP) and licensing, sales & business development, information technology (IT), and corporate planning & development. His experience includes 20 years with Murata and its subsidiaries. As the current VP of corporate planning, Maruyama is responsible for managing pSemi's corporate strategy, promoting post-merger integration of merger & acquisition activities and acting as a liaison between Murata's local and overseas affiliates. From 2013 to 2017, he served as a general manager of marketing and business development for Murata Investment Co in Shanghai, responsible for creating new business in emerging markets, especially focusing on automotive, healthcare and energy. Prior positions at Murata Manufacturing Co include manager of corporate planning. Maruyama earned his MBA and master's degree in information technology from the Katz Graduate School of Business at the University of Pittsburgh and his bachelor's degree in economics from Keio University in Tokyo.

The restructuring also includes the promotion of Mark Moffat to VP of power and Rodd Novak to VP of corporate planning & development. Moffat joined pSemi in 2012 as the UK office's director of power management, overseeing IC innovation, product design and strategic marketing for the power division. Novak returned to pSemi in 2017 as a managing consultant to oversee corporate planning. Both positions will report directly to the senior VP of administration.

www.psemi.com

Chairman & CTO to spearhead Murata's semiconductor R&D growth

pSemi's chairman & chief technology officer Jim Cable has been selected by parent company Murata to spearhead its semiconductor R&D growth plans. He will continue as chairman of pSemi and as global semiconductor R&D director for Murata Manufacturing but with a more specific mission. He will report directly to Norio Nakajima, senior executive VP & board member for Murata Manufacturing.

Cable joined Peregrine in October 1993 and was promoted to CEO and chairman of its board of directors, where he championed its acquisition by Murata, which designs and makes ceramic-based passive electronic components and solutions, communication modules and power supply modules. With staff and manufacturing facilities worldwide, Murata is developing electronic materials and multi-functional, high-density modules. Peregrine was acquired to provide the technology expertise needed to further market penetration and add additional semiconductor technology to Murata's line of products.

"Jim has been a trusted expert and advisor to both Murata and me personally for years," says Norio Nakajima, senior executive VP & board member for Murata.

Cable has a Master of Science and Ph.D. from UCLA. He is listed on over 70 patents. "As the founders of RF SOI, I am encouraged that this technology is finally moving into the mainstream," he says. "I will explore an even wider swath of technology to help identify new ways to support Murata in its semiconductor growth initiatives."

Altum RF expands Eindhoven office with RF Test Lab

Expansion includes full RF measurement capabilities

Altum RF of Eindhoven, The Netherlands (a start-up that designs high-performance millimeter-wave to digital solutions for next-generation markets and applications) has announced the expansion of its Eindhoven office with an RF Test Lab.

Founded in 20018, Altum RF's engineers are employing decades of modeling expertise and system applications knowledge to develop products based on proven technologies like gallium arsenide (GaAs), gallium nitride (GaN), silicon germanium (SiGe) or RF CMOS for commercial and industrial applications. Working with both customers and global partners on technical support and customer service, the firm says it can significantly shorten product development cycles by managing the entire supply chain from design to packaging, testing and qualification. Applications span telecom, 5G, Satcom, radar sensors, test & measurement, aerospace & defense and industrial, scientific & medical (ISM) applications. Altum RF adds that it has strategic roadmaps to rapidly expand its product portfolio.

Altum RF's office on the campus of the Eindhoven University of Technology.

The firm's office is located on the campus of Eindhoven University of Technology and now includes full RF test and characterization infrastructure up to 40GHz. The RF lab also ensures ESD-safe measurements.

"Expanding our Eindhoven office with full RF measurement capabilities demonstrates our commitment to growing our European customer base," says CEO Greg Baker. "This investment also highlights our dedication to research and development to ensure our products are the most technologically advanced and offer the highest possible performance."

www.altumrf.com

Anokiwave highlights portfolio of silicon ICs for mmWave 5G, SatCom and radar at IMS

At the IEEE's International Microwave Symposium (IMS 2019) in Boston, MA, USA (4–6 June), 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 — showcased its portfolio of silicon ICs for millimeter-wave (mmWave) 5G, SatCom and radar applications. Anokiwave says that its design capabilities enable what are claimed to be the industry's highest-performing mmWave active antennas.

This year marks Anokiwave's 20th anniversary as well as the release of its third generation of mmWave dual-polarization 5G beam-former ICs (BFICs), intermediate-frequency (IF) up/down-converters (IFICs), and second generation of K/Ka- and Ku-band SatCom BFICs.

Anokiwave says that its 5G portfolio supports everything from macro-cells to small-cells to customer premises equipment (CPE) in the mmWave frequencies that are now in play: the existing 28GHz and 39GHz bands; the 24/26GHz band (for which the auction has just completed); and the 37/39GHz bands (scheduled for auction later this year). The 5G Gen-3 family features full RF signal chain functionality that improves performance, reduces cost, and provides digital functionality that simplifies the active antenna array design.

The Gen-2 Ku- and K/Ka-band SatCom beam-former IC family offers options for both of the key SatCom bands for ground, maritime and airborne equipment, while ensuring unmatched performance and low cost. The new IC family enables active antenna-based phased-array SatCom terminals that can auto-align and auto-position and support SatCom-on-the-move using LEO/MEO/GEO satellites.

Anokiwave's highlights at the IMS 2019 conference included:

- founder & chief technology officer Dr Nitin Jain received the IEEE Fellow award for 2019 recognizing his leadership in the development of physics-based models for mmWave system-on-chip (SoC) ICs.
- Jain and chief strategy officer Alastair Upton participated and presented in the IEEE 5G Summit, a special co-organized event between the IEEE ComSec and Microwave Theory and Techniques Society (MTT-S). With the 5G auctions taking place in the USA, and new systems announced almost daily, this year's event focused on the true 5G system roll-outs, with Anokiwave highlighting the commercialization aspect of 5G and the technical and economic factors related to the rollout.

www.ims-ieee.org
www.anokiwave.com

Fraunhofer ISE inaugurates Center for Power Electronics and Sustainable Grids

3000m² of lab and office space includes Power Converters Lab, Medium Voltage Lab and Multi-Megawatt Lab

The Fraunhofer Institute for Solar Energy Systems ISE of Freiburg, Germany has officially inaugurated its new Center for Power Electronics and Sustainable Grids in the industrial area in northern Freiburg. With a propriety connection to the 110kV high-voltage grid and 40MVA transformer, the new center is said to offer a unique research infrastructure that enables it to meet the growing demands on power electronics.

"In the future energy system, electricity will be provided not by a small number of conventional power plants but by many wind and solar power plants with fluctuating electricity generation. Thus, power electronics will assume a dominant role at all grid levels," says professor Hans-Martin Henning, director of Fraunhofer ISE. "Moreover, we require new components and functions, which enable inverters to provide stability and control for the power grid of the future," he adds.

The development of new power electronic components and systems with more advanced properties is one of the main challenges. To achieve this, silicon carbide (SiC) and gallium nitride (GaN) power semiconductors will be increasingly implemented. These devices operate with high frequencies, making power converters with higher power densities possible.

Also, new grid services will be investigated, especially with respect to the stability of future, inverter-based grids — focusing not least on procedures for testing the grid assistance capabilities of inverters, e.g. voltage and frequency stability. Other properties, such as active resonance damping in power plants and power grids or the grid-forming characteristics of inverters will be addressed in the near future.

Expansive lab facilities

The new center adds an additional 3000m² of lab and office space to Fraunhofer ISE. Three laboratories cover the various thematic areas of power electronics:

- The Power Converters Lab develops systems for the low-voltage range (e.g. photovoltaic systems, batteries, electric mobility and aviation).
- The Medium Voltage Lab (equiped to operate systems up to 20MVA power) develops and tests power electronics for the medium-voltage range.
- The Multi-Megawatt Lab can perform multiple tests in parallel, with different test blocks allowing operation ranging up to 10MVA and 1000V, i.e. wind generators, large battery storage systems or combined heat and power (CHP) systems.

The total actual power of 40MV is equivalent to the power supply of a small city with about 50,000 inhabitants. The center has its own proprietary research grid, which is completely disconnected from the supply grid of the surrounding vicinity. Additionally the center's R&D infrastructure will be enhanced by the Digital Grid Lab, which deals with simulations of load profiles and energy management systems. In this lab, Fraunhofer ISE will be able to further its expertise in grid simulation and real-time communication and investigate the performance of devices and systems at important grid nodes. Still in construction, the Digital Grid Lab is a further development of the existing Smart Energy Lab of Fraunhofer ISE (located in its main building).

Development, testing and certification

With the independent TestLab Power Electronics (certified according to DIN 17025.2005), Fraunhofer ISE is now widening its service range for industrial customers to include development, testing, refurbishment and certification services for components up to the multi-megawatt and the medium-voltage range. With a specially designed over- and under-voltage ride-through system enabling dynamic voltage variations, specific grid situations like over-voltage and under-voltage can be simulated or particular grid impedances can be emulated.

With four different test blocks and independent transformers, several aggregates can be tested either separately in parallel or together in interconnected micro grids.

"In these facilities, we can optimally address future research topics, for example inverter-based grids, hybrid power supplies and large storage systems," says Dr Olivier Stalter, division director of Power Electronics, Grids and Smart Systems at Fraunhofer ISE.

The project was supported by the German Federal Ministries for Economic Affairs and Energy (BMWi), for Education and Research (BMBF) and for the Environment, Nature Conservation and Nuclear Safety (BMU), which provided a total of €10m to Fraunhofer ISE. Fraunhofer ISE itself invested a further €5m in the new laboratory.

www.ise.fraunhofer.de

PowerAmerica names deputy director & CTO Victor Veliadis as executive director

The PowerAmerica institute — a member of Manufacturing USA — says that Dr Victor Veliadis has been named its executive director.

Under Veliadis' tenure as deputy director & chief technology officer, PowerAmerica has grown into a Manufacturing USA institute accelerating wide-bandgap power electronics commercialization and creating jobs in advanced technology. "We look forward to PowerAmerica's continued growth and success under Veliadis' leadership," says the institute.

PowerAmerica aims to save energy and create US manufacturing jobs by accelerating the development and large-scale adoption of wide-bandgap (WBG) semiconductor technology made with silicon carbide (SiC) and gallium nitride (GaN) in power electronics systems. Located at North Carolina State University

(NCSU) in Raleigh, NC, the institute is funded by the US Department of Energy, industry partners and the state of North Carolina, and has a member portfolio representing more than 45 leading companies in the wide-bandgap semiconductor field.

As executive director & chief technology officer of PowerAmerica, Veliadis manages a budget in excess of $30m per year that he strategically allocates to over 35 industrial, university and National-Laboratory projects, to enable US leadership in WBG power electronics manufacturing, workforce development, job creation and energy savings.

Veliadis has given over 60 invited presentations/tutorials and keynotes at major conferences in India, Korea, China, Europe and the USA. He is an IEEE Fellow and an IEEE EDS Distinguished Lecturer. He has 25 issued US patents, six book chapters and 115 peer-reviewed technical publications to his credit. He is also professor in Electrical and Computer Engineering at NCSU. Veliadis received a Ph.D. from Johns Hopkins University in 1995 in Electrical & Computer Engineering.

Prior to taking an executive post at Power America in 2016, Veliadis spent 21 years in the semiconductor industry, where his work included design, fabrication and testing of 1–12kV SiC static induction transistors (SITs), JFETs, MOSFETs, thyristors, and unction-barrier Schottky (JBS) and PiN diodes, as well as operations and financial planning of a commercial foundry.

www.poweramericainstitute.org

Power Integrations launches GaN-based InnoSwitch3 AC–DC converter ICs

Power Integrations of San Jose, CA, USA, which provides high-voltage integrated circuits for energy-efficient power conversion, has added new members of its InnoSwitch3 families of offline CV/CC flyback switcher ICs. The new ICs feature up to 95% efficiency across the full load range and up to 100W in enclosed adapter implementations without requiring a heatsink. This increase in performance is achieved using an internally developed high-voltage gallium nitride (GaN) switch technology.

Quasi-resonant InnoSwitch3-CP, InnoSwitch3-EP and InnoSwitch3-Pro ICs combine primary, secondary and feedback circuits in a single surface-mounted package. In the new family members, GaN switches replace the traditional silicon high-voltage transistors on the primary side of the IC, reducing conduction losses when current is flowing, and considerably reducing switching losses during operation. This results in substantially less wasted energy and therefore increased efficiency and power delivery from the space-saving InSOP-24D package.

Targeting high-efficiency flyback designs, such as USB-PD (power delivery) and high-current chargers/adapters for mobile devices, set-top boxes, displays, appliances, networking and gaming products, the new ICs provide accurate CV/CC/CP independent of external components, and interface to fast-charging protocol ICs. The InnoSwitch3-CP and -EP variants are hardware-configurable, while the InnoSwitch3-Pro incorporates a digital interface for software control of CV and CC setpoints, exception handing and safety-mode options.

"GaN is a pivotal technology offering significant efficiency and size benefits over silicon," says president & CEO Balu Balakrishnan. "We anticipate a rapid conversion from silicon transistors to GaN in many power applications," he adds. "InnoSwitch3 has been the clear technology leader in the offline switcher IC market since we launched the silicon variants 18 months ago," he claims, "and the new GaN-based ICs further extend our lead by advancing both the efficiency and power capability of our flyback products."

The new InnoSwitch 3 ICs are available now, priced at $4/unit in 10,000-piece quantities. Five new reference designs describing USB-PD chargers from 60W to 100W are available on the firm's website, along with an automated design tool, PI Expert, and other technical support documentation.

www.power.com

SUNY Poly awarded $1.5m by DOE's Vehicle Technology Office to develop 1200V SiC MOSFETs and highly efficient and reliable AlGaN HEMTs for power electronics

Additional NSF and ONR grants of $255,000 and $250,000 to develop more energy-efficient materials and high-voltage power devices on SiC

State University of New York (SUNY) Polytechnic Institute says that its interim VP of research advancement & graduate studies Dr Shadi Shahedipour-Sandvik and associate professor of nanoengineering Dr Woongje Sung have been selected to receive $1.5m in federal funding from the US Department of Energy's Vehicle Technology Office (VTO) for developing 1200V silicon carbide (SiC) metal-oxide-semiconductor field-effect transistors (MOSFETs) and for reliability studies on aluminium gallium nitride (AlGaN)-based high-electron-mobility transistors (HEMTs), as superior switch components than their silicon-based counterparts in areas such as cost, performance and reliability. This could lead to highly efficient and reliable power electronics for electric drive trains for applications including improved electric vehicles (EVs).

The award will enable "advanced power electronics research, which can have a significant impact on next-generation applications, including enhancing clean transportation capabilities," says SUNY Poly interim president Dr Grace Wang. "This VTO grant showcases the in-depth expertise of our faculty that, when combined with SUNY Poly's globally recognized research capabilities, drives advancements that can strengthen our nation's energy independence and benefit our high-tech economy… Undergraduate and graduate students will gain first-hand experience in this research area."

The VTO award will support research efforts through the new 'Electric Drive Technologies Consortium', of which SUNY Poly is one of the 10 founding university members (the consortium is supported by the Vehicle Technology Office and DOE. The grant will also provide research experience for SUNY Poly graduate students, as well as several undergraduate students who will also be encouraged to take part in aspects of the effort (including design, fabrication, characterization and analysis of the SiC power devices).

Specifically, SUNY Poly will demonstrate a highly reliable wide-bandgap (WBG) aluminum gallium nitride/gallium nitride (AlGaN/GaN) HEMT-based power device. Making use of the AlGaN/GaN material's properties to enable higher performance for HEMT on GaN compared with state-of-the-art HEMTs on other substrates (such as sapphire), the device is expected to have very high performance at certain frequencies with low noise, suiting high-speed, high-frequency applications.

Also, separate funding has been gained for the following projects:

- $255,000 from the US National Science Foundation (NSF) for the 'Development of More Energy Efficient Semiconductor Materials' — Shahedipour-Sandvik will research novel efficient p-type nitrides (used to create more energy-efficient semiconductors for advanced solid-state lighting and computing capabilities). The work will form the basis of a graduate student's thesis as well as the Capstone research of an undergraduate student and will be conducted in collaboration with Virginia Commonwealth University.
- $250,000 from the Office of Naval Research (ONR) in collaboration with The Ohio State University, the Naval Research Laboratory (NRL) and CoolCAD Electronics LLC for the 'Development of High Voltage Power Devices on Silicon Carbide' — Sung will develop 12kV SiC devices that could address US Navy needs such as medium-voltage distribution on more electric ships as well as direct power for critical needs during a mission and the degaussing of ships, rail guns and solid-state transformers. This could also lead to commercial applications, such as variable-speed drives for megawatt (MW)-class electric motors, 13.8kV distribution grid equipment, the incorporation of renewables on the distribution grid, and high-voltage DC (HVDC) transmission. Sung's team will design the device and process flow. After fabrication is complete, they will evaluate devices performance and reliability at SUNY Poly's Albany campus, where graduate and undergraduate students can participate in their design, fabrication, characterization and analysis.

The VTO award "will utilize our unique epitaxial growth system and baseline process to fabricate HEMT on GaN," says Shahedipour-Sandvik. Also, the additional NSF grant will "underpin research with our partnering institution into novel materials for more energy-efficient lighting and computing capabilities, which are critical for the future because of the vast energy consumption resulting from current, less efficient computer chips," he adds. Research opportunities will provide "an excellent hands-on lab experience which can act as a launching pad for a number of our SUNY Poly graduate and undergraduate students."

"We will design the device and process flow before evaluating the performance and reliability of the SiC devices at SUNY Poly's state-of-the-art facilities," notes Sung. "In addition to this project serving as an excellent educational opportunity for SUNY Poly students, I am also honored to have received a separate grant from the ONR and look forward to working with our partners to develop high-voltage SiC power devices for a number of critical defense and commercial applications."

www.sunypoly.edu

Ascatron secures €3.5m funding for 3DSiC product development

Production process to be qualified in Q4/2019 for 1200V and 1700V JBS diodes then Q2/2020 for MOSFETs

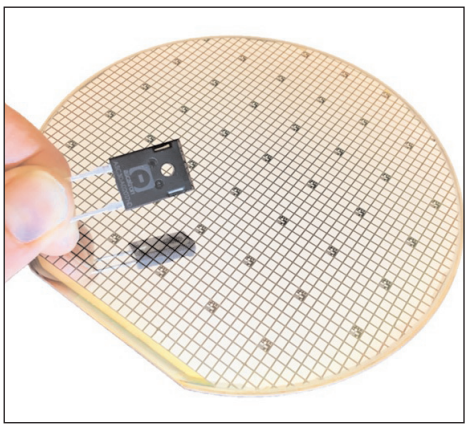
Ascatron AB of Kista, Stockholm, Sweden (which was spun out of research institute Acreo in 2011) recently completed the sale of shares in a joint venture company in China, hence securing €3.5m funding to continue the independent development of its own products.

Ascatron develops silicon carbide (SiC) power semiconductors using its proprietary 3DSiC technology. The company focuses on supplying bare silicon carbide dies for both power modules and discrete components.

The business model is semi-fabless, where Ascatron designs the power device and maintains in-house production of the key epitaxy material (with development and material production in Stockholm), while chip fabrication is outsourced (with the fabrication process for volume production of SiC power diodes and MOSFETs established at an automotive-qualified SiC foundry).

In addition to the general advantages of SiC, Ascatron says that its 3DSiC technology enables up to 30% lower power dissipation, higher current density and improved reliability.

"We use advanced epitaxial growth as part of the manufacturing process of our SiC devices to form buried doped structures as voltage-blocking elements," says chief technology officer Adolf Schöner. "These structures protect the sensitive die surface from high electric fields and allow device designs optimized for high power ratings," he adds. "The key performance advantages are 15–30% higher current density and reliable operation even at elevated temperatures".



A 150mm device wafer with Ascatron 3DSiC JBS diodes rated for 1700V and 20A.

The first 3DSiC devices available for design-in projects with customers are 1200V and 1700V junction-barrier Schottky (JBS) diodes. The production process is expected to be qualified in fourth-quarter 2019. The design is modular and can be tailored to application-specific requirements. MOSFETs will be ready for production in second-quarter 2020.

"The cost advantage of our 3DSiC devices comes into play especially at higher voltage and current ratings," says CEO Christian Vieider. "The near-term target for our SiC diodes are 1200V and 1700V power modules. Next step will be to scale up our SiC device wafer capacity together with our production partners."

Ascatron produces its SiC epitaxy material with what it claims to be state-of-the-art thickness and doping homogeneity also for thick layers, enabling a high manufacturing yield for devices with high voltage and high current ratings. The firm will continue to provide its industry-proven SiC epitaxy services to customers.

www.ascatron.com

Transphorm awarded $15.9m extension to $2.6m base ONR contract to establish US source of GaN epi

Project to produce first commercialized N-polar GaN for RF/millimeter-wave for DoD/5G applications

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified high-voltage (HV) gallium nitride (GaN) field-effect transistors (FETs) for high-voltage (HV) power conversion applications — says that the US Department of Defense (DoD) Office of Naval Research (ONR) has exercised a three-year $15.9m option on an existing $2.6m base contract with the company. This contract (N68335-19-C-0107) — administered by the Naval Air Warfare Center Aircraft Division in Lakehurst, NJ (NAWCAD Lakehurst) — establishes Transphorm as a US-based dedicated production source and supplier of GaN epiwafers for DoD and Commercial radio frequency (RF)/millimetre-wave (mm-wave) and power electronics applications. The award comprises a Base Program for key technology development and an Option Program to establish production-scale capability.

The program's core objective is to go beyond the incumbent Ga-polar GaN technology by commercializing nitrogen-polar (N-polar) GaN, which holds significant promise for the continued advancement of GaN-based electronics, in both existing RF electronics and future power conversion systems. The technology was invented under ONR and DARPA sponsorship at the University of California, Santa Barbara (UCSB) by the team of Umesh Mishra, Distinguished Professor at UCSB and Transphorm's co-founder, chief technical officer & chairman.

"The N-polar orientation of the material is reversed from the traditional Ga-polar GaN currently being widely used in base-station and DoD applications," says Mishra. "The flip produces radical benefits in output power, along with groundbreaking efficiencies to frequencies as high as 94GHz," he adds. "Applications span the frequency range of interest for 5G, 6G and beyond, and also fill a critical technological void for DoD systems."

At 94GHz, Mishra's UCSB team has demonstrated mm-wave devices with record power densities and high efficiencies. These devices simplify RF electronic systems by reducing the need for power combining multiple components and devices, while also simplifying cooling systems, ultimately resulting in higher performance at reduced cost.

As supplier of high-quality, high-reliability (Q+R) HV GaN FETs (currently in production with several customers), Transphorm has a vertically integrated business approach (spanning design, fabrication, device and application support), expertise, IP and a production-scale MOCVD epi growth platform. With this ONR program, it will address epi capability on multiple platforms, including silicon carbide (SiC), silicon and sapphire substrates ranging from 4-inch to 6-inch and ultimately 8-inch wafers. In the RF and mm-wave area, Transphorm will be a pure-play epiwafer supplier focused solely on GaN materials.

"We are excited to partner with the ONR and DoD to commercialize our high-performance GaN HEMT IP and epitaxy capability, specifically via the breakthrough N-polar and Ga-polar materials on various substrates, including silicon carbide, sapphire, and silicon," says co-founder & chief operating officer Primit Parikh. "This enables Transphorm to grow an adjacent vertical, that of epiwafer sales for DoD customers and fast-growing RF/5G markets," he adds. "We are already seeing demand and are excited to go from purchase to production in less than 36 months, a key program goal."

Transphorm says that, as with all its GaN products, the epiwafer offerings will be backed by: rapid development; production scalability; uniform, high-yielding wafer products; and statistical process control (SPC) manufacturing.

Design resources and support includes: Ga-polar and N-polar GaN baseline processes on multiple substrates of various diameters; a comprehensive suite of GaN epiwafer characterization equipment; and MOCVD experts to align on specific customer requirements.

www.transphormusa.com

Raytheon submits Lower Tier Air & Missile Defense Sensor proposal

Raytheon Company of Waltham, MA, USA has submitted its Lower Tier Air and Missile Defense Sensor proposal to the US Army as part of the competition for a new air and missile defense radar.

The firm's LTAMDS solution is a simultaneous 360º, active electronically scanned array (AESA) radar powered by Raytheon-manufactured gallium nitride (GaN), which strengthens the radar signal and enhances its sensitivity.

"Our proposal offers the Army a brand-new radar that overmatches the future threat," says Tom Laliberty, VP of Integrated Air and Missile Defense at Raytheon's Integrated Defense Systems (IDS) business in Tewksbury, MA, USA. "We brought our LTAMDS solution to the US Army's sensor demonstration and validated our ability to meet their 2022 urgent material release date."

Raytheon's LTAMDS offering was demonstrated in a 'sense-off', which put it through a series of challenging scenarios. The firm completed its sense-off participation on 15 May.

"We created a new radar because a re-designed, modified or upgraded radar simply can't defeat the type of advanced threats the US Army will face," says Doug Burgess, Raytheon's LTAMDS program director. "Our solution is proof that the Army can have it all — a capable next-generation radar, at an affordable price, fielded as quickly as possible."

Raytheon assembled a team of US-based partners (Crane Aerospace & Electronics, Cummings Aerospace, IERUS Technologies, Kord Technologies, Mercury Systems and nLogic) who played a strategic role in its proposed LTAMDS solution.

www.raytheon.com/capabilities/products/ltamds

AKHAN names vice admiral to board

AKHAN Semiconductor Inc of Gurnee, IL, USA — which was founded in 2013 and specializes in the fabrication and application of lab-grown, electronics-grade diamond as functional semiconductors — has appointed vice admiral Charles W. Moore Jr to its board.

Moore is a 36-year veteran of the United States Navy, who began his military career as a Naval Aviator and rose to the rank of vice admiral serving as the deputy chief of naval operations for Fleet Readiness and Logistics and as commander of the United States Fifth Fleet and commander of the US Naval Forces Central Command headquartered in the Middle East in Bahrain.

"The technology developed by private companies is crucial to the US Military's success, and AKHAN's Miraj Diamond technology is critical in that it can be applied to a number of capabilities to increase durability and efficiency," comments Moore.

On retiring from the US Navy in 2004, Moore joined Lockheed Martin as vice president, F-35 Program Assessment. Subsequently, he was VP, global sustainment and president of Lockheed Martin Middle East and Africa. After retiring from Lockheed Martin in 2013, Moore joined the Dodsal Group, where he was chair and president of Dodsal Resources (an oil & gas exploration and production firm in the Dodsal Group). He was also chairman of Dodsal Group's executive board, before retiring from Dodsal in 2016.

"As AKHAN continues to apply our Miraj Diamond technology to more military and defense capabilities, vice admiral Moore will be instrumental in identifying new opportunities and helping us refine the technology to ensure we're providing solutions that meet the US military's needs," says founder & CEO Adam Khan.

www.akhansemi.com

SkyWater commissions SkyTech Center to accelerate custom process technology development

Center enables specialized processing capabilities for carbon nanotubes, silicon photonics, superconducting ICs and MEMS

SkyWater Technology Foundry of Bloomington, MN, USA — a solely US-owned Trusted Foundry that manufactures differentiated integrated circuits in markets including aerospace & defense, automotive, cloud & computing, consumer, industrial, the Internet of Things (IoT) and medical — has announced its new SkyTech Center as an expansion of its operations to enhance advanced processing capabilities at its US-based manufacturing facility.

SkyWater says that it sees a growing industry need for custom process development and has made a strategic investment to repurpose cleanroom space previously used for testing to lay the ground for further company growth and new customer engagement. The SkyTech Center will also serve as the environment where critical tasks supporting DARPA's 3DSoC (Three-Dimensional Monolithic System-on-a-Chip) ERI (Electronics Resurgence Initiative) program will be performed, including carbon nanotube (CNT) deposition and lift-off metallization.

SkyWater says that its Technology Foundry model is filling an industry need for new device topologies that are capable of being produced at scale and are not available in traditional foundry manufacturing facilities. The new SkyTech Center allows customers to develop in a quality-focused fab environment that enables faster processing and ramp to volume production. It also accommodates customers who want to place their own dedicated tools in SkyWater's facility, enabling development embedded in a fab ecosystem, co-located with other capabilities needed to streamline commercialization.

Our Custom Foundry business grew approximately 50% in 2018 and is tracking at that same rate for 2019

"The unique aspects of this investment, coupled with SkyWater's 200mm manufacturing infrastructure, provides an ideal environment to enable emerging novel technologies to quickly transition to manufacturable products at the right scale," comments Dan Hutcheson of VLSI Market Research.

"Our Custom Foundry business grew approximately 50% in 2018 and is tracking at that same rate for 2019, reinforcing the trend we see in the market for advanced process development activities for an increasingly diverse field of high-technology devices," notes SkyWater's president Thomas Sonderman. "The addition of the SkyTech Center is an example of investments we are making to enable capabilities in which we see a growing demand as the industry transitions to a new era of hybrid architectures."

www.skywatertechnology.com/mpw-fastshuttle

Littelfuse breaks ground on new power semiconductor assembly facility in Philippines

Littelfuse Inc of Chicago, IL, USA, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), says that it recently broke ground on a new power semiconductor assembly plant in Lipa City — its third manufacturing facility in the Philippines — dedicated to assembly and test operations for power semiconductor modules.

The new, highly automated facility will increase the firm's footprint in the Philippines by more than 60% and will add power semiconductor modules to the sensor and circuit protection technologies currently manufactured in the country. Once completed in 2021, the new plant expects to add over 200 new jobs.

"Building on the IXYS acquisition and the high-performance power semiconductor products we added to our portfolio, the investment in this new, state-of-the-art facility in the Philippines will further expand our power semiconductor capabilities — a key driver of the Littelfuse growth strategy," says Mike Rutz, senior VP & general manager, Littelfuse Semiconductor business unit. "Over the last two decades, our existing Philippines sites have developed a reputation for strong operational excellence and we will build on that foundation to deliver the highest-quality power semiconductor products and unmatched customer support."

Littelfuse Philippines received the 2018 AME Excellence Award from the Association for Manufacturing Excellence. The AME Excellence Award primarily recognizes manufacturing plants that have demonstrated excellence in manufacturing and business, acknowledging continuous improvement, best practices, creativity and innovation.

www.littelfuse.com

Akash Systems raises $14.5m in Series A round

Funding to aid scaling transmit/receive radio modules and power amplifier business

Akash Systems Inc of San Francisco, CA, USA — which is focused on developing and supplying small satellites (CubeSats) and the RF power amplifiers (based on GaN-on-diamond) that power them — has raised $14.5m in its Series A funding round, including $10m in new equity funds and an additional $4.5m converted from prior convertible notes. Investors include Khosla Ventures, Founders Fund, ACME Capital, Sriram Krishnan, and Correlation Ventures. Akash will deploy the new capital toward scaling its transmit/receive radio modules and power amplifier business, moving it closer to profitability. "Our aim is to be the RF communications link for every satellite in space," says co-founder, CEO & GaN-on-diamond inventor Felix Ejeckam.

Akash has designed its satellite transmit/receive radio modules to easily integrate with existing ground-station and satellite infrastructure for satellite makers in all markets. Its radios, which are expected to be available for purchase in late 2019, promise performance not yet seen on the market, it is claimed.

"Akash Systems is playing a critical role in meeting the growing and vital need for improved satellite communications infrastructure," comments Delian Asparouhov of Founders Fund, which is focused on assisting entrepreneurs to build impactful new energy and technology companies.

"It's rare to see a young company with such transformative technology already approaching commercialization," says ACME's Alex Fayette. "Akash's business lies squarely at the intersection of major trends like global connectivity, high-performance telecommunications and space-based infrastructure. Their foundational technology will underpin other solutions across these industries," he adds.

Akash is currently manufacturing GaN-on-diamond-based power amplifiers and radio modules for customers who make satellites requiring high frequency and high power efficiency

"What Akash has been able to achieve in its first few years is remarkable, as it has already attracted major customers across the ecosystem," notes angel investor Sriram Krishnan. "The company is quickly shaping trends in global telecommunications."

In GaN-on-diamond, the hottest part of a transistor is brought to within tens of nanometers of synthetic diamond (the most thermally conductive material ever made), yielding a dramatic reduction in the waste heat generated from the power amplifier and hence the entire satellite system (since, in the communications base stations of space, the RF power amplifier is typically responsible for the bulk of the power consumed and the heat generated). The cooler state of operation gives RF and satellite system designers a previously unattainable thermal envelope to improve a satellite's communication bandwidth and energy efficiency while simultaneously shrinking the system's size, weight and operating costs, says Akash.

Akash is currently manufacturing GaN-on-diamond-based power amplifiers and radio modules for customers who make satellites requiring high frequency and high power efficiency. Its radio products are on track to hit the market in fourth-quarter 2019.

www.AkashSystemsInc.com

UKRPIF making £30m investment in new Centre for Integrative Semiconductor Materials at Swansea University

South Wales-based center to bring together semiconductor manufacturing and R&D

At a showcase event in London of the UK Research Partnership Investment Fund (UKRPIF), Chris Skidmore MP, UK Minister of State for Universities, Science, Research and Innovation, has announced a £30m capital investment for the new Centre for Integrative Semiconductor Materials (CISM), which is to be built at Swansea University's Bay Campus.

UKRPIF requires double-match funding from non-public sources (i.e. business, charities or philanthropic sources) so CISM will also receive support worth nearly £60m from major South Wales-based semiconductor companies in the CS Connected cluster alongside nine other industry partners, aiming to ensure the center's sustainability in the long-term.

Eleven projects are being funded through Round 6 of UKRPIF, totalling over £670m of new investment into UK research and innovation. Funding includes £221m of public funding from UKRPIF and over £450m of committed co-investment from businesses, charities and philanthropic donors.

The CISM building, which is expected to be completed in first-half 2021, will be a hub where manufacturing is brought together with R&D. The center aims to pioneer new technologies and products as well as growing and nurturing skills and talent for the UK semiconductor industry.

Swansea University academics will work with partners at Cardiff University in South Wales and other UK universities to support the growth of the semiconductor industry by addressing their needs, not only in the short and medium terms but charting the long-term future with innovative, application-driven R&D. It will also provide a range of services such as prototyping and process development, specialist analytical services, incubation, engagement, training and access to the UK and EU innovation grants portfolio.

The three-story building will house a clean fabrication environment, research laboratories and office facilities and will use sustainable, energy efficient building techniques and renewable energy technology including solar photovoltaics and heat recovery.

"The UK semiconductor industry is growing rapidly and is an emerging jewel-in-the-crown of British manufacturing. This UKRPIF funding will allow Swansea University to play our part in underpinning its continued development — driving innovation, providing capability, expertise and training," says professor Paul Meredith, the Ser Cymru National Research Chair and Swansea University CISM project lead.

The CISM concept was jointly developed by the Swansea University team in collaboration with the regional industry in the CS Connected cluster. Engineers from the partners have helped to design the proposed new facility and bring industrial principles to the new building.

"This investment in CISM will help the compound semiconductor cluster establish breakthrough technologies at the heart of the fourth industrial revolution," believes Sam Evans, director of external affairs of Newport Wafer Fab, UK's largest semiconductor campus and a CS Connected partner.

"CISM is a genuine example of industry, universities and multiple levels of government coming together to support economic growth and job creation in an area of significant opportunity," comments Kevin Crofton, corporate executive VP at Orbotech and president of Newport-based semiconductor equipment maker SPTS Technologies Ltd, who is also chairman of the South Wales-based Compound Semiconductor Applications Catapult.

http://csconnected.com
www.swansea.ac.uk/campus-development/developing-bay/key-projects-bay/cism

5N Plus investing $10m in capacity, capability and growth sustainability

Engineered materials and specialty chemicals producer 5N Plus Inc of Montreal, Quebec, Canada has begun to execute a plan to invest over $10m in process technologies aimed at substantially increasing capacity of its existing assets while enhancing its capability along with providing environmental benefits in local communities. The investment package is expected to be focused on select sites in North America, Europe and China. The plan should be fully implemented by third-quarter 2020, with certain investments to be fully commissioned beforehand. The average payback for this tranche of investments is estimated at about three years.

5N Plus provides purified metals such as bismuth, gallium, germanium, indium, selenium and tellurium, and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications.

As per its 5N21 strategic plan launched in 2016, the firm's management has limited capital expenditure to $50m over 5 years, and this package of investments is part of this total sum. 5N21 has been designed to transform the firm and aims to significantly enhance its earnings.

"We are experiencing strong demand for a number of our products and, with select investments in process technology, we will markedly enhance productivity while increasing production throughput across our existing assets, with emphasis on sustainably and managing our leadership position in the industry and the communities we serve," says Paul Tancell, executive VP of Eco-Friendly Materials.

"Through targeted investments, we will accentuate our leadership position in high-purity materials and will ensure optimal positioning to capture the growth opportunities foreseen in the markets of security, aerospace, sensing, imaging and renewable energy," says Nicholas Audet, executive VP of Electronic Materials. "Upon implementation, we will increase production capacity, improve yields and will further reduce the environmental footprint of our activities."

www.5nplus.com

IQE begins VCSEL production for second major customer at Newport Mega Foundry

IQE says its Newport Mega Foundry has started initial vertical-cavity surface-emitting lasers (VCSEL) production for a second major customer, serving the Android supply chains. Also, several more clients are in advanced stages of qualification. Performance data from the Newport foundry has exceeded previously attained performance levels, and several new qualifications are now in long-term reliability testing.

IQE has hence signed a contract extension with one of its largest VCSEL customers, extending the current contract until the end of 2021. In addition, two other existing contracts have also been extended with several other new contracts in final negotiations.

VCSELs are a key component in multiple existing and future 3D sensor systems, using both structured light and time-of-flight (ToF) technologies. Applications range from 3D facial identification (front-facing) systems and world-facing cameras on mobile handsets to light detection & ranging (LiDAR) and in cabin sensing for autonomous drive vehicles, range-finding and 3D sensing systems for a wide range of industrial and commercial applications. Production volumes should ramp strongly over the next few years as adoption across multiple mobile platforms and other use cases proliferate. IQE has hence invested heavily over the last two years in building what is claimed to be the world's largest VCSEL epi-wafer facility in Newport. IQE says it is involved in multiple engagements across all of the aforementioned applications, and is currently qualifying more than a dozen volume customers at the Newport Mega Foundry.

"The initiation of production for a second major customer at our Newport Mega Epi Foundry is another important milestone in cementing Newport as the premier location globally for large-scale, state-of-the-art VCSEL production," says Dr Mark Furlong, executive VP, global business development, Photonics and InfraRed. "Availability of the large-scale production capacity which has been established over the last 18 months at Newport, and consequent improvement in production efficiency and performance, is highly valued by our customers as they address mass-market adoption across multiple applications."

Executive Management Board formed as chief operating officer retires

IQE has announced the planned retirement of chief operating officer (COO) Dr Howard Williams.

Williams was a founding member of EPI in 1988 (which became IQE in 1999) and was appointed to the board as COO in 2004. He steps down from the board at the end of July but remains employed in a full-time capacity for the rest of 2019, after which he will remain engaged with IQE on a part-time basis as a consultant advisor.

"Howard has been pivotal in the development of the business from start-up to becoming the global leader in compound semiconductor wafer production," comments CEO Dr Drew Nelson. "His technical and project management skills have been outstanding, culminating in the design and build of our new Mega Foundry in Newport. Now that it is up and running in production, Howard has decided to execute his long-term retirement plan, stepping down from the board at the end of the month, but maintaining a full-time role for the next six months and thereafter, providing support on a part time basis," he adds. "He has built and mentored a very strong team, and executed a clear succession plan."

As part of the continuing development of its organizational structure and to maximize the opportunities ahead, IQE has formed an Executive Management Board to work with the CEO and CFO., initially comprising:

- Dr Rodney Pelzel as executive VP, global innovation (CTO) — After joining IQE in 2000 as a production engineer, he held operational and technology roles then was made VP of technology in January 2015.
- Keith Anderson as executive VP, global operations (COO) — Having joined IQE from Collins Aerospace in August 2018 as VP of global operations , he replaces Williams on the boards of IQE's Taiwanese subsidiary and CSC Ltd (IQE's joint venture with Cardiff University).
- Dr Wayne Johnson as executive VP, global business development, Wireless and Emerging Products — After joining IQE in 2013 with the acquisition of Kopin (where he was VP of technology), he became head of IQE's Wireless business unit in January 2017 and this April assumed responsibility for the Emerging Products Group.
- Dr Mark Furlong as executive VP, global business development, Photonics and InfraRed — After joining IQE in 2000 as head of sales for the Asia region, he is now leader of IQE's InfraRed business unit (including substrate manufacturing activities).

The executive management board will provide "clear focus, energy and accountability in driving the many high-growth opportunities which lie ahead for the group, with the upcoming deployment of 5G and IoT, and all the associated advanced technologies which will both drive and result from such deployment," says Nelson.

IQE announces qualification and initial production of HBTs at Taiwan facility for Asian customer

Orders received from second Asian customer; Singapore facility qualified for new Asian customer for pHEMTs

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has announced the qualification, commencement of initial production and receipt of additional orders of wireless products for Asian supply chains.

As previously communicated, because of the current trade situation between the USA and China, supply chains are being redeveloped across the globe, impacting sales volumes for IQE's products as global customers adjust to these new supply chain situations and IQE becomes qualified in these new supply chains.

However, IQE reckons that it remains well placed to support these changes because of its diverse global footprint, with manufacturing plants in the USA, Europe and importantly in Asia (Taiwan and Singapore), and its portfolio of wireless products.

IQE has now qualified with a major customer in Asia for new Asia-centric supply chains for heterojunction bipolar transistors (HBTs), used as power amplifiers (PAs) in mobile handsets, WiFi hotspots and other wireless devices. Initial production for this customer has now begun and additional qualification of significantly higher production capacity is underway from the newly installed capacity at IQE's facility in Hsinchu, Taiwan.

In addition, significant further orders have been received by IQE from a second Asian customer, specifically addressing increased demand from Asian OEMs.

Finally, IQE's Singapore operation has also completed qualification of a new Asian customer for pseudomorphic high-electron-mobility transistors (pHEMTs), used in wireless devices and networks. IQE has already received initial orders for production.

"These new qualifications for Asian supply chains reflect the strength of IQE's global manufacturing footprint, our leading product portfolio and our ability to quickly respond to the rapidly changing supply chain dynamics," says Dr Wayne Johnson, executive VP, global business development, Wireless and Emerging Products. "We look forward to significantly increasing both the volume and breadth of products we are able to provide to these new Asia-centric supply chains, including products currently under development such as filters and high-performance switches."

www.iqep.com

HEA2D project completes demonstration of end-to-end processing chain of 2D nanomaterials

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that, together with five partners, it has successfully investigated the production, properties and applications of two-dimensional (2D) nanomaterials in the HEA2D project, which has been supported by the European Regional Development Fund (ERDF) 2014–2020.

Aixtron's partners for implementing systems technology and integrating materials into plastic molded parts have been the Fraunhofer Institute for Production Technology (IPT), Coatema Coating Machinery GmbH, and Kunststoff-Institut für die mittelständische Wirtschaft NRW GmbH (K.I.M.W.) Lüdenscheid. The work was supported in terms of nano-analytics and the development of prototype components by the Electronic Materials and Nanostructures workgroup in the Engineering Faculty of the University of Duisburg-Essen (Uni-DuE) and by the Graphene-based Nanotechnology workgroup in the Science and Technology Faculty of the University of Siegen.

The conclusion is that 2D materials integrated into mass-production processes have the potential to create integrated and systemic product and production solutions that are socially, economically and ecologically sustainable. Application areas for the technologies developed and materials investigated in this project are mainly composite materials and coatings, highly sensitive sensors, power generation and storage, electronics, information and communication technologies (ICT) as well as photonics and quantum technologies.

In addition, the knowledge gained in the project has led to further development of existing system technology. Together with the project partners, prototype systems and demonstrators for 2D semiconductor materials have been manufactured and successfully tested.

www.aixtron.com

Aixtron delivers 3x2" CCS MOCVD system to Nagoya University for research on DUV opto devices

Aixtron says that it has delivered a Close Coupled Showerhead (CCS) system to Nagoya University in Japan. Installed at the university's Institute of Materials and Systems for Sustainability (IMaSS), the 3x2-inch Flip Top CCS metal-organic chemical vapor deposition (MOCVD) platform is intended for research on gallium nitride (GaN)-based deep-ultraviolet (DUV) optoelectronic devices.

Nagoya University is a leading Japanese research institution for semiconductor materials, especially in the field of GaN-based structures. By focusing on the development of DUV devices using Aixtron's 3x2-inch Flip Top CCS MOCVD tool, IMaSS is targeting a wide range of future-oriented applications in areas such as agriculture, health or water purification.

Designed especially for research and small series production, the Aixtron system enables real scaling from R&D to large series production. The firm says that its Close Coupled Showerhead concept inherently allows extremely uniform and reproducible deposition of various complex, mostly single-crystal materials. The flexibility of the reactor design enables not only further development of existing materials and their application in future devices but also extensive research into completely new materials, their properties and potential applications.

"Our Closed Coupled Showerhead Flip Top reactor is characterized by its easy maintenance and lowest running cost," says Aixtron's president Dr Bernd Schulte. "The system is one of the most successful Aixtron products, as proven by numerous orders from universities, laboratories and other research institutions worldwide," he adds. "We are looking forward to closely cooperate with Nagoya University and its renowned IMaSS."

Veeco presents at ALD/ALE 2019 conference

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that its technologists presented three papers and posters at the AVS 19th International Conference on Atomic Layer Deposition (ALD 2019) in Bellevue, WA, USA (21–24 July).

The conference, which coincided with the sixth annual International Atomic Layer Etching Workshop (ALE 2019), is dedicated to the science and technology of atomic layer controlled deposition of thin films and new topics related to atomic layer etching.

Veeco presentations included VP of applied technology Ganesh Sundaram, in collaboration with North Carolina State University, in the session 'High Performance ALD of Gate Dielectrics for 4H-SiC Power Device Application'.

www.veeco.com

Unity-SC demos capability for detecting non-scattering potential killer defects on GaAs wafers for VCSEL maker

Working with a key manufacturer of vertical-cavity surface-emitting lasers (VCSELs), inspection and metrology equipment maker Unity Semiconductor SAS of Montbonnot-Saint-Martin, Grenoble, France (Unity-SC) has been able to improve their yield by sorting out wafers that presented defects only visible using the LIGHTsEE PSD (Phase Shift Deflectometry) system. If not detected, these defects can lead to failure later in the process or after system delivery.

Over the last decade, VCSELs have attracted increasing interest in many fields for their unique optical and electrical properties, coupled with their advantages in terms of in-line testing and manufacturability, notes Unity-SC. Mostly based on gallium arsenide (GaAs) wafers for red to infrared (IR) wavelengths, they are widely used in light detection & ranging (LiDAR) and 3D recognition. Due to automotive applications, the LiDAR market is growing rapidly with the need for failure-free devices. 3D sensing also represents a very large market, as smartphone makers are now embedding such sensors for face recognition. As such, the need for high-quality and high-reliability GaAs inspection systems is growing constantly, adds the firm.

On top of common surface scanning inspection systems (SSIS) and automatic optical inspection (AOI) systems, Unity has demonstrated what it claims is its unique capacity for detecting otherwise invisible topographic defects. These defects are not visible on standard optical inspection systems, since they do not scatter or absorb light, and can only be revealed by their topography. While they have little impact on the structural quality of the substrate itself, they can lead to device failure later on in the process. For example, during the production of Bragg grating reflectors, these topographic defects can lead to the wrong Bragg period or, in some specific cases, to stress-induced cracks. These failures can occur during the process or after system delivery under heat or stress conditions, resulting in system failure.

Due to the phase shift deflectometry technology embedded inside the LIGHTsEE series, these defects can be easily detected, says Unity-SC. PSD provides a full-wafer, non-contact, high-throughput solution with height sensitivity below 5nm. Since acquisition is made without moving the substrate, it is stress-free and compliant with any fragile substrate, says the firm.

Demonstrated with a major VCSEL maker, the technology revealed a yield improvement and a decrease in device failures by systematically supressing dies impacted by such defects. So, by using PSD in incoming quality control, VCSEL makers can further increase their yield and improve their supply chain, says Unity-SC.

www.unity-sc.com

III-V Components awarded patent for MTZ-Block multi-temperature substrate holder

III-V Components of Santa Barbara, CA, USA — which provides components and services for compound semiconductor manufacturing including effusion cells, substrate heaters and component rebuilding services — has been awarded a patent by the United States Patent and Trademark Office (USPTO) for its MTZ-Block multi-temperature substrate holder, which provides what is said to be up to a 10x increase in throughout for any 3"-wafer molecular beam epitaxy (MBE) system.

Currently in use by leading universities, research laboratories and semiconductor fab operations, III-V Components says that the MTZ-Block is proven to hold consistent and highly accurate temperature differentials across multiple partial substrates grown simultaneously inside an MBE reactor. With adjustable heat-shielding used to control the temperature within each zone of the MTZ-Block, the resulting temperature of each substrate is calibrated to the existing substrate heater thermocouple reading. Along with the slim profile of the MTZ-Block and with multiple sizes and configurations available, the complete assembly installs into any deposition system, just like a standard semiconductor substrate/wafer, with absolutely no system modifications necessary, the firm says.

III-V Components adds that the MTZ-Block is particularly well suited to temperature-dependent materials research, temperature calibrations or even multiple growths at identical temperatures to improve the throughput and efficiency of compound semiconductor manufacturing and materials science research. Aside from the significant cost and time savings offered, the MTZ-Block greatly improves quality or results by eliminating unwanted variables typically seen between substrates grown separately, such as variable deposition rates and growth chamber pressures.

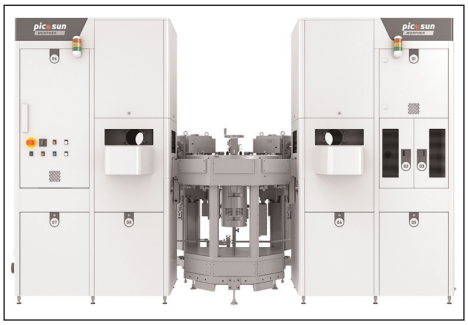
Options are available for a wide range of applications, materials and deposition systems with a capacity for 2" wafers or greater and growth temperatures of 200–1400°C+ with an adjustable temperature differential of 5–100°C+ depending on the configuration.

www.iii-vcomponents.com

Picosun launches ALD product platform for up to 200mm wafer applications

At SEMICON West 2019 in San Francisco, CA, USA (9–11 July), atomic layer deposition (ALD) thin-film coating technology firm Picosun of Espoo, Finland launched PICOSUN Morpher, a new ALD product platform for up to 200mm wafer markets in 'Beyond CMOS' and 'More than Moore' applications, designed to enable fast, cost-efficient, high-volume production of, for example, MEMS, sensors, LEDs, lasers, power electronics, optics and 5G devices, with high process quality, reliability and operational agility.

"Morpher starts a completely new era in PICOSUN products, enabling the most advanced devices and components for IoT, 5G communications, autonomous transportation,



AR [augmented reality] and VR [virtual reality], to name just a few end-applications," says chief technology officer Dr Jani Kivioja.

Picosun says that Morpher adapts to the changing needs of different business verticals, from corporate R&D to production and foundry manufacturing, adding that versatility in substrate materials, substrate and batch size, as well as a comprehensive process range, make it a transformable, all-inclusive manufacturing tool for a wide range of semiconductor industries. The SEMI-certified Morpher comes with completely new software where intuitive and user-friendly HMI allows unified control of the whole cluster.

"Morpher's flexibility and adaptability, combined with the latest design attributes and the state-of-the-art software truly manifest our slogan 'Agile ALD'," says Kivioja. "Together with our comprehensive consultancy, knowledge transfer and lifecycle management services we provide our customers a genuinely strategic partnership."

www.picosun.com

EVG earns seventh consecutive triple win in VLSIresearch annual Customer Satisfaction Survey

EV Group — a supplier of wafer bonding and lithography equipment for semiconductor, MEMS and nanotechnology applications — has again been voted by customers as one of the '10 BEST Focused Suppliers of Chip Making Equipment' and one of 'THE BEST Suppliers of Fab Equipment' in VLSIresearch Inc's annual Customer Satisfaction Survey for 2019, increasing its score and ranking in both award segments compared with last year's listings. EVG also received a 'RANKED 1st in Specialty Fab Equipment' award again, marking the seventh consecutive year that it has received all three customer satisfaction awards.

Also, for a third consecutive year, EVG was recognized as one of 'THE BEST Suppliers of Fab Equipment to Specialty Chip Makers', increasing its score and ranking in this category as well.

According to VLSIresearch, EVG earned its highest '10 BEST' rating ever this year, with customers rating the firm best at partnering, recommend supplier, technical leadership, trust in supplier, and quality of results.

This year marks the 17th consecutive year that EVG has been listed among 'THE BEST Suppliers of Fab Equipment', as well as the seventh year that EVG has achieved the number-one spot as the highest ranked wafer bonder supplier. Since 2017 when VLSIresearch began including a fourth award category for Suppliers to Foundation and Specialty Chip Makers, EVG has won awards in all four categories.

"EV Group continues to increase its customer satisfaction over the years, with this year being its best year so far," notes VLSIresearch's CEO & chairman G. Dan Hutcheson. "The company's ongoing investments in technology invention, innovation and implementation, as well as in its customers, are the keys to its strong customer satisfaction performance. This is evident in the results of our survey, where EVG has consistently outperformed the largest equipment companies in its markets with a strong emphasis in partnering with customers," he adds. "Excellent development partner, willingness to support 'out-of-the-box' processes, excellent technical support, and responsiveness to customer needs are just a few of the stand-out comments that we received from EVG customers that participated in this year's survey."

"Throughout our nearly 40-year history, EV Group has dedicated itself to being first in exploring new process techniques that serve next-generation applications," says Hermann Waltl, EVG's executive sales & customer support director. "Yet the true mark of our success has always been defined by the success of our customers, and we have invested significant resources over the years to ensure that we are always positioned to help enable our customers to successfully commercialize their new product ideas."

www.EVGroup.com
www.vlsiresearch.com

Plasma-Therm wins four 'RANKED 1st' awards in VLSIresearch's 2019 Customer Satisfaction Survey

In market analyst firm VLSIresearch Inc's annual 2019 Customer Satisfaction Survey of semiconductor industry customers, Plasma-Therm of St Petersburg, FL, USA (which makes plasma etch, deposition and advanced packaging equipment for specialty semiconductor and nanotechnology markets) has earned four 'RANKED 1st' awards in the categories of '10 BEST Focused Suppliers of Chip Making Equipment', 'THE BEST Fab Equipment', 'THE BEST Suppliers of Fab Equipment to Specialty Chipmakers' and 'Etch and Clean Equipment'.

Survey participants are asked to rate semiconductor equipment suppliers in 14 categories based on (1) supplier performance, (2) customer service, and (3) product performance. VLSIresearch received feedback from more than 86% of the chip market and 87% of subsystems customers in this year's survey, which was conducted over two and a half months and in five languages.

VLSIresearch cited a number of factors responsible for the high scores that PlasmaTherm earned for its plasma-processing systems, including its partnership with customers, technical expertise, and support after sales.

The four 'RANKED 1st' awards contributed to Plasma-Therm's 2019 total of seven '5 VLSI Stars' ratings awards. The firm previously was awarded 'RANKED 1st' in 'THE BEST Suppliers of Fab Equipment' in the 2016 survey, and has earned a total of 49 awards in Customer Satisfaction Survey results in the 21 years since 1998.

"Being recognized with the highest rating of any company as the 'RANKED 1st in FAB EQUIPMENT' winner is a testament to the dedication and commitment to excellence of our entire Plasma-Therm team," says director of operations Robert Conte.

Plasma-Therm has won the 'RANKED 1st' award in 'Etch and Clean Equipment' for the eighth consecutive year (every year since the category was first awarded in 2012).

This year is the fourth time in the past seven years that Plasma-Therm has been 'RANKED 1st' in the '10 BEST Focused Suppliers of Chip Making Equipment', as well as being ranked among the '10 BEST Focused Suppliers of Chip Making Equipment' every year since 2011.

"In today's competitive semiconductor equipment market place we continue to differentiate with our service," says global customer service manager Bill Davis. "Our diverse customer base and the complex nature of the equipment has always driven our dedicated team approach. This approach supports frequent, quality communication and promotes a collaborative relationship with our customers."

"Plasma-Therm's focus on continually improving its technology and services have made it stand out in an industry dominated by multi-billion-dollar corporations," comments VLSIresearch's CEO & chairman G. Dan Hutcheson. "The extraordinary survey scores show that Plasma-Therm has an edge in both equipment quality and providing support for customers throughout the equipment lifecycle," he adds.

www.vlsiresearch.com
www.plasmatherm.com

OEM Group launches Torrent Spray Acid Tool

At the SEMICON West 2019 event in San Francisco (9–11 July), OEM Group of Phoenix, AZ, USA (which supplies new and re-manufactured semiconductor capital equipment and upgrades focused on emerging markets) introduced the Torrent Spray Acid Tool (SAT), a batch spray tool for wet etch and clean processes, featuring proprietary independent flow control nozzles, wafer-to-wafer repeatability, sealed PVDF tanks, Smart Parts intelligence and more for semiconductor manufacturing, advanced packaging, optoelectronics, MEMS and compound semiconductors.

"Industry 4.0 is creating an inflection point for technologies like 5G, artificial intelligence, machine learning, edge computing and autonomous vehicles, increasing the demand for high-density devices, sensors and power electronics," says president Spencer Wall. "As device dimensions continue to shrink, and varied technologies call for heterogeneous integration, best-in-class tools targeting back-end-of-line wafer-level processes are vital."

Meeting the stringent specifications for wafer-level packaging processes such as under-bump metallization, redistribution layer patterning and backside wafer thinning at high volumes calls for advanced manufacturing equipment, says the firm. Specifically, for MEMS and compound semiconductors, 300mm process solutions for metal etch and polymer removal are in high demand, it adds.

"We designed the Torrent to meet the wet wafer processing production demands of today and for the future," says global product marketing manager Rich Maduzia. "Based on the production-proven Semitool and Cintillio platforms, we added enhancements to expand the process window, created a more user-friendly interface, and improved controls by building in intelligence," he adds. "We believe this tool to be the most advanced batch spray tool in the world," Maduzia says,

In addition to proprietary adjustable AccuFlow nozzles that control flow rates up to 40/lpm, the Torrent SAT features easy access to, and proper placement of, filters to eliminate gas locks that may impede flow. The process chamber was designed with improved drain channel output. The increased chamber depth eliminates the so-called first-wafer effect, which happens when the first few wafers run after idle time have less than optimal processing and must be scrapped, impacting yield.

Dynamic temperature control allows process temperature tuning from 0°C to 80°C. A common rotor design with inserts makes the Torrent suitable for bridge tools and fabs with multiple substrate sizes up to 300mm.

Additional features include:

- maintenance-free sealed tanks that eliminate the risk of internal tool leaks;
- a pull-out PLC drawer for easy maintenance and troubleshooting;
- next-generation software with a graphical user interface (GUI), and wide touchscreen capability when using Windows 10; and
- an offline recipe editor and download, for easier recipe creation and editing.

The Torrent platform can also be configured for spray solvent applications.

www.semiconwest.org
www.oemgroupinc.com

Atlas Copco completes acquisition of Brooks' cryogenics business

Industrial productivity solutions provider Atlas Copco Group of Stockholm, Sweden has completed its acquisition of the semiconductor cryogenic business of Brooks Automation Inc of Chelmsford, MA, USA (announced on 27 August 2018). The cryogenic business has about 400 staff and provides cryo-pumps and and cryo chillers for the semiconductor and related industries through its CTI-Cryogenics and Polycold product lines.

The acquisition includes cryo pump operations located in Chelmsford as well as Monterrey, Mexico, plus a worldwide sales and service network, and Brooks Automation's 50% share of Japan-based joint venture company Ulvac Cryogenics Inc (UCI). Revenue from UCI will not be consolidated into Atlas Copco's revenue. Instead, the Group's share of the profit after tax will be treated as profit from joint ventures.

Atlas Copco says that the acquired business will significantly expand its technology offering to customers in the semiconductor and general vacuum industries through the Edwards business, a brand in the Atlas Copco Group.

The acquisition complements Atlas Copco's existing technology portfolio with a new range of high-vacuum pumps that optimize the removal of water vapour and hydrogen (critical to many semiconductor and industrial processes).

The new division Semiconductor Chamber Solutions (headquartered in Chelmsford) in the Vacuum Technique business area will be created to increase the focus on expanding Atlas Copco's chamber solutions range for the semiconductor and flat-panel display markets.

www.edwardsvacuum.com
www.atlascopco.com

ClassOne opens new Technology Development Center

Expanded capabilities address growing demand for electroplating and wafer cleaning equipment for compound semiconductor manufacturing

ClassOne Technology of Kalispell, MT, USA (which makes electroplating and wet-chemical process systems for ≤200mm wafers) has relocated and opened its technology demonstration and applications laboratory. Formerly located in ClassOne's Atlanta, Georgia location, the Technology Development Center has been relocated to Kalispell, site of ClassOne Technology's engineering and manufacturing facilities.

Triple the size of the previous incarnation, the new 2000ft^2 raised-floor laboratory has a new Class 1000 cleanroom facilitized for both acid/base and solvent applications. ClassOne has installed wet-processing and metrology tools to facilitate rapid development and accelerated technology demonstrations for existing and prospective clients, and has begun taking orders for process analysis and development work. Chief among these are ClassOne's Solstice wet processing platforms, which

are claimed to be the lowest-cost single-wafer electroplating platforms available for up to 200mm substrates.

With combined experience of over 125 years in almost every aspect of semiconductor wet processing (including plating, wet etching, cleaning and solvent processes), ClassOne says that its Technology Development Center (TDC) has the expertise to handle every process challenge, from problem diagnosis to sophisticated process development.

"Technology demonstrations have become a vital part of the sales process, and we've expanded our lab to accommodate the rapidly growing demand for our electroplating and wet-process tools," says John Ghekiere, director of the ClassOne Technology Group. "This state-of-the-art facility gives us the freedom and flexibility to rapidly develop unique, leading-edge solutions. Co-location of the lab here in Kalispell provides us with convenient access to our engineering and manufacturing teams, and enables us to provide robust, rapid-response solutions for our customers," he adds.

"Our Solstice electroplating platform has become the tool of choice for the compound semiconductor and other emerging markets, and demo requests are growing rapidly," says ClassOne Technology's CEO Byron Exarcos. "Our new Technology Development Center is perfectly positioned to allow ClassOne to meet those requests quickly and efficiently, while keeping pace with growing market demands."

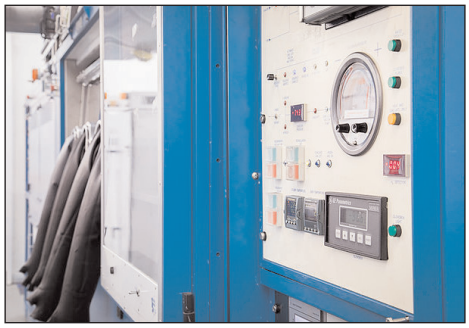
www.classone.com/products

BluGlass brings online BLG-300II upgraded RPCVD tool

Installation boosts development and foundry capacity by over 30%

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 — says that the BLG-300II, its newest remote-plasma chemical vapour deposition (RPCVD) system, is now commissioned and has begun RPCVD material growth runs at its manufacturing facility.

The new platform is an upgraded hardware design of BluGlass' RPCVD workhorse system, the BLG-300, which has been the backbone of the firm's development programs and enabled the recent technology breakthrough in RPCVD tunnel junctions for the LED industry.



"This new platform incorporates all the learnings and hardware development expertise gained by the company to date and represents the cutting edge of the RPCVD process and hardware," says managing director Giles Bourne. "It will significantly assist BluGlass in delivering our industry goals."

The installation significantly increases BluGlass' development and foundry capacity by over 30%.

www.bluglass.com.au

US Court awards Lumileds permanent injunction against Elec-Tech for misappropriation of epi trade secrets

The Superior Court of California has granted Lumileds LLC of San Jose, CA, USA a permanent, worldwide injunction immediately prohibiting China's Elec-Tech International Co Ltd (ETI) and its affiliates from using, disclosing, licensing or selling Lumileds' epitaxy technology trade secrets that ETI was found to have misappropriated. It also prohibits ETI from manufacturing, distributing, importing, exporting or selling any products that use certain of ETI's own epitaxy growth recipes that the jury concluded were produced using Lumileds' trade secrets.

This results from a bench trial (following last August's jury trial), where Lumileds presented experts and evidence demonstrating the appropriateness of a permanent worldwide injunction. The court found that Lumileds' trade secrets continue to exist and are valuable. It determined that, without an injunction, ETI would continue to misappropriate Lumileds' trade secrets and that, if ETI continued to use the stolen intellectual property, Lumileds would suffer irreparable harm. Further, it has denied ETI's motions for a new trial and for the jury's verdict to be set aside.

The permanent injunction "further validates the jury's findings from the 2018 verdict," says Lumileds' chief legal officer & senior VP Cheree McAlpine. "Protecting our innovations is paramount to our business, and we will continue to vigorously defend our intellectual property."

After a four-week jury trial beginning in July 2018, a jury of 12 people found that ETI misappropriated and used five Lumileds' trade secrets related to epitaxy technology. These include the foundational epitaxy-development technology used by Lumileds to produce its high-performance LEDs. The jury determined that ETI used Lumileds' trade secrets in six of their recipes, and the misappropriation and use of the trade secrets was a substantial factor in causing ETI to have obtained an unjust benefit of $66m. ETI has filed several actions in China that are retaliatory and frivolous, says Lumileds, and has not made any attempt to resolve the dispute since the jury's July 2018 verdict.

www.lumileds.com

SemiLEDs quarterly revenue rises 7% to $1.75m

For its fiscal third-quarter 2019 (to 31 May), LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan reported revenue of $1.75m, up 7% on $1.63m last quarter.

Gross margin was 19%, versus breakeven last quarter. Operating expenses rose from $917,000 to $1,041,000, driven mainly by R&D spending rising from $298,000 to $444,000 despite selling, general & administrative expenses being cut from $619,000 to $597,000.

Operating margin has improved from −56% to −40%. However, net loss has worsened slightly from $847,000 to $859,000 (remaining $0.24 per diluted share). During the quarter, cash and cash equivalents fell from $1.64m to $1.06m.

On 5 July, SemiLEDs entered into two new loan agreements totaling $3.2m (NT$100m) to refinance an existing real-estate loan of $2m (NT$62m) and provide for operating capital of $1.2m (NT$38m).

For fiscal fourth-quarter 2019 (to end-August), the firm expects revenue to drop back to $1.6m.

www.semileds.com

BluGlass awarded US patent for buried activated p-type gallium nitride in tunnel junctions

RPCVD developer working with prospective customers on applications

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 — has been awarded US Patent 10,355,165 ('Buried Activated p-(Al,In)GaN Layers') by the United States Patent and Trademark Office. The firm says that the proprietary technology has significant performance potential in applications including high-brightness LEDs, micro-LEDs, laser diodes, solar cells, and other optoelectronic and power electronics devices.

BluGlass says that its remote-plasma chemical vapour deposition (RPCVD)-grown buried activated p-type gallium nitride (p-GaN) layers can help to address the LED industry's critical challenge of efficiency droop (where the light emission efficiency of an LED falls as operating power is increased), resulting in many existing high-powered LEDs being operated outside their peak efficiency. Incremental efficiency improvements continue to be a major objective for LED makers.

A potential resolution of efficiency droop is multi-junction or cascade devices (LEDs or laser diodes as examples).

BluGlass claims that RPCVD-grown buried activated p-GaN layers are a critical building block to enable the tunnel junction, which in turn allows multiple LEDs to be grown in a continuous vertical stack and interconnected in a single, high-efficiency chip (a cascade LED). As a result, less power is needed to deliver the desired light output, potentially eliminating efficiency droop and significantly increasing device performance.

Cascade LEDs are expected to enable smaller, cheaper and higher-performing LEDs (the LED industry's three key interests). To date, functioning tunnel junctions — and therefore cascade LEDs — have been prohibitively difficult to produce due to the challenges in achieving buried activated p-GaN using conventional growth technologies such as metal-organic chemical vapour deposition (MOCVD).

Our growing strategic patent portfolio, comprising 63 internationally granted patents, continues to underpin the commercialization of our RPCVD technology across a range of market segments with long-term market exclusivity

BluGlass is developing and commercializing RPCVD technology as an approach to manufacturing group III nitride materials and devices. RPCVD is said to offer better-performing, lower-cost devices and more environmentally sustainable processes for electronics manufacturers producing LEDs for automotive and overhead lighting, micro-LEDs for wearables and virtual reality displays, and power electronics for efficient power conversion.

"This patent adds an important cornerstone to BluGlass' intellectual property portfolio, protecting our unique RPCVD process, hardware and competitive advantages," says managing director Giles Bourne. "RPCVD allows us to develop this elegant new option for resolving the challenges of efficiency droop in high-performance LEDs — something that's been very difficult to resolve using the industry-standard MOCVD technology," he adds. "Our growing strategic patent portfolio, comprising 63 internationally granted patents, continues to underpin the commercialization of our RPCVD technology across a range of market segments with long-term market exclusivity," Bourne continues.

BluGlass says there has been strong interest in the performance potential of RPCVD tunnel junctions and cascade LEDs from the industry. Discussions with a number of groups are continuing.

www.bluglass.com.au

Plessey presents micro-LED display technology for AR & MR devices at Micro LEDforum

During the Micro LEDforum 2019 in Taipei, Taiwan on 2 July, Dr Wei Sin Tan, director of epitaxy & advanced product development at UK-based Plessey Semiconductors Ltd, discussed the firm's proprietary gallium nitride on silicon (GaN-on-Si) platform for micro-LEDs for augmented reality (AR) and mixed reality (MR) devices.

Focusing on Plessey's pioneering approach to enable manufacturing of monolithic micro-LED arrays using GaN-on-silicon technologies to develop better optimized AR or MR displays applications, the presentation described the problems associated with incumbent micro-display technologies and the challenges that remain to pixel sizes of 8μm and sub-pixels of about 4μm.

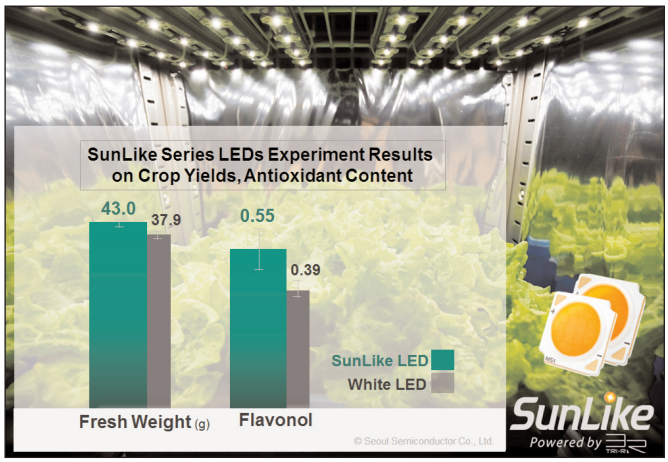
www.plesseysemiconductors.com/products/microleds

Seoul Semiconductor's SunLike Series natural-spectrum LEDs enhance crop yields, antioxidant content

South Korean LED manufacturer Seoul Semiconductor Co Ltd has announced the results of a series of experiments that demonstrated a higher growth rate and higher flavonol (antioxidant) content in crops grown under its SunLike Series natural-spectrum LEDs than those grown under standard white LEDs.

The experiments were conducted on lettuce using SunLike Series LED lighting and standard white LED lighting of the same color temperature and light intensity. After two weeks of crop growth, the fresh weight of lettuce grown under SunLike Series LEDs was 43g (13.5% higher than the yield produced by standard white LEDs) and the flavonol content had a measured antioxidant effect of 0.55 (41% higher).

The significant difference in growth and flavonol content is directly related to light spectrum output (the combined wavelengths of energy produced by a light source). SunLike Series LEDs were able to promote more growth due to having a spectral output that more closely matches the spectrum of natural sunlight, says the firm. The experiment hence concluded that SunLike Series natural-spectrum LEDs can shorten the growth period of crops while enhancing yield, quality and marketability.



"According to the results of this experiment, LED light sources with the same measured correlated color temperature and intensity but different spectral output may produce different effects on the growth rate and nutritional content of crops," says Nam Ki-bum, sales executive VP. "Therefore, growers using greenhouses and indoor farms will benefit by selecting horticulture LED lighting sources that offer a natural spectrum close to sunlight — one of the key factors in the growth cycle of plants," he adds. "As an optimized horticulture LED solution, Seoul Semiconductor's SunLike Series natural-spectrum LEDs will deliver significant benefits to enhance growth cycles and the year-round development of crops, as well as improve the overall growth environment."

Seoul Semiconductor notes that SunLike Series natural-spectrum LEDs have been adopted for numerous horticultural applications as a lighting solution for indoor farms, including Netherlands-based horticultural lighting specialist company Rofianda B.V.

www.seoulsemicon.com

Seoul Semiconductor enforces patents against mobile phone and TV distributors including Phillips TV vendor

South Korean LED maker Seoul Semiconductor Co Ltd has filed a lawsuit in the District Court of Düsseldorf, Germany, against European electronic products retailer Conrad Electronic S.E., alleging that LEDs in backlit mobile phones sold by Conrad are infringing its patent for LED light extraction technology. The patent covers fundamental LED chip fabrication technology to extract light efficiently, significantly enhancing brightness. Conrad is currently selling hundreds of different models of Korean, US and China mobile phones.

Seoul says it has already warned suppliers of LED backlight units (BLUs) for global mobile phones to cease using products suspected of infringement. The firm investigates mobile phones incorporating such products and will consider whatever legal enforcement is necessary if such infringement continues unabated.

Seoul has established significant LED backlight patents applicable to TVs and mobile phones for enhancing LED brightness, color qualities and power consumption reduction. In recent litigations, Seoul has asserted 68 of its patents, including five patent litigations involving LED TVs utilizing backlight technology, including against Philips TV products.

"Sensor Electronic Technology Inc, a subsidiary of Seoul, has also patented fundamental technology for controlling multiple colors to enhance the color quality of mobile phone flash lights," says Sam Ryu, Seoul Semi's VP of IT business. "Most premium mobile phones are using this technology without authorization," he believes. "This is a problem that Seoul and its related companies will seek to resolve because, if LED companies do business fairly, it is virtually impossible to produce LEDs that are applied to mobile phones without utilizing these patents," Ryu states.

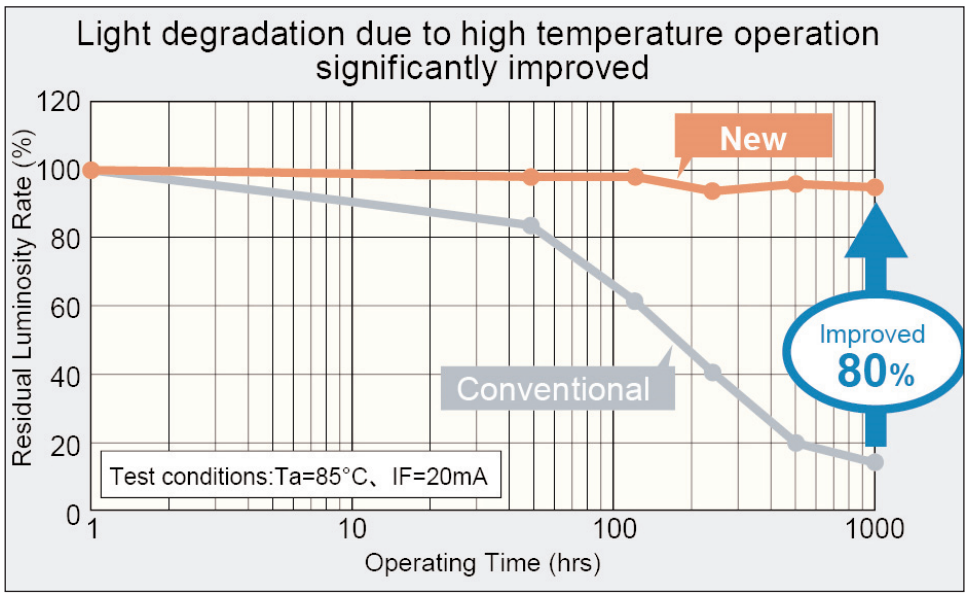
www.SeoulSemicon.com

ROHM's new compact high-output-lens LEDs eliminate light leakage countermeasures in vehicle instrument clusters

ROHM Semiconductor of Kyoto, Japan has announced the availability of compact high-output surface-mount LEDs equipped with a lens. The new lineup includes 18 devices, consisting of the CSL0901 series featuring standard brightness and the high-brightness CSL0902 series.

Recently, most vehicle instrument cluster designs have adopted shields to prevent light leakage from the LEDs to surrounding areas. However, light leakage remains a challenge due to the small amount of space that is required between the shield and the PCB to account for expansion caused by temperature changes. Additionally, some applications using LEDs (such as automotive and industrial systems where electrical components are exposed to severe conditions) require high reliability from these components, so they can better withstand the effects of aging caused by the extreme environments they are exposed to.

In response, ROHM has developed products targeting applications that require high reliability at the component level, such as developing the first high-brightness silver-free LEDs to prevent sulfuration (one of the leading causes of aging).



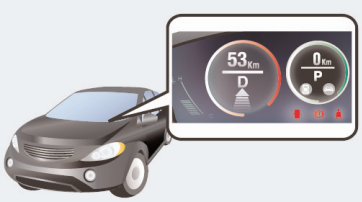
The new series consists of automotive-grade products that ensure high reliability in vehicle instrument clusters which operate under harsh environments. Raising the light source position from 0.18mm in standard products to 0.49mm allowed ROHM to significantly reduce light leakage. Meanwhile, size was reduced by about 18x compared with conventional reflector-type LEDs.

In addition, all devices are designed to prevent light degradation even under high-temperature environments (i.e. automotive). To achieve higher reliability, ROHM also developed a new type of resin for blue, green and white LEDs. As a result, during high-temperature testing with blue LEDs (85°C, I_F=20mA, 1000hrs operation), ROHM improved the residual luminosity rate by about 80% over conventional products, contributing to greater application reliability. Furthermore, achieving higher precision during the manufacturing process (i.e. die bonding, molding) while maintaining the compact 1608 size (1.6mm x 0.8mm) made it possible to increase core brightness by 5–7 times over conventional LEDs.

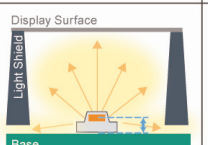
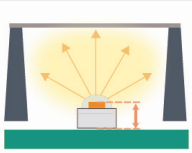
www.rohm.com/products/led/chip-leds-mono-color-type

CSL0901/0902 Series Advantages

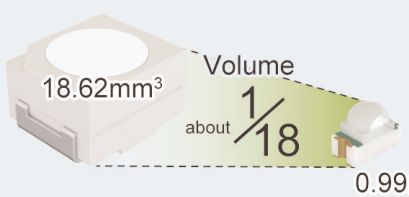
1. Optimized light source position prevents light leakage



Ideal for vehicle instrument cluster

	Conventional Replacement Product	New Series
Type	Compact Molded Type (SML-D1 Series)	Compact Lens Type (CSL0901/0902 Series)
Construction		
Light Leakage	✓	none
Display Image		

2. Compact LED contributes to greater space savings



Conventional Product	New Series
Reflector Type (3.5×2.8mm t=1.9mm)	Compact Lens Type (1.6×0.8mm t=1.24mm)

Bridgelux boosts third-generation EB Series LED products to 200lm/W while expanding color point and form factor options

Bridgelux Inc of Fremont, CA, USA (a vertically integrated manufacturer of solid-state light sources for lighting applications) has expanded its EB Series LED product family to include increased efficacy of up to 200lm/W, new 2700K standard CCT (correlated color temperature) options, new 90 CRI (color rendering index) options, and new slim linear and square form factors.

As a customizable emitter-on-board platform using Bridgelux's surface-mount device (SMD) LEDs, the EB Series hence offers a choice of form factors, color points and CRI options tailored to a specific project.

With customization and personalization now expected in today's lighting market, customers demand that manufacturers build comprehensive solution platforms that offer choice in efficacy, form factor, color point and light quality, notes Bridgelux.

EB Series products hence now include third-generation standard linear (280, 560 and 1120mm) and slim linear (340, 590 and 1190mm) lengths with typical efficacies of 200lm/W and an expanded CCT range of 2700–5700K. New 90-CRI options are also available for improved quality of light and enable luminaires to be in compliance with California's Title 24 regulation. New custom products include 8" and 12" square form factors with increased lumen output, suitable for many commercial applications.

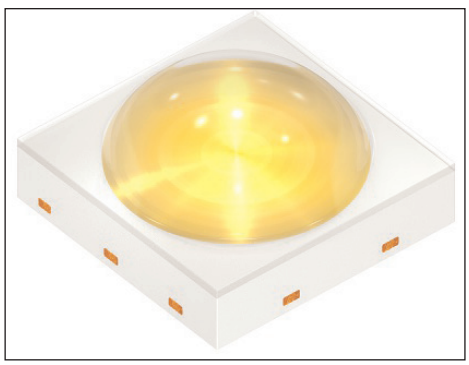
The new EB Series products are now available for sampling and ordering as Gen 3, Slim Gen 3 and Square.

www.bridgelux.com

Osram launches Osconiq P 3030 LED providing long lifetime and high brightness and efficiency for flashlights and work lamps

Osram Opto Semiconductors GmbH of Regensburg, Germany is expanding its portfolio of high-power LEDs for general lighting with the highly reliable, long-lasting (>70,000h) and robust Osconiq P 3030.

Osram says that, using their years of experience in the automotive sector, developers have transferred their knowledge of combining lead-frame technology with high-performance chips to high-volume products for the general lighting industry. Compared with the ceramic packages commonly used in this field, the firm's new package provides a more robust component with a longer lifetime. The specially developed surface-mount device (SMD) package with silicone lens provides high brightness and efficiency as well as a better lumens-per-dollar ratio than ceramic packages used in similar applications.



Osram Opto's new Osconiq P 3030 high-power LED.

Customers can choose between two color rendering index versions (CRI 70 and CRI 80) from the complete range of correlated color temperatures (CCTs) for different applications such as professional indoor or outdoor lighting. While the CRI 70 version is available in color temperatures of 2700–6500K, the CRI 80 version spans 2200–5000K. The CRI 80 version is available in two different configurations. Both products have compact dimensions of 3.0mm x 3.0mm and a height of only 1.63mm, enabling space-saving luminaire designs.

"Thanks to a universal contact pad design, previously used ceramic components can be replaced easily," says Boo Hian Voon, product manager for General Lighting. The 1mm^2 chip in the CRI 70 version reaches 160lm at 5000K and has luminous efficiency of 161lm/W. The CRI 80 version delivers 135lm at 3000K and has efficiency of 136lm/W. Both can be operated with high currents up to 1.3A and simplify system design with a low thermal resistance.

The two white LEDs will be joined later this year by color versions in deep blue (450nm), blue (470nm), true green (528nm), red (623nm), hyper red (660nm) and far red (730nm) for professional horticulture and outdoor lighting.

www.osram-group.com

Osram supports public takeover offer of €35 per share from Bain Capital and Carlyle Group

Investor agreement supports strategy and growth, with commitments to employees and locations

The managing board and supervisory board of OSRAM Licht AG have decided to support a legally binding public takeover offer from a bidding consortium composed of Bain Capital and The Carlyle Group.

Osram and the consortium have also signed an investor agreement that includes comprehensive commitments. "Bain and Carlyle are the right partners for Osram at the right time," says Osram's CEO Olaf Berlien. "They support our strategy and facilitate growth," he adds. "Both are committed to our employees and offer shareholders an attractive premium."

As part of the public takeover offer, shareholders are to be offered €35 per share in cash. This is a premium of about 21% above the last closing price of the shares before the publication of Osram's ad-hoc announcement regarding the evaluation of a legally binding transaction offer by Bain and Carlyle, and a premium of 22.6% on the volume-weighted average price of Osram shares in the past three months. In both cases, talks with Bain and Carlyle have been public knowledge for some time and therefore had an effect on the share price.

The offer values Osram at an equity value of €3.4bn and an enterprise value of about €4bn. Bain and Carlyle have announced a minimum acceptance threshold of 70% (not including the shares owned by Osram Licht AG itself). The offer period is expected to end at the beginning of September. Both Osram's managing board and supervisory board assume that they will recommend in their reasoned response that shareholders should accept the offer. The managing board intends to sell its own Osram shares to the bidders as part of the takeover.

Osram says that its ongoing transformation to a high-tech photonics firm is in response to a profound change in the lighting industry. In the event of a successful takeover offer, Osram reckons that it will have an ownership structure that will enable it to continue its necessary transformation more effectively in the current economically and geopolitically uncertain times. Both private equity firms have extensive experience in supporting companies through transformation processes, have access to an international network, and have successfully developed several firms in the past. "We welcome the offer from Bain and Carlyle and are convinced that it represents both a fair value for the shareholders and strategic added value for our company," comments supervisory board chairman Peter Bauer.

In connection with the investor agreement, Bain and Carlyle will support the current growth path and, among other things, are making extensive commitments regarding employees and locations. For example, the investors are committed to the existing management plan and strategy with its focus on optical semiconductors, the automotive sector and digital applications. Bain and Carlyle have given assurance that they will fully support the management team and will collaborate closely with the current managing board to further Osram's transformation. After the takeover, the firm will continue to operate under the existing name, the corporate headquarters will remain in Munich, and the rights to all patents will remain with Osram. Also, the investor agreement acknowledges that Osram operates in a challenging and volatile market environment that requires flexible action.

Osram reckons that it will have an ownership structure that will enable it to continue its necessary transformation more effectively in the current economically and geopolitically uncertain times

Both investors will support all ongoing growth projects, possible acquisitions as well as investments in new product developments. They also confirm that existing labor agreements, collective bargaining agreements and similar agreements as well as existing pension plans will remain unchanged. The existing steering committee dealing with labor issues (with equal representation between the managing board and the workforce representatives) will also remain in its present form. The investors are explicitly committed to the cornerstones laid out in the document 'Future Concept Germany' that was agreed in July 2017 with the trade union IG Metall and the workforce. Also, the locations of the essential business units will remain unchanged.

In accordance with the requirements of the German Securities Acquisition and Takeover Law, the offer document will be published at a later time by Luz (C-BC) Bidco GmbH, a holding company jointly controlled by investment funds advised and/or connected with Bain Capital Private Equity and The Carlyle Group, following approval by the German Federal Financial Supervisory Authority. After publication, the managing board and supervisory board will review the document in accordance with their legal obligations and submit a reasoned response.

www.osram-group.com

TriLumina announces first automotive-qualified AEC-Q102 Grade 1 semiconductor laser

TriLumina Corp of Albuquerque, NM, USA, which develops flip-chip vertical-cavity surface-emitting laser (VCSEL) array light sources for automotive, consumer and industrial 3D sensing and interior illumination products, has completed all required tests for AEC-Q102 Grade 1 operation, which means it can reliably operate at temperatures ranging from –40°C to 125°C. This is said to be the first time that any semiconductor laser product has qualified for AEC-Q102 Grade 1 operation.

The Automotive Electronics Council (AEC) determines the prerequisites that are necessary to be accepted by tier-1 automotive electronics manufacturers. One is compliance with the applicable AEC-Q reliability standards; the other is compliance with IATF 16949 specifications (Quality Management System) of Zero-Defect supply chain quality management standards. The reliability test of automotive integrated circuits (AEC-Q) is broken down into several subcategories, of which AEC-Q102 (Discrete Optoelectronics) is the applicable standard for TriLumina's VCSEL products.

TriLumina's patented back-emitting VCSEL arrays with optional integrated microlenses are used in solid-state direct 'Flash' LiDAR (light detection and ranging), time-of-flight (ToF) LiDAR, scanning LiDAR and automotive in-cabin systems with full performance from –40°C to 125°C without need for active cooling.

"We design our products from the ground up to perform reliably over wide temperature ranges in extremely rigorous automotive operating conditions," says president & CEO Brian Wong. "Having the first AEC-Q102 Grade 1 qualified VCSEL product in the industry proves just that."

AEC-Q102 Grade 1 qualification also means that the devices are very robust for consumer and industrial applications exceeding the quality requirements for those market segments.

www.trilumina.com

Lynred IR detector launched onboard India's Chandrayaan-2 expedition to Moon's South Pole

Lynred of Palaiseau (near Paris) and Veurey-Voroize (near Grenoble), France, which designs and manufactures infrared (IR) detectors for aerospace, defense and commercial applications, says that the payload on the Chandrayaan-2 orbiter — which launched by the Indian Space Research Organization (ISRO) on 22 July from the Satish Dhawan Space Centre in India — includes its Neptune infrared (IR) detector.

Chandrayaan-2 is viewed as ISRO's most complex mission to date, as it will be the first to explore the Moon's south polar region.

Lynred (a recent merger between Sofradir and ULIS) delivered the Neptune IR detector onboard the Chandrayaan-2 probe to ISRO in November 2017.

"This is the second time that ISRO has selected a Lynred IR detector for a space launch [after the hyperspectral imaging satellite HYSIS, last November], which further strengthens our more than ten-year partnership," says Philippe Chorier, head of business development for space activity at Lynred. "We look forward to designing other IR products for future ISRO instruments."

The Chandrayaan-2 weighs 3877kg. The payload includes 11 instruments, one of which is an imaging IR spectrometer (IIRS) designed with Lynred's Neptune IR detector. It will conduct a more indepth onsite chemical analysis of the Moon and detection of minerals, water molecules and hydroxyl (containing oxygen and hydrogen atoms, i.e. hydroxyl radical OH). Since water is essential for life to function on Earth, the composition of the water-ice on the surface and subsurface and its origin are important objects of study for future space exploration and travel. The orbiter is expected to orbit the Moon for a year.

This is the second time that ISRO has selected a Lynred IR detector for a space launch, which further strengthens our more than ten-year partnership

The presence of water on the Moon was confirmed during the previous Chandrayaan-1 mission, which did not include a Lynred IR detector. For Chandrayaan-2, the Lynred IR detector was chosen for its capacity to increase the upper spectral limit to 5.3µm (up from 3µm on Chandrayaan-1) in order to improve observation capabilities.

Lynred developed the IR detector for the IR imaging spectrometer, a 500 x 256 pixel SWIR-MWIR detector with a pitch of 30µm and a spectral range of 0.9µm to 5.3µm. It operates at 90K and is equipped with a special cold filter with four bands. Based on the space-proven Neptune/Saturn IR space detectors, the IR detector is designed for hyperspectral applications in which the image of the ground is distributed spectrally on the detector.

www.lynred.com

Hamamatsu to construct second building at Shingai Factory

Opto device production to begin at Shingai Factory Building No.2 in October 2020

Artist's rendering of Shingai Factory Building No. 2.

Japan's Hamamatsu Photonics K.K. is to construct a new building at its Shingai Factory in Hamamatsu City to cope with increasing sales demand for optoelectronic semiconductors, x-ray image sensors and x-ray flat-panel sensors. Sited on the east side of Shingai Factory No.1, construction of Shingai Factory Building No.2 should start this month and be completed in August 2020 (at a total cost of ¥6.5bn), for operation from that October (with the capacity to accommodate 400 staff). Production capacity should equate to annual sales of ¥25bn.

Hamamatsu Photonics has been supplying opto products for a wide range of applications such as medical diagnosis and treatment, industrial instrumentation, automotive and scientific measurement. Recently, there has been increasing demand for plastic-molded opto devices mass-producible in large quantities as well as for x-ray image sensors and x-ray flat panel sensors used in radiation inspection devices. The firm expects a further increase in sales of these products across a diverse spectrum of applications.

Construction of the new building will also consolidate the firm's opto semiconductor production processes that are currently sited in different locations at the Shingai Factory and associated companies. These will now all take place in the new factory building, streamlining production efficiency and creating a more robust supply system through labor-saving and automation.

To boost x-ray image sensor and x-ray flat panel sensor production in response to the growing demand, the firm aims to speed up product development by consolidating design, development and evaluation into a single area and will also streamline its supply system by locating production processes on the same floor.

Specifically, the four-story steel-frame structure (with a building area of 4560m^2 and total floor space of 15,285m^2) comprises:

- 1st floor — visitor entrance, shipping area, production cleanroom for opto semiconductors;
- 2nd floor — production cleanroom for opto semiconductors;
- 3rd floor — production cleanroom for x-ray image sensors and flat-panel sensors;
- 4th floor — design room, evaluation room, meeting rooms, restrooms; and
- roof floor — 186kW solar power plant (to supply the power consumption needs of the factory).

To ensure business continuity in the event of natural disasters, the firm will make anti-disaster measures more robust by incorporating earthquake and flood control measures into the building structure based on its business continuity planning. At the same time, the new building is designed to actively incorporate eco-friendly measures such as LED lighting, heat-insulated walls, a solar power plant and rainwater reuse systems.

www.hamamatsu.com

FBH presents custom diode lasers and UV LEDs and demonstrating systems for LiDAR & SERDS

At the joint Berlin-Brandenburg stand at the Laser World of Photonics 2019 in Munich (24–27 June), Berlin-based Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) — together with spin-off UVphotonics — presented its latest developments in diode lasers and ultraviolet light-emitting diodes (UV LEDs), from chips and modules with and without fiber coupling to live demonstrators for LiDAR and Raman spectroscopy.

LiDAR demonstrator: standalone, PC-controlled pulsed laser source

As part of the 'Research Fab Microelectronics Germany', FBH presented a live demonstrator for pulsed laser sources that allows flexible adjustment of pulse duration and intensity. Visitors could use a tablet to change the desired parameters and monitor the results in real time on screen. With its PLS flex, FBH offers laser sources that deliver pulses in the range from 200ps to 20ns. The systems can be equipped with diode lasers of various wavelengths (630–1180nm) and power ranges. Laser diodes, which are wavelength stabilized at 905nm, achieve output powers of up to 100W at ambient temperatures up to 85°C. This makes them suitable for use in light detection & ranging (LiDAR) systems. FBH offers the chips in a complete development environment with driver electronics and control software.

SERDS turnkey system in use — for Raman spectroscopic measurements on site

The compact turnkey laser system for Raman measurements is equipped with a monolithic Y-dual-wavelength diode laser, which alternately emits light at two slightly different wavelengths. The system allows very fast measurements using shifted excitation Raman difference spectroscopy (SERDS). The spectral distance of both wavelengths can be adjusted via microheaters above the distributed Bragg reflector (DBR) gratings that define the wavelength. If the systems are complemented with a suitable power supply, spectrometer, data acquisition and software interface, they can be used for on-site measurements. In-house-developed portable systems have already been used successfully for measurements on food, soil, plants and human skin.

FBH presented a live demonstrator for pulsed laser sources that allows flexible adjustment of pulse duration and intensity. With its PLS flex, FBH offers laser sources that deliver pulses in the range from 200ps to 20ns. The systems can be equipped with diode lasers of various wavelengths (630–1180nm) and power ranges. Laser diodes, which are wavelength stabilized at 905nm, achieve output powers of up to 100W at ambient temperatures up to 85°C

CLEO Europe conference

At the accompanying conference 2019 Conference on Lasers & Electro-Optics (CLEO)/Europe (23–27 June), FBH gave 16 scientific presentations:

- Dual-Wavelength Y-Branch DBR-RW Diode Laser at 785nm with Adjustable Spectral Distance from 0 up to 1.6nm (Poster);
- Passively mode-locked quantum-well semiconductor laser subject to ultra-short optical self-feedback with nanometric fine-delay (Poster);
- Efficient Tm:YAG and Tm:LuAG lasers pumped by red tapered diodes;
- Monolithic master oscillator with tapered power amplifier diode laser at 1060nm with additional control section for high-power operation.
- Determination of the residual amplified spontaneous emission in single-mode semiconductor optical amplifiers;
- Widely tunable Watt-level MOPA systems emitting at 976nm;
- Coherent superposition of pulsed high-brightness tapered amplifiers;
- Wavelength-stabilized 905nm diode lasers in the 100W class for automotive LiDAR;
- Efficient Narrow Stripe Ridge Waveguide Lasers for Single-Spatial Mode Operation up to 2.5W;
- Narrower Far Field and Higher Efficiency in 1kW Diode-Laser Bars Using Improved Lateral Structuring;
- Efficient, High Power Pumps for Mid-IR Solid State Lasers Enabled by 200K Operation of 808nm Diode Lasers;
- Optimization of 808nm DBR RW Laser Bars for Operation at Low Noise and High Reliability.
- Development and qualification of miniaturized, UHV-compatible optical systems for integrated atomic quantum sensors.
- A micro-integrated mode-locked extended-cavity diode laser emitting in the wavelength range around 780nm;
- Polarisation-resolved investigations of the pico- and nanosecond dynamics of broad area distributed Bragg reflector lasers under very high-current pulse excitation;
- Continuous-wave THz source based on an electrically tunable monolithic two-color semiconductor diode laser.

www.world-of-photonics.com
www.fbh-berlin.com
www.uvphotonics.de

Extremely low-excess-noise and high-sensitivity APDs developed using AlAsSb lattice matched to InP

Cardiff, Swansea and UCLA's CNSI co-develop ultrafast receiver technology for networking and sensing

A team at Cardiff University led by professor Diana Huffaker — the Sêr Cymru chair in Advanced Engineering and Materials and scientific director of the Institute for Compound Semiconductors (ICS) — has collaborated with the UK's University of Sheffield and the California NanoSystems Institute at University of California, Los Angeles (UCLA) to develop an ultrafast and highly sensitive avalanche photodiode (APD) that creates less electronic noise than its silicon rivals (Xin Yi et al, 'Extremely low excess noise and high sensitivity $AlAs_{0.56}Sb_{0.44}$ avalanche photodiodes', Nature Photonics, published 8 July 2019).

Faster, supersensitive APDs are in demand worldwide for use in high-speed data communications and light detection and ranging (LIDAR) systems for autonomous vehicles.

However, the indium phosphide (InP) and indium aluminium arsenide (InAlAs) typically used as the gain material in APDs have similar electron and hole impact ionization coefficients (α and β, respectively) at high electric fields, giving rise to relatively high excess noise and limiting their sensitivity and gain bandwidth product.

Now, the new work has reported extremely low excess noise in an $AlAs_{0.56}Sb_{0.44}$ APD lattice matched to InP. A deduced β/α ratio as low as 0.005 with an avalanche region of 1550nm is close to the theoretical minimum and is significantly smaller than that of silicon, with modeling suggesting that vertically illuminated APDs with a sensitivity of –25.7dBm at a bit error rate of $1x10^{-12}$ at $25Gbs^{-1}$ and 1550nm can be realized.

"The innovation lies in the advanced materials development using molecular beam epitaxy (MBE)," says Huffaker. "This particular material is rather complex and challenging to synthesize as it combines four different atoms, requiring a new MBE methodology. The Sêr Cymru MBE facility is designed specifically to realize an entire family of challenging materials targeting future sensing solutions," she adds.

"The results we are reporting are significant as they operate in very low-signal environment, at room temperature and, very importantly, are compatible with the current indium phosphide (InP) optoelectronic platform used by most commercial communication vendors," says Dr Shiyu Xie, Sêr Cymru co-fund fellow. "These APDs have a wide range of applications. In LiDAR [light detection and ranging] or 3D laser mapping, they are used to produce high-resolution maps, with applications in geomorphology, seismology and in the control and navigation of some autonomous cars," he adds. "The material we have developed can be a direct substitute in the current existing APDs, yielding a higher data transmission rate or enabling a much longer transmission distance."

The Sêr Cymru Group within ICS is now preparing a proposal with collaborators at Sheffield for funding from UK Research and Innovation to support further work.

"The work of professor Huffaker's Sêr Cymru Group plays a vital role in supporting the ongoing success of the wider compound semiconductor cluster, CS Connected, which brings together industry and academic partners in South Wales to develop 21st Century technologies that create economic prosperity," comments Cardiff University vice-chancellor professor Colin Riordan.

"Our research produces direct benefits for industry," Huffaker asserts. "We are working closely with Airbus and the Compound Semiconductor Applications Catapult to apply this technology to future free-space optics communication system."

www.nature.com/articles/s41566-019-0477-4.epdf
www.cardiff.ac.uk/institute-compound-semiconductors
www.ukri.org

Light Communications Alliance formed

Open, non-profit association aiming to establish and advocate standards

To promote new wireless technologies enabling light communications, global leaders in the communications, lighting, infrastructure and device manufacturing industries have formed the Light Communications Alliance (LCA), aiming to establish and advocate the use of standards for this emerging industry.

The founding members are Nokia, Emirates Integrated Telecommunications Company, LEDVANCE, Liberty Global, Lucibel, Orange, pureLiFi, LiFi Research & Development Centre, Velmenni, Zero.1, CEA Leti, and Institut Mines-Télécom.

The LCA is an open, non-profit association aiming to promote light communications technology with a consistent, focused and concise approach. It will highlight the benefits, use cases and timelines for light communications adoption. The organization aims to align leaders across the industries that light and communications touches, defining standards for education, communication and interoperability.

Light communications technologies complement and enhance 5G wireless communications and other radio frequency technologies such as Wi-Fi. By utilizing its greater available spectrum, light can be used to deliver larger amounts of data at faster speeds and with greater security.

Light communication technologies include light fidelity (LiFi) and optical camera communications (OCC), both of which have been attracting increased attention in recent years within several industries, such as smart cities and homes, Industry 4.0 and manufacturing environments, as well as retail and tourism.

Global Market Insights predicts that the LiFi market will grow to $75bn by 2025, creating broad, far-reaching opportunities for the related industries to benefit from visible light communications (VLC).

LiFi offers a fully networked, bi-directional mobile communication solution using light, which has the potential to deliver massive bandwidth and higher speeds for short-range wireless communications. It can be integrated easily alongside traditional wireless technology such as Wi-Fi and can enhance these networks with greater speeds and security. LiFi can be deployed in various environments, both professional and domestic, including smart offices, smart transport, Industry 4.0 and in the smart gigabit connected home of the future.

The organization aims to align leaders across the industries that light and communications touches

Optical camera communications (OCC) has the potential to create value-added services by using the light for both broadcast communications and indoor positioning in environments such as office buildings, convention centres, and parking lots.

Light communication technologies can offer thousands of additional channels for secure high-speed communications, providing faster more reliable connections, as well as greater security because light can be contained, for example inside buildings.

The LCA is open to membership from all industries spanning both light and communications including chip manufacturers, OEMs, network operators, lighting manufacturers and light communications innovators.

www.LightCommunications.org

CST Global presents at AOP 2019 on how to 'design in' ridge-waveguide DFB laser longevity

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Glasgow, Scotland, UK says that, at the IV International Conference on Applications in Optics and Photonics (AOP 2019) in Lisbon, Portugal (31 May–4 June), its research engineer Horacio Cantu was a guest speaker, presenting his submitted paper 'Reliability of Ridge Waveguide Distributed Feedback Lasers for Communications Applications: from Device Specification and Failure Analysis to Life-time Calculation'.

A high-volume, data transmission solution suitable for widespread use in optical fiber networks must be low-cost and capable of reliable deployment in an uncooled, non-hermetic package, without temperature control, notes CST Global. This is a challenging environment for indium phosphide (InP), ridge-waveguide (RW) distributed feedback (DFB) lasers, and can adversely affect their longevity, adds the firm.

"The research carried out at CST Global looked at how reliability performance is affected by power, temperature and humidity along with the impact of fabrication and assembly processes like epitaxial growth, etching, die bonding and wire bonding," says Horacio. "We not only understand how the fabrication processes used for ridge-waveguide DFB lasers impact device quality and yield, but also their effect on longevity," he adds. "Systematic design improvements, right back at the characterization stage, helped to optimize the lasers. We then accurately predicted longevity with lifetime calculations showing less than 0.01% fails after ten years," Horacio explains.

www.aop2019.org

www.compoundsemi.co.uk

TowerJazz, Cadence and Lumerical deliver silicon photonics and SiGe integrated PDK with complete optical transceiver design environment, targeting 400 & 800Gb data-center and telecom applications

Specialty foundry TowerJazz, electronic design automation (EDA) software provider Cadence Design Systems Inc of San Jose, CA, USA and photonic design and simulation software tool provider Lumerical Inc of Vancouver, British Columbia, Canada have announced the availability of a complete custom design silicon photonics (SiPho) and silicon germanium (SiGe) integrated process design kit (PDK).

The differentiated PDK is based on the Cadence Virtuoso custom IC design platform, providing native synthesis using the Cadence CurvyCore engine and Electrical-Optical co-simulation capability in Lumerical's photonic integrated circuit simulator INTERCONNECT. The complete, photonics-optimized solution provides SiPho designers with a single, streamlined design environment for developing complex multi-fabric systems, while enabling them to collaborate in a shared IC design environment to leverage the electro-optical interface that is critical for enabling 400GB optical transceivers.

"We are excited to expand our industry-leading SiPho technology, and to be the first major foundry to offer — through this collaboration with Cadence and Lumerical — the co-optimization of electrical SiGe and optical SiPho components in a single EDA environment," says Marco Racanelli, senior VP & general manager of the Analog IC business unit at TowerJazz. "This new capability enables our mutual customers to shortcut development cycles and accelerate the introduction of 400Gb and 800Gb breakthrough products."

Customers using the new TowerJazz PDK can now synthesize non-Manhattan shaped photonics designs utilizing the Cadence CurvyCore technology, which allows users to systematically manage curvilinear shapes within the Cadence Virtuoso design environment using its high-performance shape generation and manipulation infrastructure with dedicated SKILL API.

Delivery of the new TowerJazz process design kit encompasses the previously available Lumerical Compact Model Library (CML) to enable a proven, complete solution incorporating co-simulation utilizing industry-leading tools.

"TowerJazz and Cadence customers can begin leveraging the high-performance shape generation technology within the Virtuoso design environment to further advance the development of complete multi-chip photonics systems," says Glen Clark, VP, research & development at Cadence. "TowerJazz, Lumerical and Cadence have a long history of collaboration that enables our mutual customers to achieve success in delivering quality products to market faster and easier," he adds.

"A touchstone of the commercialization of photonics is ecosystem development by world-class companies," comments Lumerical's chief technology officer James Pond. "Our partnership with Cadence and TowerJazz enables photonic integrated circuit designers to co-simulate their electro-optical and photonic components using leading tools they are familiar with, and fabricate those designs at TowerJazz."

www.towerjazz.com
www.lumerical.com

Rockley Photonics raises $52m in first close of Series E investment round

Total funding rises to $165m

Rockley Photonics of Pasadena, CA, USA (formed in 2013 to develop a silicon photonics platform for optical I/O in next-generation sensor systems and communications networks) has announced the first closure in its Series E funding round. Investors in the additional $52m funding include a key strategic partner, Morningside Technology Ventures, and numerous private investors. This latest funding round takes the total raised by Rockley to date to $165m.

"With this latest round of investment, Rockley is strengthening its position as a leading integrated silicon photonics solutions provider," says chief financial officer Mahesh Karanth. "It will support the full execution of our business plan and continued growth as we make significant strides in co-packaging for optoASICs and data-center connectivity, LiDAR and consumer electronic applications," he adds.

As silicon photonics transforms applications that were once the domain of traditional, pure electronic chip technologies, it is evolving into a core enabling technology for numerous burgeoning markets including Web 2.0 data centers, 5G, artificial intelligence (AI), autonomy, machine vision and healthcare, says Rockley. Market research firm Yole Développement estimates that the global market for silicon photonics is growing from $500m in 2018 to more than $3.5bn by 2025.

This latest round of investment will support the full execution of our business plan and continued growth as we make significant strides in co-packaging for optoASICs and data-center connectivity, LiDAR and consumer electronic applications

"Rockley is uniquely positioned, having developed a proprietary photonics platform and manufacturing technologies, underpinned by a depth of expertise that goes back some 30 years," says CEO Andrew Rickman. "We are currently using our platform to address applications in the data-center and high-performance computing, medical and life sciences, and 3D imaging/sensing verticals with the potential for additional verticals in the future."

www.rockleyphotonics.com

POET reschedules shareholder meeting to allow more time for internal approvals of DenseLight sale

POET Technologies Inc of Toronto, Canada and San Jose, CA, USA — a designer and manufacturer of optoelectronic devices, including light sources, passive waveguides and photonic integrated circuits (PIC) for the sensing and datacom markets — has changed the meeting date for its annual and special meeting of shareholders.

A revised notice of the meeting date, now set for 20 September (at 10am Eastern Time at Vantage Venues 150 King Street West, 27th Floor, Toronto), has been provided to the relevant intermediaries by transfer agent TSX Trust. The extension is intended to allow the firm and the buyer of POET's DenseLight subsidiary the time to secure all necessary internal approvals, except the required approval of POET's shareholders.

The record date for the meeting (the date on which those holding POET's common stock as of the close of business will be entitled to vote in person or by proxy at the meeting) has also been changed to 9 August. Representatives of the buyer of DenseLight intend to be present at the meeting.

"We have made good progress on the drafting of a definitive share sale agreement and both parties have confirmed an expected closing date on or before 31 October, a change from our previous indication of 15 September," says chief financial officer Thomas Mika. "We have postponed the shareholder meeting in order to provide that all necessary approvals on the part of the buyer will have been secured by mid to late August. This would allow us to include in the management information circular an agreement signed by both parties that is contingent solely on approval by POET's shareholders," he adds.

At the meeting, in addition to the election of directors and the ratification of the appointment of auditors, POET's shareholders are expected to be asked to approve a resolution related to the proposed sale of its DenseLight subsidiary. A relevant management information circular will be made available to shareholders of record as of the record date prior to the meeting. The meeting date and location are subject to further postponement or change at POET's discretion.

www.poet-technologies.com

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Emcore cuts June-quarter revenue guidance from $20–22m to $17–17.5m

Chip product sales and GPON hit by US-China trade dispute

In preliminary financial results for its fiscal third-quarter 2019 (ended 30 June), Emcore Corp of Alhambra, CA, USA — which provides indium phosphide (InP)-based optical chips, components, subsystems and systems for the broadband and specialty fiber-optics markets — says it expects revenue of $17–17.5m, cut from its prior guidance of $20–22m. This would be down on $21.7m last quarter (rather than being roughly level) and down slightly on $17.7m the prior year.

"Our chip product sales, and GPON in particular, experienced a significant decline in the third quarter, largely due to additional negative effects of the trade dispute with China," notes president & CEO Jeffrey Rittichier. "Within the cable TV market, overall MSO capital spend remained soft compared to expectations earlier in the quarter," he adds.

"Demand for our Satcom and inertial navigation products, including the recently acquired Systron Donner operations, remained robust, with demand outpacing supply," Rittichier continues. "Sales of these Aerospace and Defense products continue to meet our growth expectations, while also reducing volatility in demand and improving corporate profitability."

www.emcore.com

QSFP-DD MSA Group adds updated Common Management Interface Specification 4.0 and Hardware Specification 5.0

The Quad Small Form Factor Pluggable Double Density (QSFP-DD) Multi Source Agreement (MSA) group has released an updated Common Management Interface Specification (CMIS) revision 4.0 for the QSFP-DD form factor. To continue to address the evolving industry needs for an improved high-density, high-speed networking solution, 65 firms came together in support of the QSFP-DD MSA.

As the adoption of 400 Gigabit Ethernet (GbE) grows, CMIS was designed to cover a wide range of module form factors, functionalities and applications, ranging from passive copper cable assemblies to coherent DWDM modules. CMIS 4.0 can be used as a common interface by other 2-, 4-, 8- and 16-lane form factors, in addition to QSFP-DD. Other features include firmware upgrade, diagnostic capabilities, improved State Machine support and support for WDM/coherent modules.

The group has also announced the release of an updated hardware specification revision 5.0 for QSFP-DD. This update supports up to 20W of power with improved thermal management. It includes new optical connectors; SN and MDC, a label area specification, improved latching definition and an enhanced Pulse Per Second (ePPS) pin.

QSFP-DD is the premier 8-lane data-center module form factor. Systems designed for QSFP-DD modules can be backwards compatible with existing QSFP form factors and provide maximum flexibility for end users, network platform designers and integrators.

"Through strategic collaborations with our MSA companies, we continue to test the interoperability of multiple vendors' modules, connectors, cages and DAC cables to assure a robust ecosystem," says Scott Sommers, founding member and MSA co-chair. "We remain committed to developing and providing next-generation designs that evolve with the changing technology landscape."

Established in March 2016, the QSFP-DD MSA group aims to satisfy the market demand for a next-generation high-density, high-speed pluggable backwards-compatible module form factor. QSFP-DD MSA founder-promoters included Broadcom, Cisco, Corning, Finisar, Foxconn Interconnect Technology, Huawei, Intel, Juniper Networks, Lumentum, Mellanox Technologies, Molex and TE Connectivity.

"As the industry continues to converge on QSFP-DD, we believe the economies of scale will manifest and allow 400GbE to reach its full potential," says Mark Nowell, founding member and MSA co-chair. "We are excited to share new updates and grow the previous thermal and high-speed signal integrity validation previously shared by the MSA."

Contributors include Acacia, ACON, Alibaba, Amphenol, Applied Optoelectronics, APRESIA Systems, Celestica, Ciena, ColorChip, Credo, Dell EMC, Delta Products, Dust Photonics, Eoptolink, Fourte, Fujitsu Optical Components, Genesis, H3C, Hisense Broadband, Hitachi Metals, Hewlett Packard Enterprise, Inno-Light, Innovium, Inphi, JPC, Kaiam, Keysight Technologies , LEONI, Lorom, Luxshare-ICT, MACOM, Marvell, MaxLinear, MultiLane, NeoPhotonics, Nokia, Panduit, PHY-SI, Ranovus, Samtec, SENKO, Semtech, Sicoya, Siemon, Skorpios Technologies, Source Photonics, Spectra7 Microsystems, Spirent, Sumitomo Electric, US Conec, Xilinx and Yamaichi Electronics.

www.qsfp-dd.com

NeoPhotonics appoints Dr Yanbing Li to board

NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of hybrid photonic integrated opto-electronic modules and subsystems for high-speed communications) has appointed Dr Yanbing Li to its board of directors.

Currently VP of engineering at Google (focusing on Google Cloud), Li has extensive leadership experience in general management and engineering in the USA and China.

Previously she was senior VP & general manager for the Storage and Availability business unit at VMware, responsible for a portfolio of products in software-defined storage, hyper-converged infrastructure, data protection, and storage and availability services for the cloud. She led product development, engineering, and go-to-market strategies and led the business to become one of the fastest-growing businesses for VMware and a market leader.

During her 11-year tenure with VMware, Li held multiple executive leadership roles including general manager for vCloud Air storage, VP of engineering for storage, VP of central engineering, VP of continuing product development, VP of global R&D sites and managing director of China R&D.

Prior to VMware, Li worked at electronic design automation (EDA) software provider Synopsys for nine years in research, development and engineering leadership roles.

Li has a Ph.D. degree from Princeton University, a master of science degree from Cornell University and a bachelor of science degree from Tsinghua University (Beijing, China) in electrical engineering & computer engineering. She is also a graduate of the Stanford Executive Program at the Stanford University Graduate School of Business.

NeoPhotonics is a "recognized leader in photonic integration for coherent high-speed transmission," comments Li. "This technology is a critical enabler for the growth of cloud computing and artificial intelligence and offers exciting growth potential," she believes.

"Her extensive background in data-center and cloud operations and deep technology experience in cloud services will provide our board with valuable insights in the ongoing evolution of the key markets we address," says chairman & CEO Tim Jenks.

www.neophotonics.com

NeoPhotonics shipping early limited volumes of single and quad 53Gbaud GaAs linear driver ICs for silicon photonics modulators in 100G-per-wavelength DR1 and DR4 data-center transceivers

NeoPhotonics has shipped early limited volumes of its new 53 Gbaud linear driver ICs designed to work with silicon photonics-based Mach-Zehnder modulator chips in 100G-per-wavelength data-center optical transceiver modules. Manufactured using NeoPhotonics' proven, in-house gallium arsenide (GaAs) wafer fabrication facility, the driver ICs are available in both single and quad formats.

Silicon photonics (SiPho) has emerged as a promising technology for optical data transmission over intermediate reaches of about 500m (DR) inside data centers. Several vendors have designed 53Gbaud SiPho modulator chips that can modulate four separate optical signals using 4-level pulse amplitude modulation (PAM4) encoding to achieve 100Gbps on four separate channels, resulting in a total of 400Gbps for the module. The SiPho modulator chip designs generally require a larger voltage swing than is normally produced by the CMOS electronics used in the PAM4 digital signal processor (DSP) chip. NeoPhotonics' linear driver IC amplifies the electrical signal so that it is of an appropriate voltage to operate the SiPho modulator and produce the desired optical signal. NeoPhotonics' quad driver chip combines four separate drivers in a single compact, low-power chip designed to support compact pluggable modules such as OSFP and QSFP-DD.

The SiPho-based transceivers also need a high-power laser to provide the initial input light to the modulator. NeoPhotonics also offers such high-power, non-hermetic lasers and has begun volume shipments. The high-power DFB lasers are qualified to the non-hermetic test compliance with Telcordia GR-468-CORE Issue 2.

"We are pleased to announce the initial shipments and availability of our 53Gbaud GaAs driver ICs just before the Fiber Optic Expo in Tokyo, as these products have been designed and manufactured at our NeoPhotonics Semiconductor GK division in Hachioji City of Tokyo," notes chairman & CEO Tim Jenks. "Our 53Gbaud driver ICs and our high-power, non-hermetic DFB lasers, high-speed photo-detectors, trans-impedance amplifiers (TIAs) and EML lasers provide designers with several of the key optical components required for the highest-speed data-center transceivers," he adds.

NeoPhotonics exhibited its new driver chips and other lasers and optical ICs for 100G and 400G data-center applications, along with its suite of coherent components for 100G to 600G data-center interconnect (DCI) and telecom applications, plus its switches and passive products, at the Fiber Optic Expo (FOE) trade show in Tokyo, Japan (17–19 July).

NEDO, Sharp and Toyota to begin public road trials of electric vehicles with high-efficiency solar cells

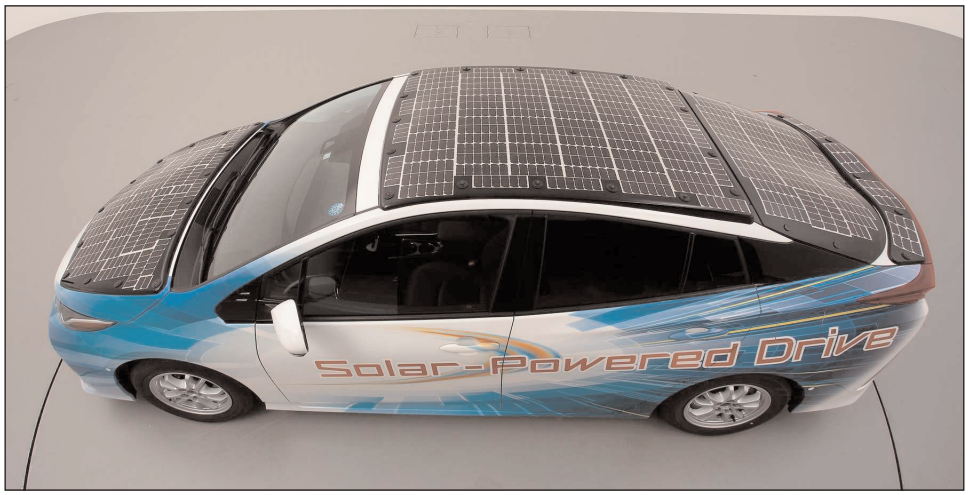
Toyota Prius PHV demo car generates 860W using 34%-efficient triple-junction cells, versus 180W using 22.5%-efficient cells in commercial model

The Japan National Research and Development Agency's New Energy and Industrial Technology Development Organization (NEDO), Sharp Corp and Toyota Motor Corp plan to begin public road trials from late July that aim to assess the effectiveness of improvements in cruising range and fuel efficiency of electric vehicles (EVs) equipped with high-efficiency solar cells.

To facilitate execution of the trial, Sharp has modularized its triple-junction compound semiconductor solar cells (which have a conversion efficiency of 34%-plus, based on cell output measured by Sharp under AM1.5G standard test conditions), previously developed for a NEDO-led project, in order to create an onboard solar panel. Since the solar cell comprises a thin film about 0.03mm in thickness, it can be installed efficiently to fit the curves of parts with limited space, including the vehicle roof, hood, rear hatch door and other parts of Toyota's Prius PHV, and hence a demo car was produced for public road trials.

By enhancing the solar panel's efficiency and expanding its onboard area (utilizing several solar cells), Toyota achieved a rated power generation output of about 860W (total module output based on calculation of cell output, as measured by Sharp), which is about 4.8-times higher than the 180W for the commercial model Prius PHV (equipped with a solar charging system with solar cell conversion efficiency of 22.5%).

Also unlike the commercial Prius PHV (which charged the driving battery only while parked), due to the improvements in power output the demo car employs a system that charges the driving battery also while being driven. This is expected to lead to significantly improved battery electric vehicle (BEV)-mode cruising range (rising from 6.1km to 44.5km for charging when parked per day, or 56.3km when also being driven).

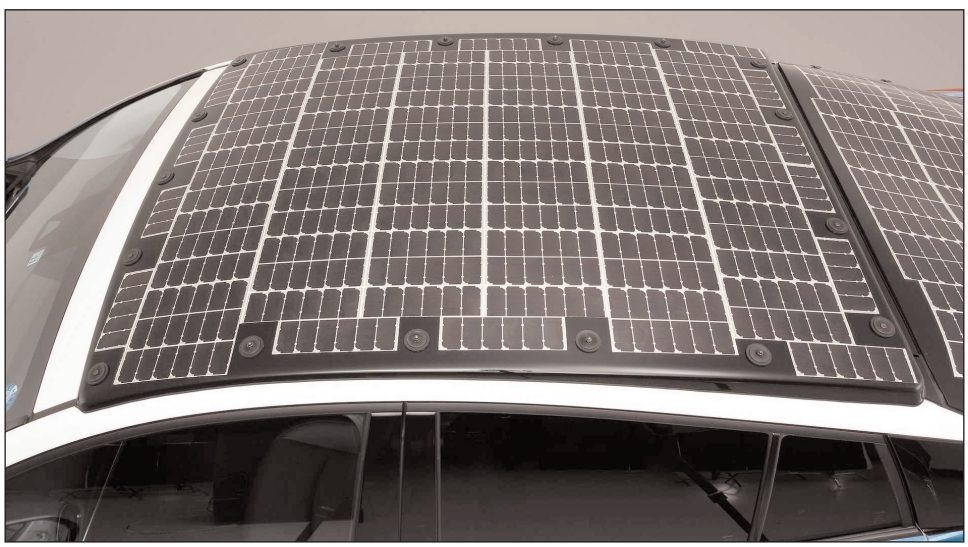


Toyota's Prius PHV solar demonstration car.

Toyota plans to conduct the trials under various driving conditions in Toyota City, Aichi Prefecture, Tokyo, and other areas. Various data (including power output of the solar panel and how much the drive battery is charged) will be obtained and verified, and then used in the development of an onboard solar recharging system.

Toyota plans to share a selection of trial data results with NEDO and Sharp. The PV-powered Vehicle Strategy Committee (established in April 2016), sponsored by NEDO and other entities, will evaluate the benefits based on improvements in CO_2 emission reduction and convenience (e.g. the number of times a vehicle requires recharging). The goal is to contribute to creating a new solar panel market (including the transport sector) and to finding solutions for energy and environmental issues in the transport sector.

www.global.toyota.com



MiaSolé boosts its CIGS PV cell efficiency to 20.56%

Large-area CIGS module efficiency record also raised to 17.44%

Copper indium gallium diselenide (CIGS) thin-film photovoltaic solar cell and panel maker MiaSolé of Santa Clara, CA, USA (which was founded in 2004 and acquired by Beijing-based renewable energy firm Hanergy in December 2012) says that the US Department of Energy's National Renewable Energy Laboratory (NREL) has independently confirmed a 20.56% cell efficiency for a thin-film device (0.86cm^2) deposited on a stainless-steel foil (a new internal record for MiaSolé).

The films were produced directly from the MiaSolé Roll Coater production line in Santa Clara using a process that incorporates multiple breakthroughs for delivering select alkali elements as well as precise compositional control of the silver (Ag)-alloyed CIGS absorber. The processes that enabled this high-efficiency device are directly transferrable to high-volume manufacturing, says the firm.

"Our innovative continuous deposition system enables us to rewrite the process development playbook," says Dr Neil Mackie, senior director of process development. "By experimenting at the manufacturing scale, we can bring high-efficiency thin-film solar cells into production at a faster rate," he adds. "Seamless integration of manufacturing methods into advanced process development is already enabling the next generation of high-efficiency and high-reliability thin-film solar products from MiaSolé."

MiaSolé raises large-area CIGS module efficiency record to 17.44%

Earlier in July, MiaSolé said that Germany's Fraunhofer Institute for Solar Energy Systems (ISE) had independently confirmed a 17.44% aperture-area efficiency on a commercial-size PV module (with an aperture area 1.08m^2). This has been recognized as a new certified record large-area CIGS module in the latest Progress in Photovoltaics compendium of PV records (Prog Photovolt Res Appl. 2019;27:565–575).

The cells and record module were made using MiaSolé's production lines in Santa Clara. The firm's cell manufacturing process deposits CIGS on a flexible substrate using high-speed physical vapor deposition (PVD) that produces high-efficiency solar cells in a continuous and high-throughput process.

"This achievement is the result of our targeted focus in research and development to increase conversion efficiency and to provide durable, high-power, flexible and lightweight products," says chief technology officer Atiye Bayman.

www.miasole.com

First installation of Midsummer's new improved integrated solar cell roof

Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines as well as flexible, lightweight copper indium gallium diselenide (CIGS) thin-film solar panels for building-integrated photovoltaics (BIPV) — has announced the first installation of its new, slimmer energy-producing 'Midsummer solar roof'. Sited on a house in Kivik, south Sweden (belonging to the same private customer who installed the first version of Midsummer's energy-producing metal roof last year), the thin-film solar panels are integrated with the folded metal roof. "Our end customer in Kivik was very happy with the previously installed solar cell roof," says CEO Sven Lindström.

The new model solar cell roof is slimmer than the previous one and increases the installed power per square meter. It also offers the possibility to connect the solar panels for longer roofs, so Midsummer can supply its metal roof with integrated solar panels in lengths of up to 12m.

Midsummer solar roofs are supplied with solar panels already mounted, and installation is said to be as simple as for a metal roof without solar cells. The firm also offers installation with turnkey contracts. The light, thin and flexible solar panels are fit to walk on and the weight does not differ significantly from a standard metal roof (and likewise for the appearance and price).

Midsummer solar roofs have an expected lifetime of 25 years with a guarantee of 15 years for the roof, and a guarantee that the roof delivers 90% of the installed peak power after ten years and 80% of the installed peak power after 25 years.

www.midsummer.se

Laser diode market to grow to $14bn in 2029, with direct-diode lasers contributing $2bn

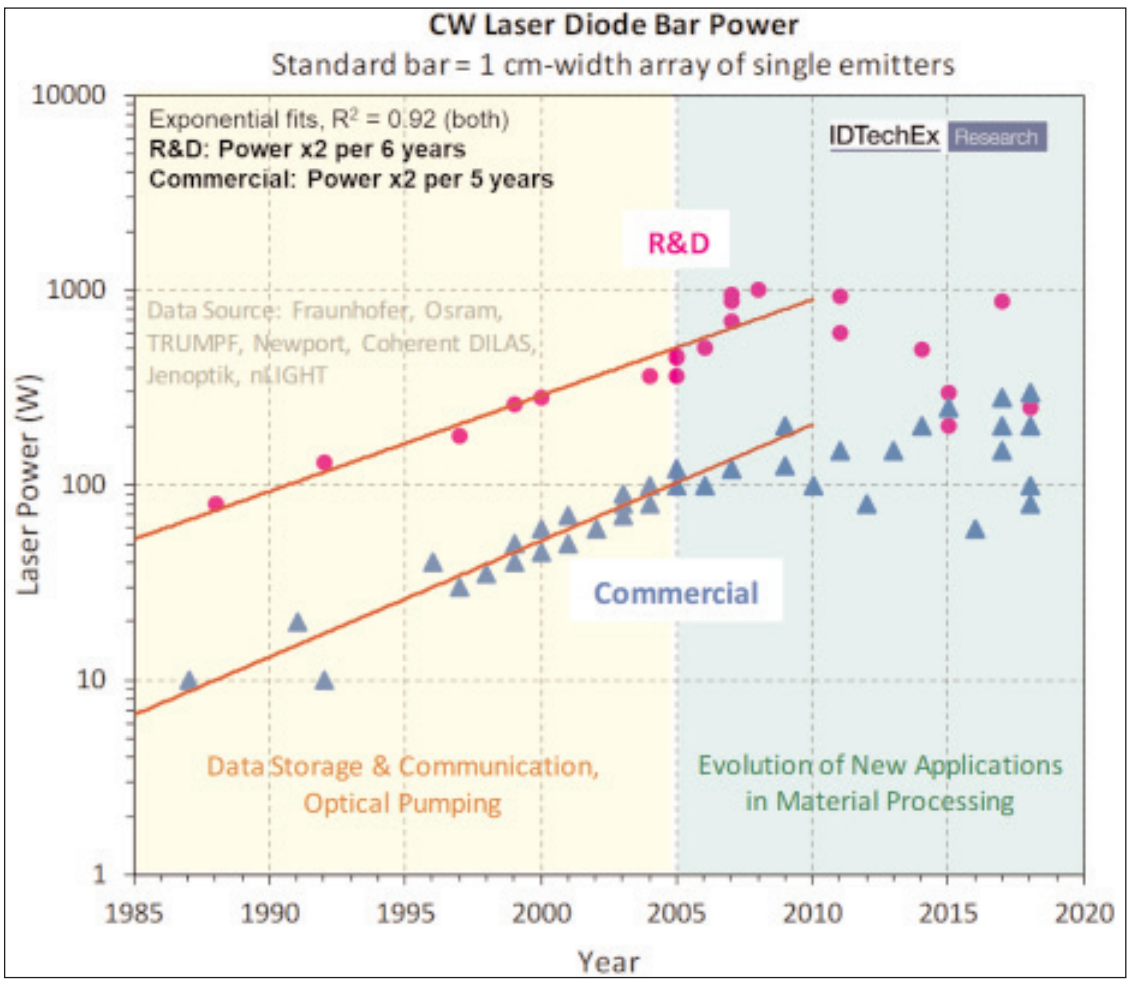
Laser price and performance evolution is rapidly opening up new markets, enabling novel applications in laser material processing and industrial manufacturing, says IDTechEx Research.

The global market for laser diodes and direct-diode lasers will reach $14bn by 2029, with direct-diode lasers contributing $2bn, forecasts technology consulting firm IDTechEx Research in its report 'Laser Diodes & Direct Diode Lasers 2019–2029: Technologies, Markets & Forecasts' by analyst Dr Nilushi Wijeyasinghe.

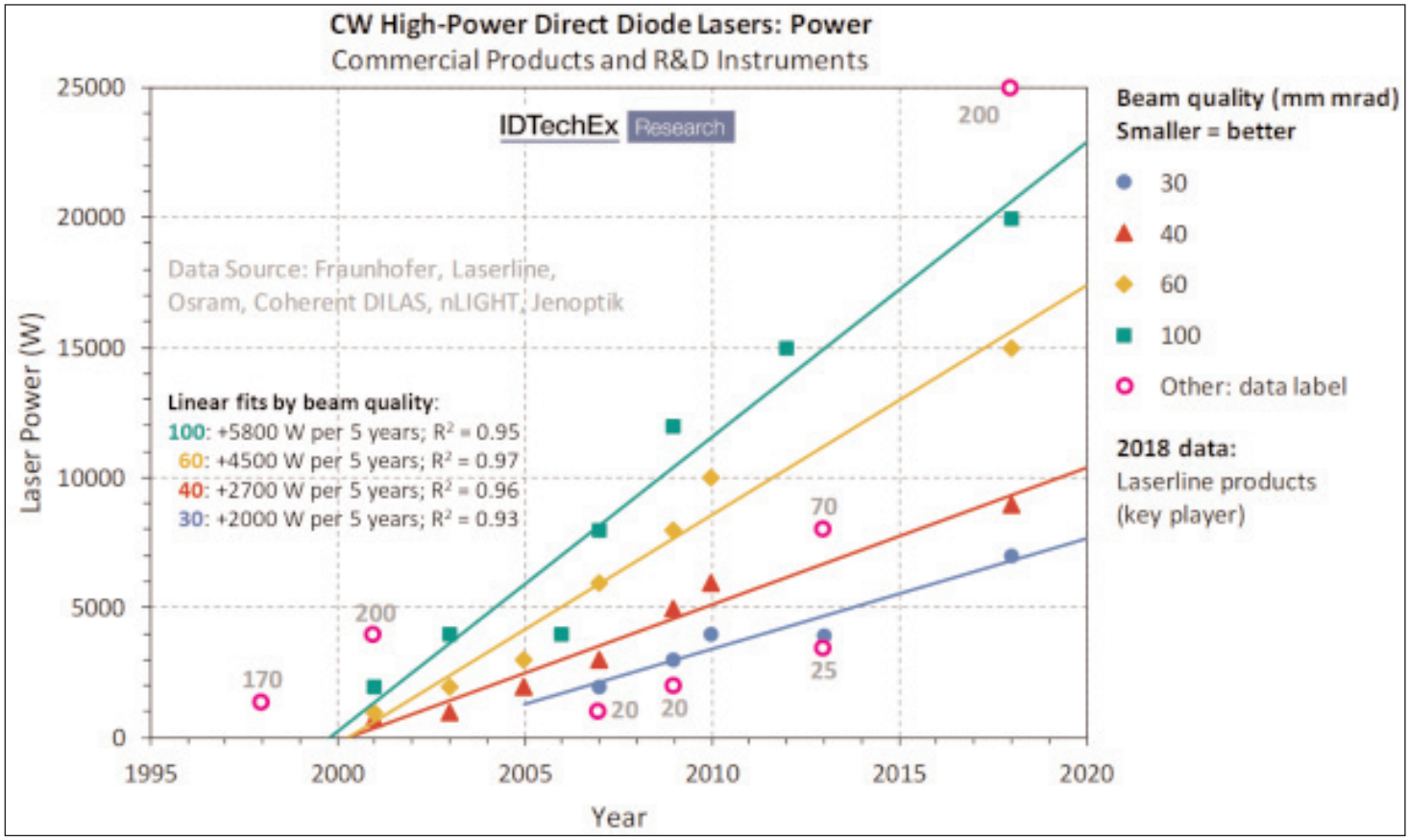
Evolution of laser diodes and diode bars

Technology advances have enabled lasers to progress from specialist technical instruments to a diverse range of markets. Specifically, while becoming the most widely available laser technology, the average power of laser diodes has increased significantly during the past three decades, and their average price per watt has fallen exponentially. Consequently, laser diodes are displacing some established laser and non-laser technologies, while enabling entirely novel optical technologies. Mature applications of laser diodes include data storage, data communication and the optical pumping of solid-state lasers. In contrast, material processing and optical sensing are examples of rapidly evolving market segments with many emerging applications.

With the output power of a single laser diode ranging from milliwatt to multi-watt levels, power can be



The increase in diode bar power contributed to the development of direct diode lasers and enabled new applications in material processing. Ongoing evolution of diode laser technology includes the improvement of infrared beam quality for precision engineering and the development of novel visible light lasers for metal processing.



Evolution of output power and beam quality in high-power direct diode lasers (HPDDLs) at 1μm infrared wavelength, according to data collected and analysed by IDTechEx. HPDDLs are a rapidly evolving tool for material processing and industrial manufacturing.

scaled up by combining single emitters into laser diode bars and stacks of bars, and a standard bar has a width of 1cm. For decades, there was strong competition between companies to increase the output power of diode bars, and an exponential growth trend was seen. While commercial diode bar products usually offer power less than 200W per diode bar at 1μm wavelength, R&D divisions of laser manufacturers have demonstrated continuous wave (CW) average power exceeding 1kW per bar.

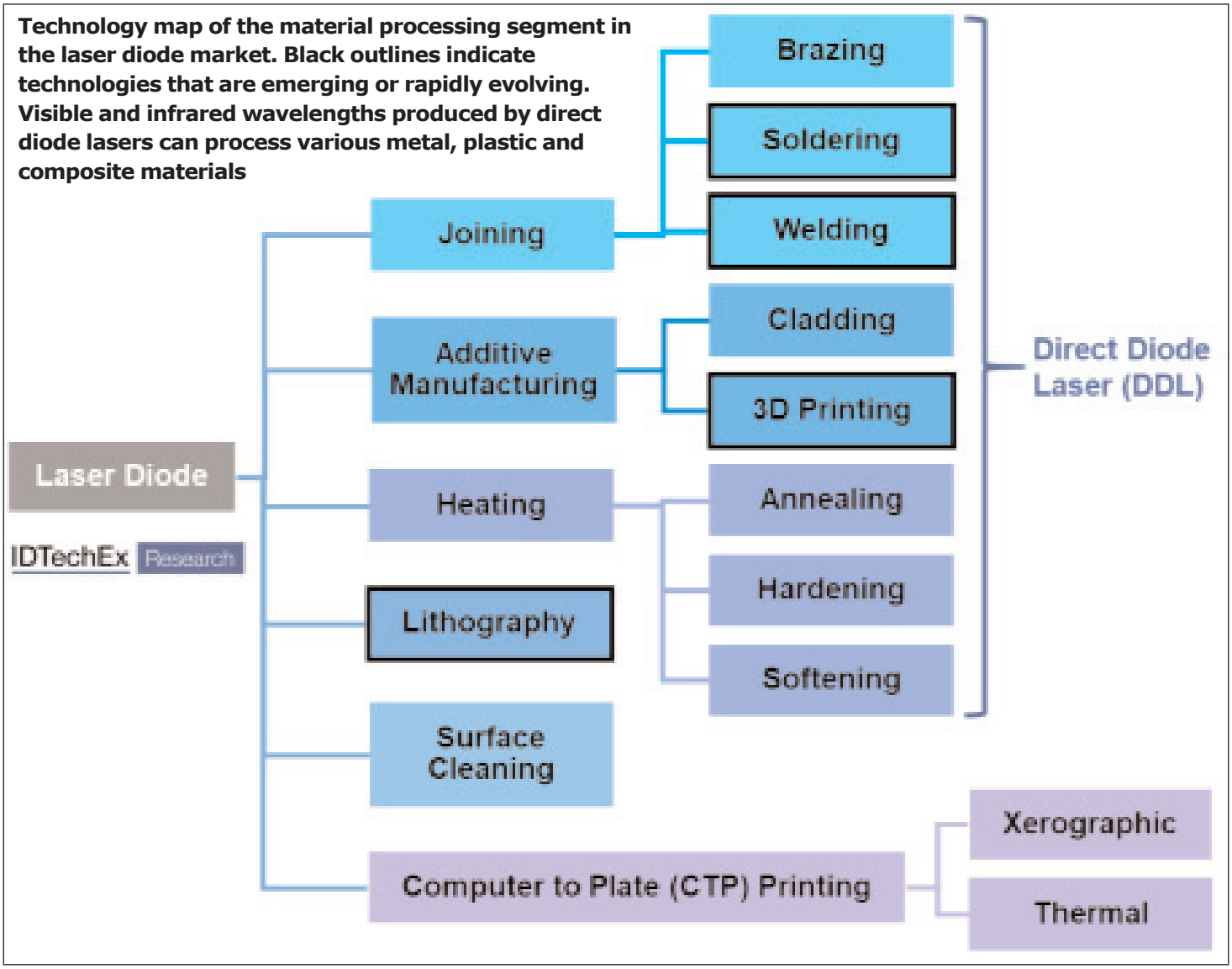
Increasing diode bar power has enabled new applications in material processing, but some emerging applications demand the enhancement of laser parameters like wavelength stability and device lifetime. Therefore, competing on power is no longer the priority for companies in this market. The ongoing evolution of diode laser technology includes the improvement of infrared beam quality for precision engineering and the development of novel visible light lasers for metal processing.

Power and precision: emerging direct-diode laser technologies

The advances in semiconductor laser technology enable the development of direct-diode lasers (DDLs), including high-power direct-diode lasers (HPDDLs) that produce multi-kilowatt output power. DDLs combine numerous diode bars with beam-shaping optics, control electronics and a cooling unit. Technology advances now enable DDLs to generate output power exceeding 20kW in multi-mode systems and produce multi-kilowatt power at higher beam quality than before. In addition to DDLs, companies like Germany's Laserline offer diode lasers coupled to active fiber converters, which produce 4-6kW output power at a beam quality of 4–6mm.mrad.

Dramatic improvements in beam quality now enable users to focus laser light to a small point, and this revealed DDLs as rapidly evolving tools for processing metal, plastic and composite materials. In applications like laser welding which require high precision and deep penetration, DDLs can now compete with fiber lasers. While DDLs directly convert electricity to laser light, fiber lasers are based on rare-earth metal doped optical fibers which must be optically pumped with energy input from laser diodes or diode bars.

The unit price of a DDL is significantly lower than a fiber laser for CW output power up to 1kW. In 2018, the typical unit prices were $20,000 for a 1kW HPDDL and $25,000 for a 1kW fiber laser, as quoted by key player companies interviewed by IDTechEx. The difference in price between DDLs and fiber lasers is larger at sub-kilowatt output power. Additionally, the wavelengths offered by DDLs are different to fiber lasers,



Technology map of the material processing segment in the laser diode market. Black outlines indicate technologies that are emerging or rapidly evolving. Visible and infrared wavelengths produced by direct diode lasers can process various metal, plastic and composite materials

which means that DDLs can process materials with matching absorption spectra more efficiently.

Consequently, DDLs and HPDDLs are emerging as major global trends in industrial manufacturing. To enhance their position in high-growth DDL/HPDDL markets, key players are making strategic acquisitions and investing in production capacity expansion. For example, Japan's Panasonic acquired US-based laser company TeraDiode for its expertise in HPDDLs that generate high-quality beams via a patented optical process.

Overall, the technology advances outlined above provide excellent business growth opportunities, believes IDTechEx.

Welding and 3D printing copper with bright blue diode lasers

A particularly important trend is the development of blue direct-diode lasers for applications like welding and 3D printing copper, with Laserline launching a 1kW product in 2019. Blue laser light is faster and more efficient at processing metals that are poor absorbers of the 1μm infrared radiation produced by most industrial laser systems.

In 2018, Japan's Shimadzu commercialized the BLUE IMPACT diode laser, which produces 100W of power at high brightness. This was developed in collaboration with Osaka University as part of a Japanese national project. The BLUE IMPACT laser combines many gallium nitride (GaN) blue laser diodes made by Nichia, which have doubled in efficiency and increased by an order of magnitude in output power since 2006.

A key application of Shimadzu's 450nm blue diode laser is in 3D printing copper. High absorption of blue laser light by copper enables a fast process with reduced back reflections, which are serious challenges for conventional infrared lasers. The newly developed 3D printer can efficiently print objects using pure copper powder. Existing 3D printer technologies typically use copper alloys like the CuCr1Zr instead of pure copper.

IDTechEx expects rapid adoption of blue DDLs in copper processing from 2019 onward as more products are commercialized. ■

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VCSEL market growing at 31% CAGR to $3.7bn in 2024, driven by new smartphone and automotive functionalities

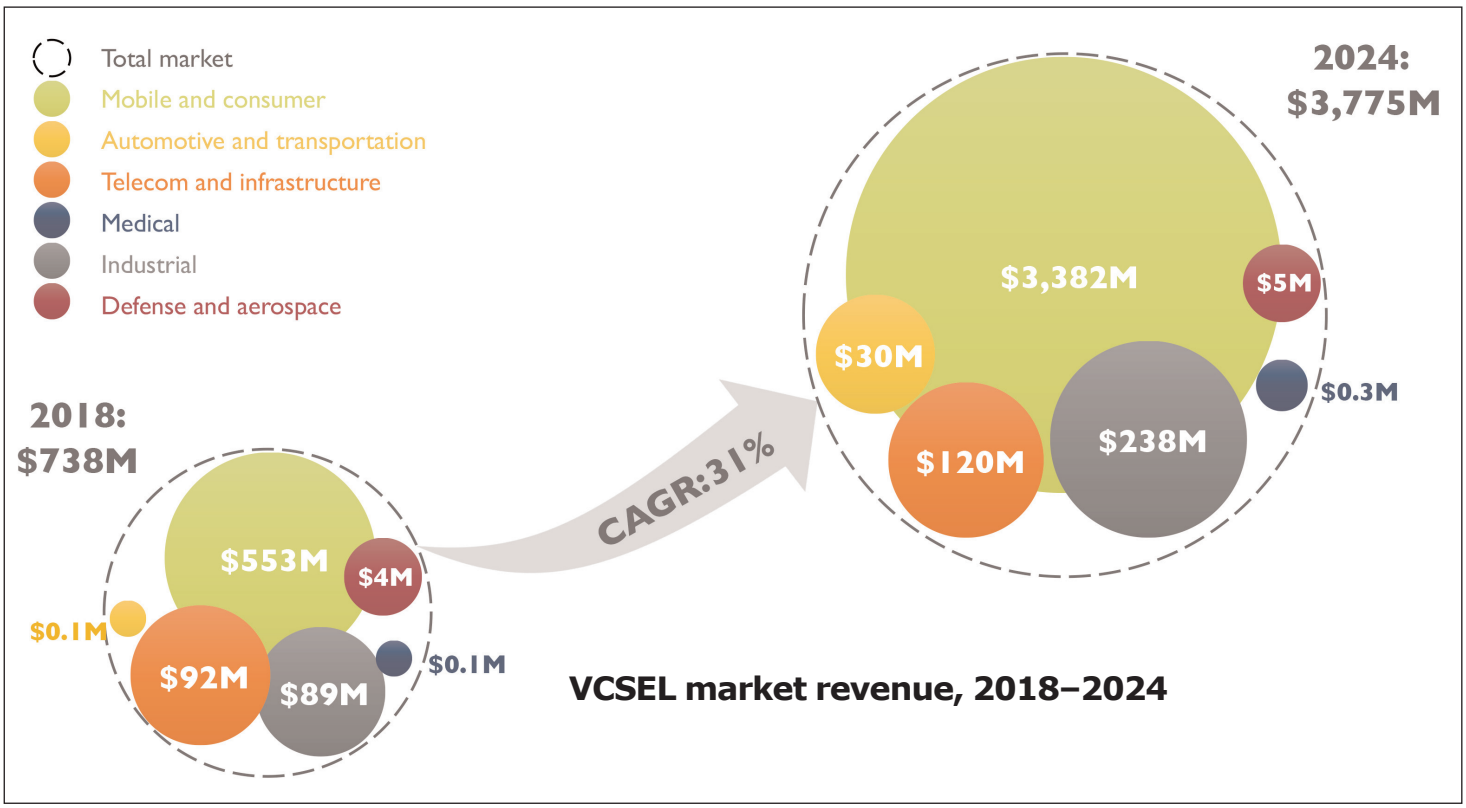
Consumer segment to contribute $3.4bn, but automotive growing at 185%, says Yole Développement.

The global vertical-cavity surface-emitting laser (VCSEL) market is rising at a compound annual growth rate (CAGR) of 31% from $0.738bn in 2018 to $3.775bn in 2024, mostly from the consumer segment (growing from $0.553bn to $3.382bn).

"Today, up to three VCSEL dies can be integrated in a smartphone: 3D recognition with the flood illuminator, the dot projector, and the proximity sensor; all are based on VCSEL laser components," notes Sylvain Hallereau, project manager at Yole company System Plus Consulting. "Already integrated in flagship smartphones, these functions will quickly find a home in all smartphones, causing a sharp increase in VCSEL demand."

Behind the smartphone applications, the automotive sector with emerging 3D sensing functionalities will also playing a key role, growing at a CAGR of 185% from just $0.1m in 2018 to $30m in 2024, reckons Yole Développement.

This year, the Yole group of companies has released two reports focused on VCSEL technology and applications: 'VCSELs – Market and Technology Trends' and 'VCSEL in Smartphone – Comparison', from Yole and System Plus Consulting, respectively. The firms have now combined their market and technical expertise to give their vision of the VCSEL industry, technology status, players' positioning and strategies, highlighting the direct link between each VCSEL type and its applications. Yole and System Plus collaborated to get a better, more accurate understanding of market evolution and technical issues. In particular, since the previous edition of the report, the Yole group has taken into account the drastic decrease in VCSEL average selling price (ASP).



VCSEL market revenue, 2018–2024

"In 2017, the total VCSEL cost per smartphone was estimated at $4–5. In 2018, this dropped to $2–3, evidence of a strong price decrease," states business unit manager Pars Mukish. "There are several explanations for this: higher volumes leading to lower cost; more VCSEL manufacturers qualified by smartphone manufacturers, leading to lower margins; and higher manufacturing yields leading to increased 'good' VCSELs per wafer," he adds. "In the future, a smartphone should embed VCSELs for proximity sensing and front and rear 3D sensing, with a total VCSEL cost around $2."

In November 2017, Apple released the iPhone X with the new feature FaceID, which detects and recognizes the smartphone's owner and unlocks the phone, thanks to three VCSELs working together. With this implementation of VCSELs for front 3D imaging, Apple set the proverbial 'cat among the pigeons' in the smartphone world, and consequently in the VCSEL industry, says Yole. Following the iPhone X's release, several smartphone makers announced that their next flagship would embed a similar feature. Front 3D imaging was implemented as a first step, and more recently smartphone makers have released new products with a rear 3D sensing module, using the time-of-flight (ToF) principle. Mobile and consumer VCSEL applications are exhibiting impressive growth, at a 35% CAGR from 2018 to 2024.

Other applications are also expected to implement VCSELs in the mid to long term in different market segments: mobile & consumer, automotive & transportation, and industrial. In light detection & ranging (LiDAR), VCSELs are expected to compete with edge-emitting lasers (EELs), especially for mid- and short-range LiDAR.

"Use of VCSELs for long-range detection is still challenging due to the VCSEL's limited output optical power compared to EELs," explains technology & market analyst Pierrick Boulay. "Also, cost is still prohibitive. But, due to their ability to easily be built in arrays, VCSELs are a good opportunity for reducing LiDAR cost and reaching the targets set by OEMs."

In the long-term, the VCSEL market for LiDAR could generate revenue of about $800m by 2032.

Following on from Apple, rival smartphone makers Xiaomi and Oppo released their flagship phones with a 3D sensing feature, and even more recently the two market leaders Huawei and Samsung began implementing VCSELs. On the technology side, structured light (used for facial recognition for the first time on high-end smartphones) implies the use of two different VCSELs: one flood illuminator and one dot projector. Using these two light sources hence adds a tangible cost to the 3D sensing module.

Meanwhile, a face recognition module using the ToF principle was implemented by LG in early 2019. This leads to using only one VCSEL (a flood illuminator) and therefore reduced cost of the 3D sensing module compared with modules using the structured light principle.

Conducted by System Plus Consulting, the report 'VCSEL in Smartphone – Comparison' provides insights into the structures, technology and design choices related to these components, which are at the center of innovative functions for smartphones. Analysts have compared four dot projectors, four flood illuminators, and two ToF systems, extracted the VCSEL dies, and performed a full physical analysis. The System Plus Consulting report gives a technical and economic comparison of 10 VCSEL dies integrated by the major smartphone makers: Apple, Xiaomi, Huawei, Oppo and Lenovo in their flagship smartphones, and by Intel in its RealSense product suite. ■

www.i-micronews.com/products/vcsels-market-and-technology-trends-2019

Chromium/aluminium n-electrode for reflection boost of deep-ultraviolet LEDs

Thinning a chromium layer increases diode light output power and external quantum efficiency.

Researchers based in China have been applying reflective n-type electrode metal structures to boost light extraction in 280nm-wavelength deep-ultraviolet light-emitting diodes (DUV-LEDs) [Yang Gao et al, IEEE Transactions on Electron Devices, vol66, issue7 (July 2019), p2992]. One of the big challenges for sub-300nm DUV devices is pushing the efficiency above 10%.

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

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

The researchers see DUV applications in sterilization, water/air purification, medical and bio-related equipment. Competing mercury-lamp devices have drawbacks such as system fragility and bulk, along with short lifetime and low efficiency. And, of course, mercury is highly toxic.

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

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

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

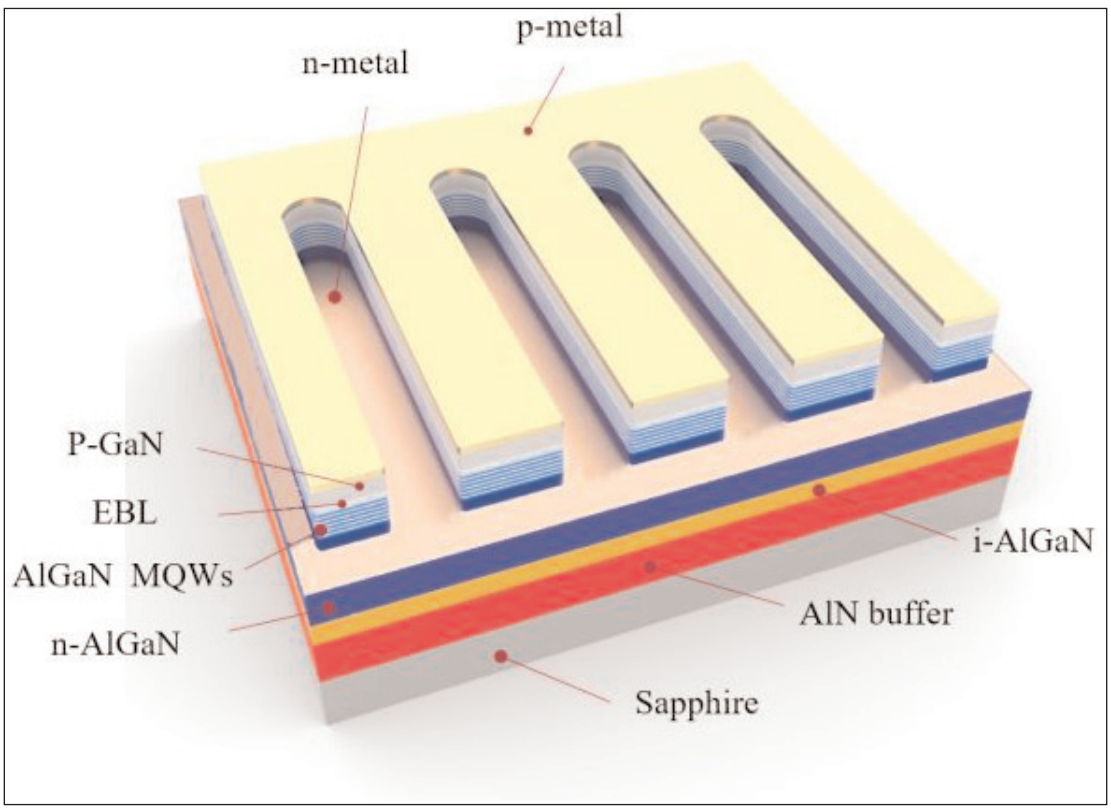


Figure 1. Schematic of flip-chip DUV-LED device.

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

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

In terms of light output power (LOP) at a given current injection, the device with 1nm chromium in the reflector (LED-1) gave the highest value (Figure 2). At 180mA injection, the output power was 40.9% higher than that for the LED with the thickest chromium layer — LED-5 with 20nm Cr. The researchers suggest that the higher turn-on voltage and contact resistance of LED-1 versus LED-2 could be due to the chromium layer being too thin to form the high-quality Al-Cr and Cr-N alloys needed for ohmic contact. The higher light output is attributed to the high reflectivity of the aluminium layer.

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

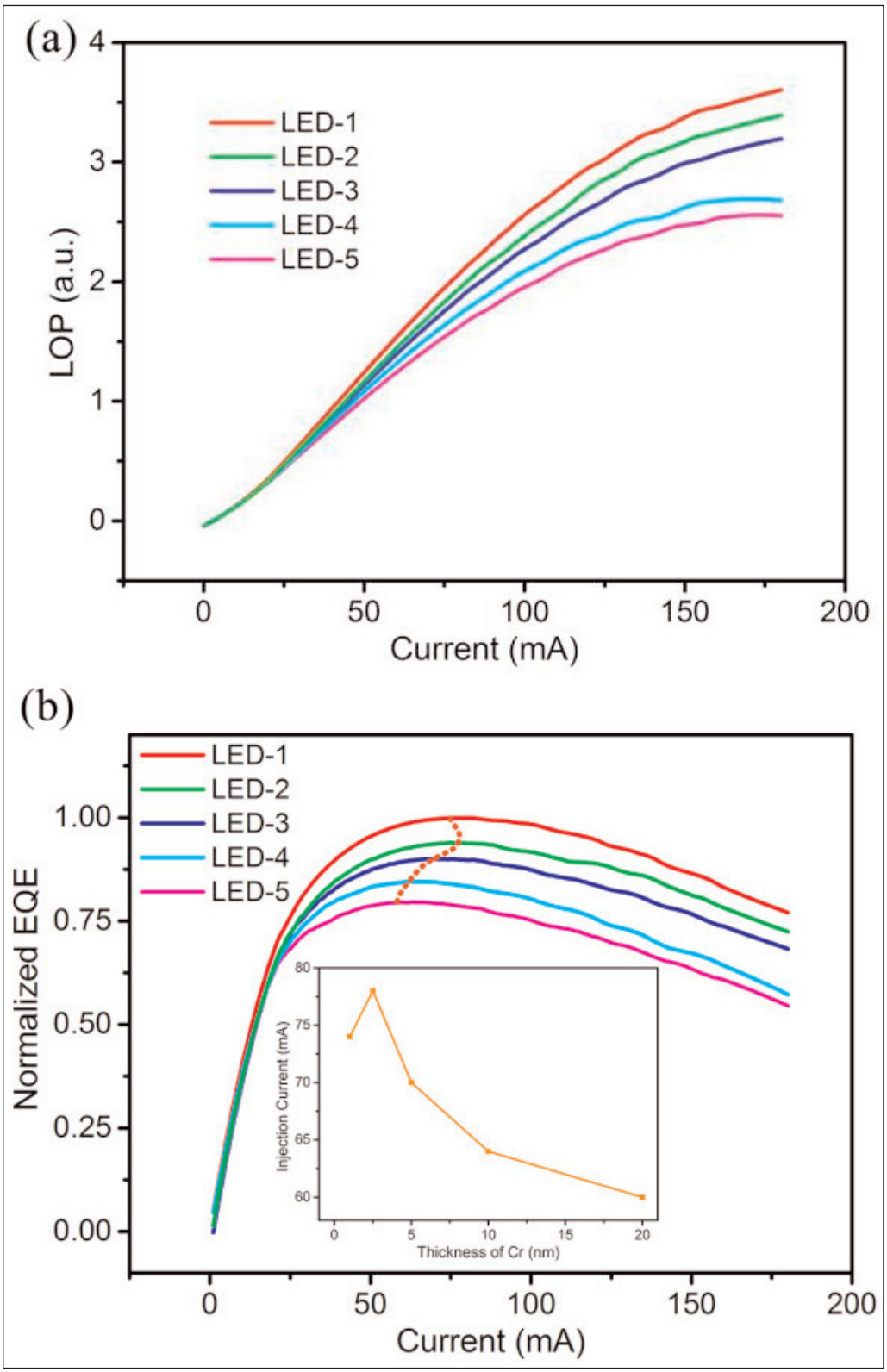


Figure 2. (a) LOP versus injected current for five fabricated DUV-LED devices. (b) EQE in terms of current. Inset: corresponding injection current to achieve peak EQE. LED-3 and LED-4 had 5nm and 10nm Cr, respectively.

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

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Author: Mike Cooke

Nitrogen-polar performance from gallium-polar growth

Researchers flip a light-emitting diode structure using buried tunnel junctions for hole injection.

Cornell University in the USA has been using plasma-assisted molecular beam epitaxy (PAMBE) to realize bottom- and top-tunnel junction (TJ) vertical III-nitride blue and green light-emitting diodes (LEDs) [Henryk Turski et al, J. Appl. Phys., vol125, p203104, 2019]. This enabled the team to explore the advantages of reversing the orientation of the charge-polarization-induced electric fields relative to the forward bias direction.

Turski, the lead author, was visiting Cornell from the Institute of High Pressure Physics in Poland, supported partially by the Polish National Centre for Research and Development and the Foundation for Polish Science co-financed by the European Union.

The charge polarization induction of electric fields in III–nitrides arises from the lack of inversion symmetry of the wurtzite crystal structure. Fixed sheet charges arise at heterostructure junctions, giving rise to electric fields of ~1MV/cm. These fields can pull apart electrons and holes, inhibiting recombination into photons (the 'quantum-confined Stark effect').

In addition to these problems, the conductivity of n-type III–nitrides tends to be much higher than for p-type material. The gallium nitride substrates used for indium gallium nitride (InGaN) vertical LEDs therefore are n-type in conduction character. Conventional LEDs then have the p-GaN contact at the top of the device (p-side up). The direction of the polarization fields then depends on whether the epitaxy is performed with gallium- or nitrogen-polar growth.

Although it is expected that N-polar LEDs should perform better, growth in that orientation seems to result in material with low internal quantum efficiency (IQE), as found from photoluminescence experiments.

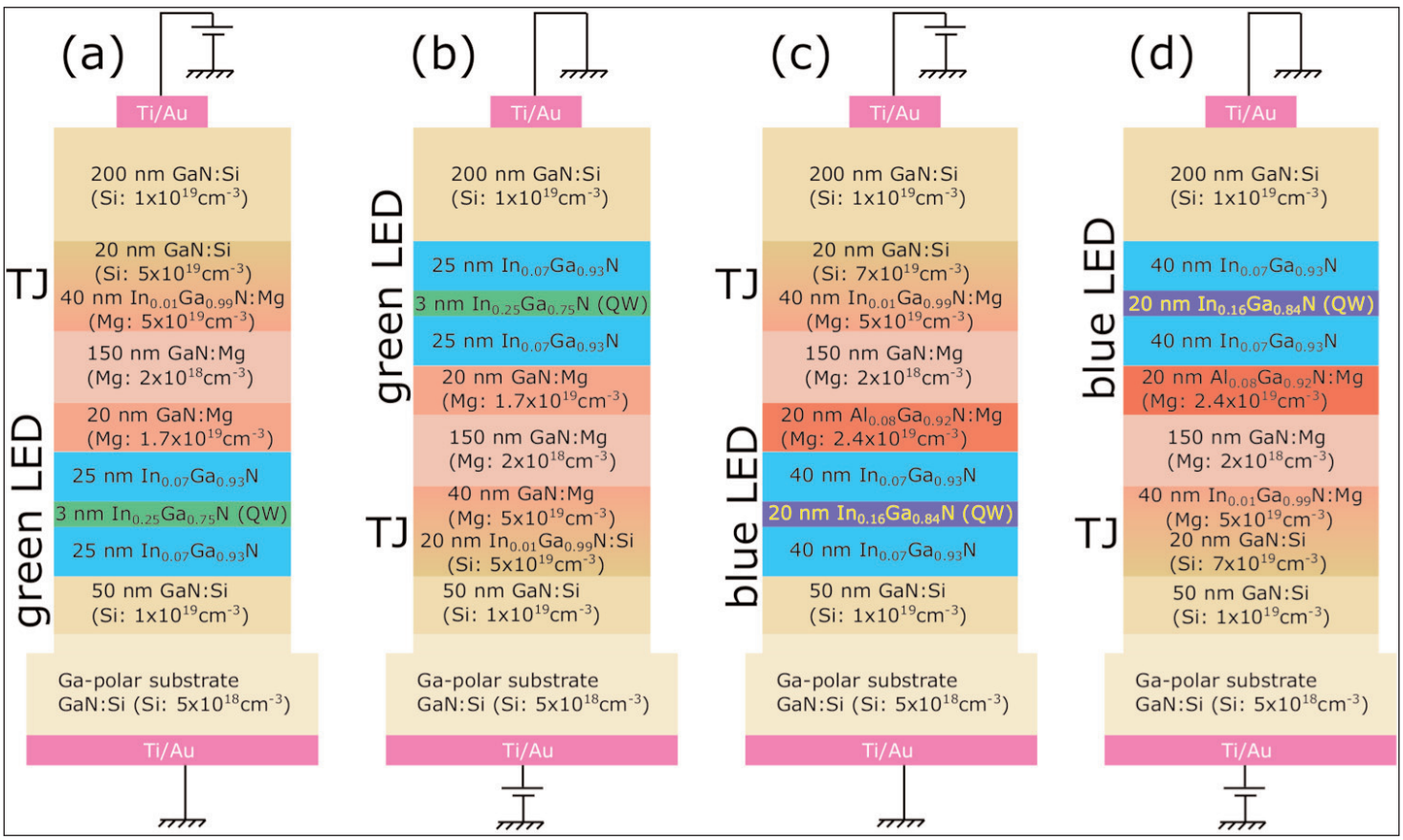

Figure 1. Layer and doping details of quantum well heterostructures with top (a, c) and bottom (b, d) tunnel junctions aimed at blue (c, d) and green (a, b) emission. Researchers referred to structures presented in (a), (b), (c), and (d) as A, B, C, and D, respectively.

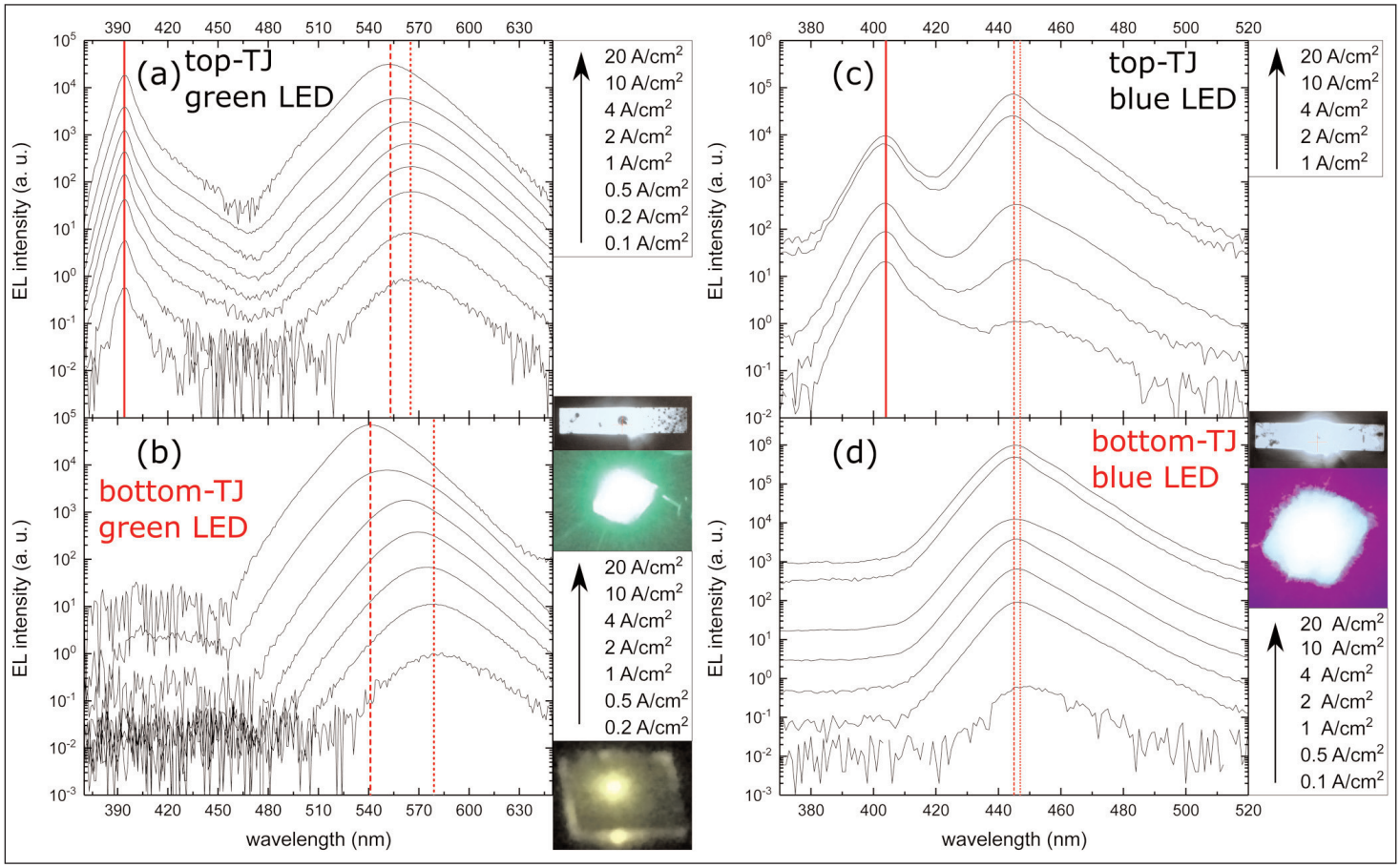

Figure 2. (a)–(d) Electroluminescence spectra in log scale measured on-chip for indicated current densities for 80μmx80μm device. Real-color pictures next to (b) and (d) is whole 1cmx1cm wafer. Above real-color images are monochromatic images collected under microscope for 100μmx500μm Bottom-TJ devices under 100mA injection, showing excellent current spreading.

The researchers comment: "The reason for this remains a mystery and is unsolved to date. It is likely related to the difference in defect formation mechanics, e.g. higher layer contamination for growths in the N-polar orientation by metal-organic vapor phase epitaxy (MOVPE) and molecular beam epitaxy (MBE), due to the drastically different growth dynamics and the chemistry of the N-polar and Ga-polar structures."

The Cornell researchers used tunnel junctions to enable placement of the p-side of the device above or below the active region, avoiding the need for N-polar growth. The tunnel junctions consisted of n- and p-type material.

For effective p-GaN one needs to avoid passivation with hydrogen. For MOVPE growth this is achieved with activation annealing. However, the out-diffusion of hydrogen is blocked when there are overlying layers, restricting devices to top p-GaN contact layers. MBE growth can be arranged to avoid the presence of hydrogen, using nitrogen plasma rather than ammonia (NH_3) as precursor, allowing the creation of buried p-type layers.

Another advantage of tunnel junction structures is that the outside contact to metal electrodes can be through thick n-GaN layers, which enable more effective current spreading than p-GaN. Tunnel-junction devices could also realize new geometries for integrating and stacking multiple light emitters. The team also hopes that such "fresh ideas" could eventually lead to lower threshold currents in laser diodes.

The researchers used plasma-assisted molecular beam epitaxy on commercial bulk n-GaN substrates to grow various tunnel-junction/LED combinations (Figure 1). The threading dislocation density of the Ga-polar substrate was ~$5x10^7/cm^2$. The devices were aimed at blue and green emissions with the tunnel junction variously on top and below the active layers. The GaN layers were grown at 740°C. A lower temperature of 650°C was used for InGaN layers. The 'quantum wells' (QWs) in the blue devices were 20nm thick, giving them more the character of double heterostructures. The resulting materials were smooth, with atomic force microscopy (AFM) of 5μmx5μm fields giving roughness values less than 0.5nm.

Fabrication involved device isolation by inductively coupled plasma etch and deposition of titanium/gold electrodes. The bottom electrode consisted of a common contact on the back-side of the substrate. The top electrodes were circular, placed in the center of the mesa. Titanium/gold has a low contact resistance on n-GaN.

The researchers suggest that in future the bottom tunnel-junction contact resistance could be lowered by exploiting a larger cross-section area than for the LED mesa itself. This is not possible for top tunnel-junction devices.

Bottom-TJ devices with 80μmx80μm mesas had higher current flow near the turn-on voltage. This effect was greater in the green-emitters. The researchers say that low leakage levels in all the devices show that the density of extended defects propagating through the LEDs is similar.

The team also suggests that lower tunnel-junction resistance could be achieved by increased doping and polarization-induced effects from InGaN or AlN interlayers. However, such techniques carry the risk of degraded crystal quality in the active region.

The top-TJ LEDs had electroluminescence spectra with two peaks (Figure 2). The high photon energy (shorter wavelength) peak was attributed to parasitic recombination in lower-indium-content layers around the wells. In fact, the parasitic recombination dominated at low current injection levels. The parasitic peaks were not observed for bottom-TJ structures.

The bottom-TJ LED also had higher peaks: ~2.5x for green-emission at 20A/cm^2, and ~13x for blue. The researchers comment: "The quantitative differences between the enhancement for green and blue emitters can be attributed to differences in active regions and the electron-blocking layer (EBL) design but, irrespective of the details, the bottom-TJ structures for both wavelengths demonstrate the important advantages offered by this conceptual change in the LED design."

The high-indium-content green LED saw some yellow-to-green shift in the spectral output with increasing injection: from 565nm/580nm for top-/bottom-TJ LEDs to 552nm/541nm, respectively. This was attributed to localized state filling and screening of the internal polarization electric field as injection increased. The researchers see the more pronounced shift in the bottom-TJ device as being evidence of more efficient injection at higher currents. The increased carrier concentration in the quantum well is thought to lead to the higher light output in the bottom-TJ LED.

Simulations of the devices suggested to the researchers that bottom-TJ LEDs suffered less from carrier overshoot effects that can result in efficiency droop at high currents. Overshooting carriers (mostly electrons) recombine non-radiatively in the doped contact layers.

In the presented devices the overshooting carriers could also recombine in the barrier layers, leading to higher-energy photon emission in some cases. The inverted polarization field in the bottom-TJ devices retains the electrons and holes in the quantum well, it is thought. The researchers add: "Because of the separation of electrons and holes outside the QWs, the recombination in the barrier surrounding the QW is significantly reduced for the bottom-TJ LEDs compared to the top-TJ case."

Capacitance–voltage measurements at 5MHz showed significant hysteresis between up and down sweeps in blue LEDs with top junctions, attributed to charge trapping in the active region. Energy-band simulations suggest that a deep triangular well forms, trapping electrons near the p-side and holes near the n-side of the quantum well. "The hysteresis is caused by charging/discharging of this local, triangular minimum of the potential due to carriers injected or extracted from this region," the researchers write.

The same triangular structures are also thought to raise barriers to carrier injection into the well at low current, reducing active-region recombination and increasing high-energy photon creation in the cladding layers.

Charge-trapping effects would be detrimental in applications requiring fast modulation, such as is needed for visible light/VLC and 'light fidelity'/LiFi data communication. ■

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Developing a III-nitride-on-Si optoelectronic platform

Researchers demonstrate a light-emitting diode and photodiode on-chip power monitoring system with the potential for gas and liquid analysis.

China's Nanjing University of Posts and Telecommunications continues to develop III–nitride optoelectronic systems with light-emitting diodes and photodiodes (PDs) connected with waveguides [Yongjin Wang et al, Semicond. Sci. Technol., vol34, 065017, 2019]. The new work used a metal-bonded III–nitride-on-silicon platform "for the first time", according to the researchers.

The platform was also used in the group's recent work on enhancing LED extraction by eliminating waveguide modes in the LED itself by the thinning of epitaxial layers [www.semiconductor-today.com/news_items/2019/mar/nupt_190319.shtml]. Previously, the Nanjing researchers constructed LED/PD systems that were transferred to glass [www.semiconductor-today.com/news_items/2018/may/nagoya_020518.shtml].

In the latest work, III-nitride thin-film material was metal-bonded to (100) silicon. The film was flipped so that the 125nm p-GaN side was down. The other layers consisted of a 50nm multiple quantum well, a 70nm InGaN spacer, and a 2800nm top n-GaN contact. On top of the n-GaN there was also 800nm undoped GaN

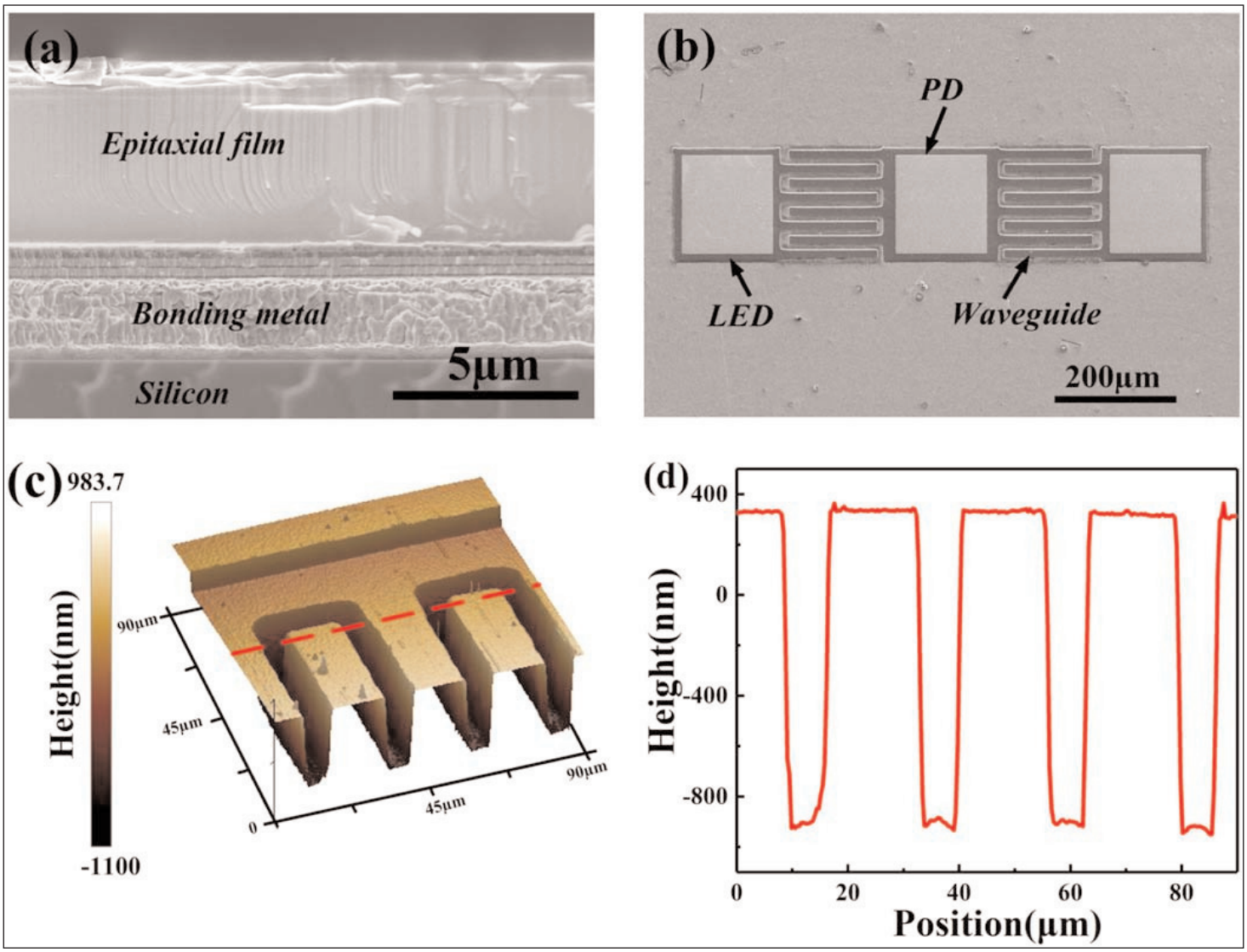

Figure 1. (a) Cross-sectional scanning electron microscope (SEM) image of III-nitride films on Si (100) substrate. (b) SEM image of on-chip power monitoring system. (c) Three-dimensional atomic force microscope image of waveguides. (d) Device height profile.

Figure 2. Transmitted signals of LEDs versus induced photocurrent temporal traces of photodiode: (a) R-LED and (b) L-LED. (c) Measured superimposed signals versus calculated signals.

and 700nm from the AlN/AlGaN buffer layers from the epitaxial growth process. The metal bonding included a silver reflector.

The device structure (Figure 1) was created using mesa and waveguide etching down to the silver-bonding layer, isolating the components electrically. The etch plasma consisted of a mix of chlorine and boron trichloride gases. Further patterned etching defined the p- and n-contact areas. Contact electrodes consisted of nickel/gold.

The device incorporated two LEDs and a central photodiode. The different sections were connected with waveguides consisting of 155μm-long fingers. The width and height of the waveguides were 18μm and 1253nm, respectively.

The light from the LEDs was transmitted along the waveguides and then across a 12μm air gap into the photodiode. The researchers see such structures as having potential for liquid and gas analysis, where fluids would flow through isolation trenches and channels, modulating light propagation.

The LED emission peak was at ~452nm, which was in the range of detection of the photodiode. By imposing different signals on the left and right LEDs, the researchers were able to distinguish the responses in the superposed photodiode output signal (Figure 2).

The filling factor of the right LED was found to be 0.5 under 1MHz pulses with 0.4V peak-to-peak voltage and 5.0V offset. The left LED had a filling factor of 0.3. The researchers comment: "The filling factor of signals constitutes the codes used by the LEDs to modulate light for information transfer in the system."

The team adds: "If the received signals from one LED is measured, the received signals from another LED can be obtained by subtracting the known signals using the superimposed signals. According to the difference in the filling factor, the mixed signals can be extracted to identify the individual LED."

The system could be used as an on-chip monitor, enabling one photodiode to check dynamic emission power fluctuations from multiple LEDs.

Reflectivity studies suggested that thinning the epitaxial layer — confining the Fabry–Perot modes of the waveguide — could enhance light extraction in the systems. ■

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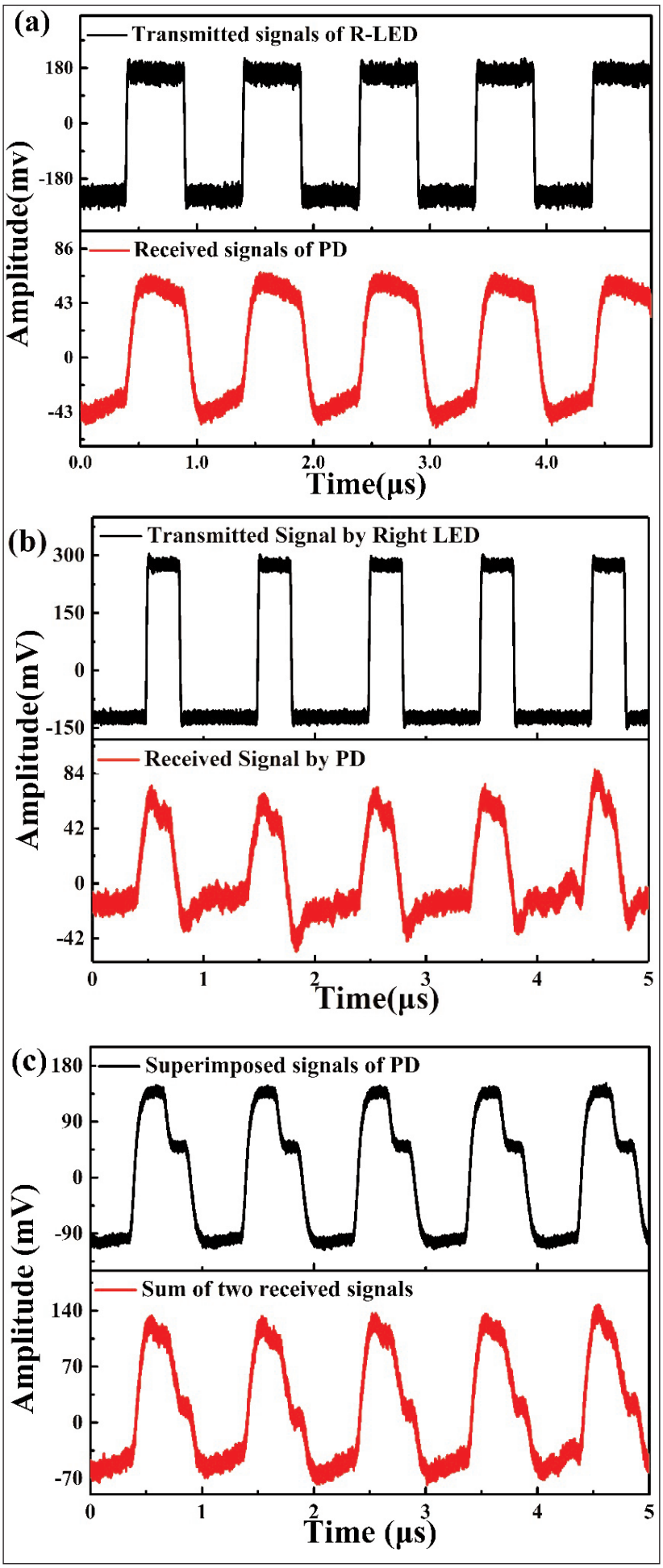

Two-dimensional optoelectronic integration with silicon systems

Mike Cooke reports on proposals and explorations of the potential of combining graphene, transition metal dichalcogenides, and hexagonal boron nitride with complementary metal-oxide-semiconductor electronics.

As global communication networks and remote storage facilities expand, the demand is for broader bandwidths and high-speed computer processing with low power consumption. Optical communications offer high data rates with low transmission decay. As purely electronic systems reach physical atomic limits, such systems are being combined with optical communications — both long-haul, and increasingly board-to-board, or even chip-to-chip. As always, these developments must be aimed at power-efficient performance at low cost.

Researchers are seeking photonic integrated circuits on silicon platforms using processes compatible with complementary metal–oxide–semiconductor (CMOS) technology. An important class of materials consists of few-layer or even one-layer two-dimensional (2D) lattices of elements. The archetypal example is graphene (G), consisting of carbon atoms in a hexagonal formation with so-called sp^2 bonding. More recently, transition-metal dichalcogenides (TMDs, MX_2) have come to prominence in the research literature.

Bulk TMDs tend to have indirect bandgaps, but mono-/few-layer versions often have the direct transitions needed for efficient light emission and detection. The metal 'M' parts of the MX_2 chemical formula can be molybdenum (Mo), tungsten (W), tantalum (Ta), titanium (Ti) or niobium (Nb). The dichalcogenic 'X_2' part is supplied by sulfur (S), selenium (Se) or tellurium (Te). There are also possibilities of compounding group III elements gallium and indium with chalcogenic elements (GaX, In_2X_3).

Tianhua Ren and Kian Ping Loh of National University of Singapore [J. Appl. Phys., vol125, p230901, 2019] comment: "Two-dimensional transition-metal dichalcogenides are attractive candidates as on-chip emitters and absorbers due to their direct bandgaps, compatibility with miniaturization, large exciton binding energies, anisotropic polarizations, and strong light-matter interactions."

Unfortunately, direct growth of TMDs and related materials on silicon or silicon dioxide (SiO_2) is still a bottleneck. Most research uses laborious techniques such as mechanical exfoliation of TMD flakes with sticky 'Scotch Tape' and manual manipulation, which are not suitable for precision mass production.

The different 2D (i.e. mono- or few-layer) TMDs can provide various metal, semi-metal and semiconductor electrical transport. Ren and Loh favor hexagonal boron nitride (hBN) as an insulator material and for waveguide cladding/optical confinement. "On-chip integrated photonic circuits are proposed based on heterostructures of hexagonal boron nitride and two-dimensional materials with functions of light sources, optical modulators, and photodetectors toward high-bandwidth optical interconnects," they report.

hBN has been reported with an in-plane refractive index of 2.3, compared with silicon dioxide's less than 1.5 at visible and near-infrared wavelengths. This contrast is one way to provide light confinement. Further confinement could be achieved in hBN/TMD/hBN stacks, with Van der Waals (VdW) bonding between the layers, creating opportunities to create optical cavities for laser and other emission and detection schemes. Although some work has already used such structures, problems arose from 0.7–4.8eV mid-gap energy levels, arising from crystal defects in the hBN.

Ren and Loh envisage vertical confinement arising from the refractive index contrast between hBN and silicon dioxide substrates/templates and top layers. Horizontal confinement could be achieved with patterning and etching mesa or photonic crystal/air-hole 2D lattice structures.

Light-emitting diodes

Proposals for TMD LEDs come in two forms: lateral and vertical. In the lateral setup, the p- and n-doped regions of the LED are placed side-by-side, creating carrier sources for recombination in the region/junction between the doped materials. The vertical structure instead places the doped material in a stack — a form familiar from the epitaxial growth of III-V LEDs.

Some 2D TMD LEDs have already been reported, such as the first such device in 2013. This LED consisted of a Schottky junction between MoS_2 and chromium/gold. Attempts to use electrostatic doping to give p- and n-type regions failed on this occasion. The external quantum efficiency (EQE) of the Schottky junction was a very low 10^{-5}. Higher EQEs of up to 10% were achieved with vertical stacks using naturally n-type MoS_2 and p-WSe_2 in 2014.

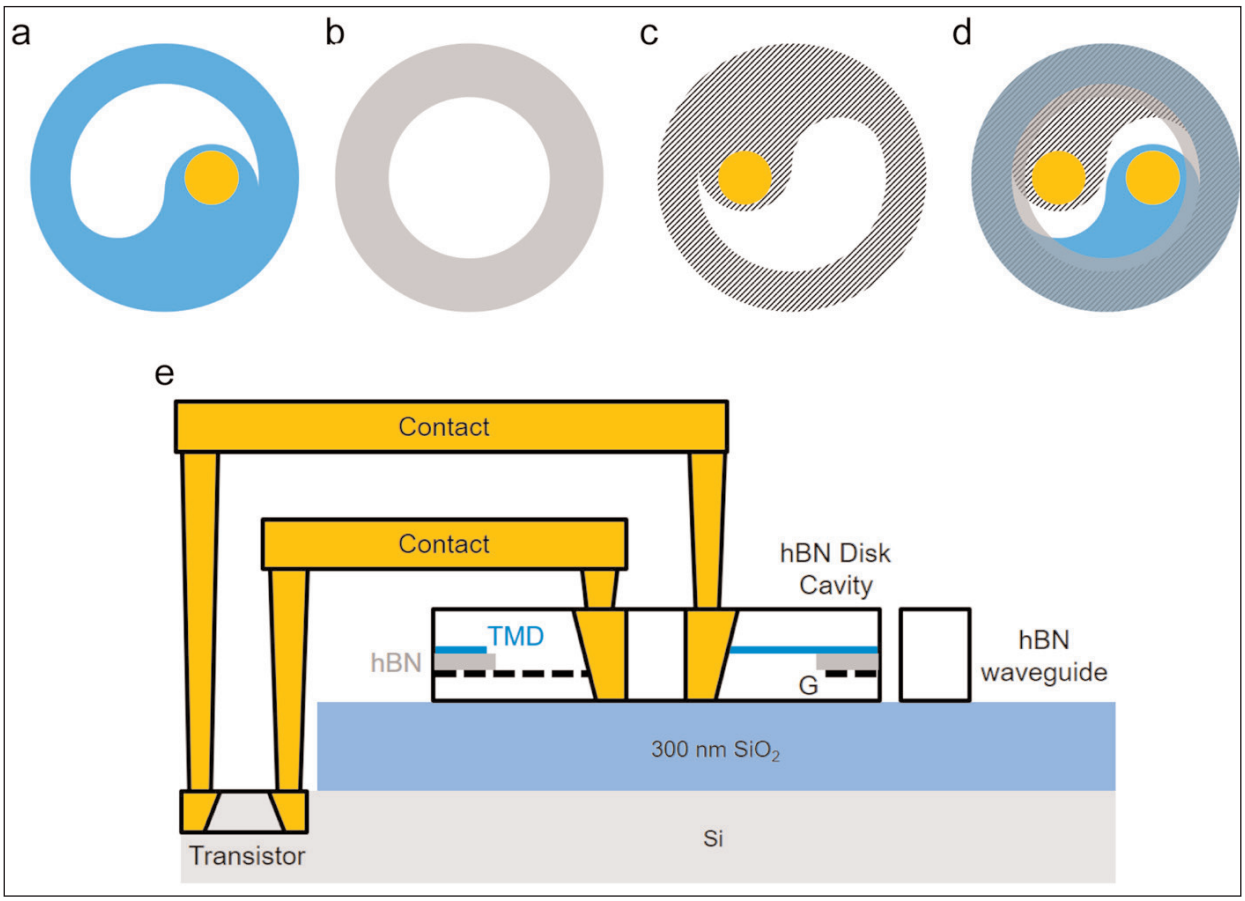

Figure 1. Schematic design of proposed LED with hBN disk cavity. Top view patterns of (a) top TMD layer, (b) middle hBN layer, (c) bottom graphene (G) layer, and (d) TMD/hBN/graphene trilayer; (e) side view of LED structure connected with silicon transistor.

Ren and Loh suggest that a cavity-enhanced LED could be constructed using a graphene/hBN/TMD stack as the active region (Figure 1). By applying differently shaped layers extending from a ring of material, an hBN cavity with whispering gallery modes that couple with the active junction is formed. The researchers suggest that, with a high enough quality-factor cavity, laser action could be possible. Metal interconnects could link the diode electrodes to silicon CMOS circuitry.

Optical modulators and detectors

Moving on to the original 2D material (graphene), Ren and Loh see — among its other potentials — the use of its refractive-index modulation by electrostatic doping via top or bottom gate structures in optical modulator stages, giving amplitude and phase manipulation. Mach–Zender interferometers have been realized with 35dB modulation and 5GHz bandwidth using a gate swing of the order of 2V, rather than the typical 10–50V in amplitude modulators. Ren and Loh comment: "The real-world application of 100GHz bandwidth optical interconnects should require multiplexing of wavelengths using multi-channels of graphene optical modulators."

Again, Ren and Loh want to combine graphene modulation with an hBN cavity structure. The modulation would be achieved by an aluminium oxide layer sandwiched between graphene layers, and strongly coupled to the whispering gallery modes of the hBN cavity.

TMDs have also been used as the basis of the easier photodetector function using either metal–semiconductor–metal (MSM) or photovoltaic structures.

MSM devices have demonstrated high response (the current for a given light power), but the bandwidth for detecting modulated signals is limited. Increasing the bandwidth requires boosting mobility and improving crystal quality. By contrast, graphene-based MSM devices tend to have high bandwidth but poor response. Also, multi-layer TMD detectors have improved bandwidth at the cost of reduced response. MSM detectors have been realized in both lateral and vertical formats.

Photovoltaic detectors based on pn-junction separation of the generated carriers offer reduced dark current in reverse-bias mode. Again, Ren and Loh propose using hBN cavities to enhance the detector performance. At present, they favor a graphene/TMD/graphene sandwich as the detector component due to its potential for GHz-level bandwidths.

Ren and Loh see their hBN cavity components as forming an electronic-photonic-electronic chain:

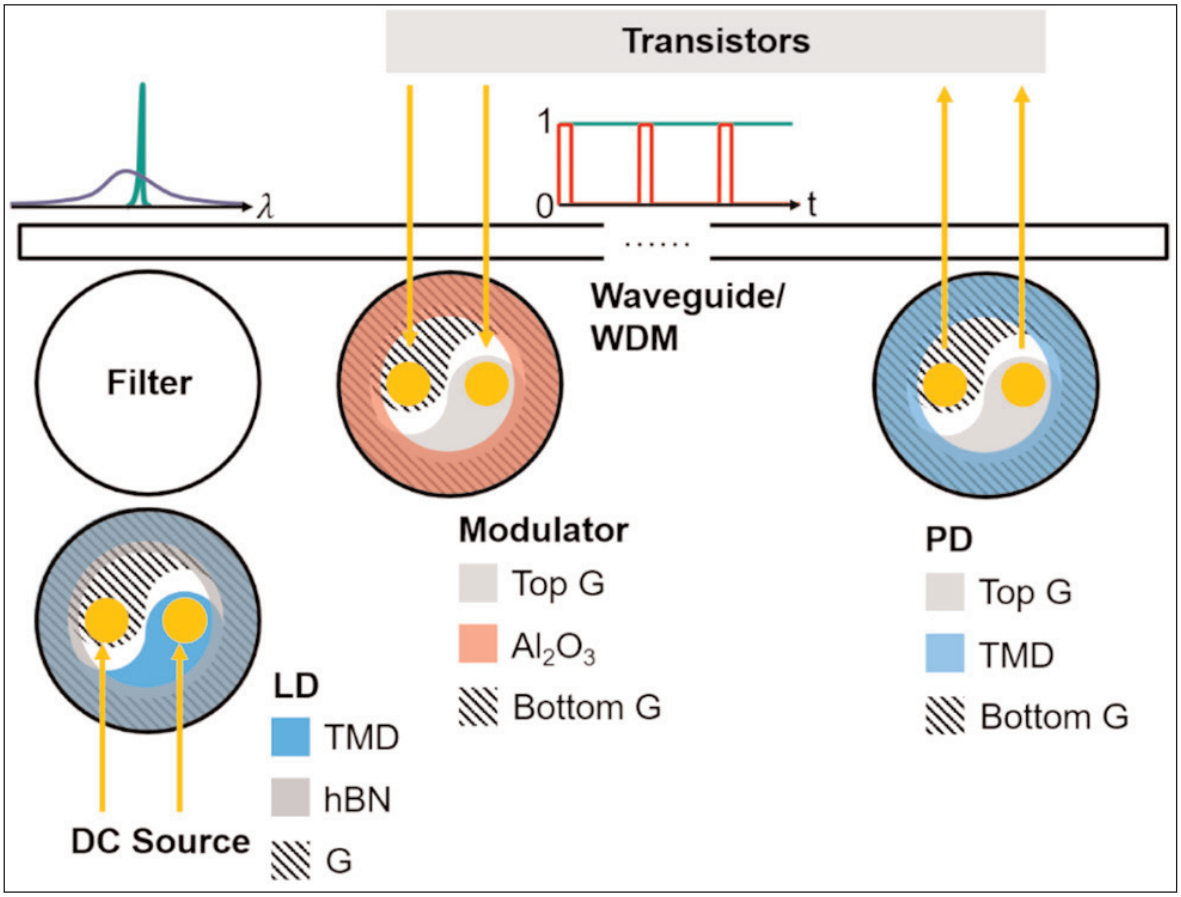

Figure 2. Integrated photonic circuits with hBN disk cavity and waveguide on SiO_2/Si platform.

graphene/hBN/TMD laser diode/LED, filtering to a single wavelength with a passive hBN cavity with continuous output, modulation into wavelength division multiplex (WDM) signals, transmission by waveguide/optical fiber, and detection with photodetectors (Figure 2).

Ren and Loh admit: "The practical realization of these photonic circuits requires the monolithic growth of large-area TMD and hBN on the silicon platform, which has yet to be achieved to date. Nonetheless, breakthroughs in large-area TMD and hBN growth have been achieved on other substrates; thus, future developments in automated wafer-to-wafer transfer techniques may help address the gap in materials integration."

Visualization

TMDs, graphene and hBN also feature in the work of a group of researchers based in the USA, the UK and Italy who have used 2D VdW graphene/hBN/graphite heterostructures to realize micron-scale, angle-resolved photoemission spectroscopy (microARPES) as a platform for investigating the electronic structure of graphene and TMDs [Paul V Nguyen et al, Nature, online 17 July 2019].

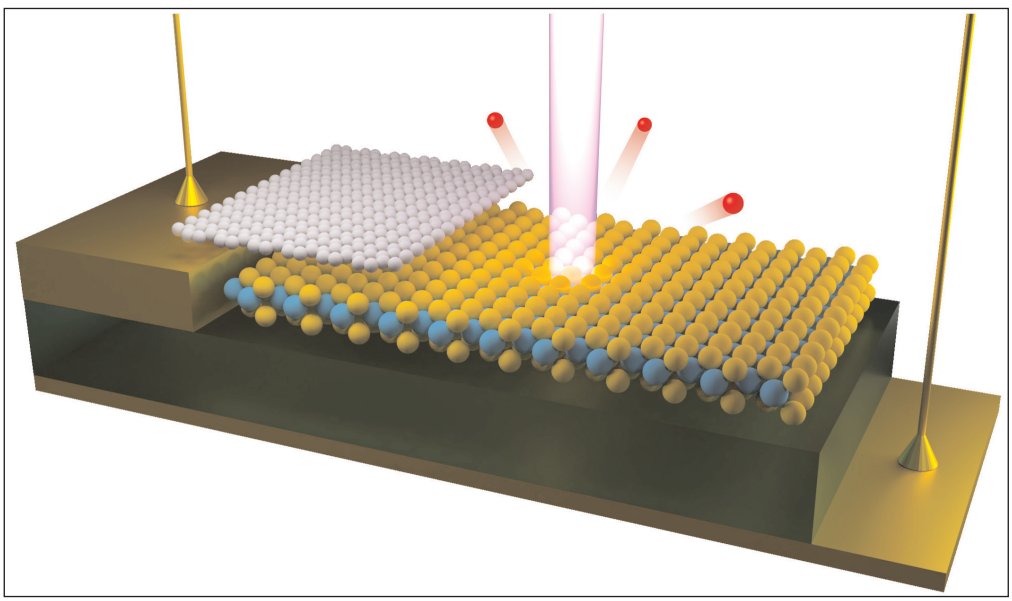

Figure 3. Electrons ejected by a beam of light focused on two-dimensional semiconductor device are collected and analyzed to determine how electronic structure in material changes as voltage is applied between electrodes. Credit: Nelson Yeung/Nick Hine/Paul Nguyen/David Cobden.

The team from University of Washington (USA), University of Warwick (UK), Elettra-Sincrotrone Trieste SCpA (Italy) and University of Cambridge (UK) comments: "The technique provides a powerful way to study not only fundamental semiconductor physics, but also intriguing phenomena such as topological transitions and many-body spectral reconstructions under electrical control."

ARPES techniques use narrow-spectrum ultraviolet or x-radiation to eject electrons from samples (Figure 3). The direction and energy of these electrons provide information about energy levels within the sample of interest. ARPES tends to only give data on near surface levels, so it is generally not that

useful for bulk properties. However, 2D materials such as graphene and TMDs are essentially all about surface states.

Recently, focusing techniques such as Schwarzschild objectives, Fresnel zone plates, and capillary mirror optics have enabled focusing of synchrotron beam-lines to provide the micron-scale spots needed for microARPES. The researchers used a Schwarzschild objective to focus radiation produced at the Elettra synchrotron facility in Italy. The photon energy was mainly 27eV.

Since ARPES sees only filled levels, doping techniques are needed to explore the conduction band. The researchers used electrostatic doping with a gate potential applied to the graphite underlayer, rather than introducing chemical impurities.

The researchers were particularly keen to explore the directness of the conduction band edge (CBE) in monolayer and few-layer 2D materials. It is thought that monolayers of many TMDs such as WSe_2 have a direct gap at the corner of the hexagonal Brillouin zone, designated as 'point K', rather than at the central 'Γ point' (Figure 4). The directness arises since the valence band is highest at point K. As one adds layers an intermediate valley at the less symmetric 'point Q' between K and Γ reduces in energy and the gap becomes indirect.

The team reports: "Using electrostatic doping in microARPES, we confirm that the CBE is at K in all of the monolayer semiconductors — MoS_2, $MoSe_2$, WS_2 and WSe_2 — and in each case we obtain a measure of the bandgap. We also study the layer-number dependence in WSe_2, finding that the CBE moves to Q in the bilayer, and measure for the first time the renormalization of the band structure on gating." ■

Author: Mike Cooke

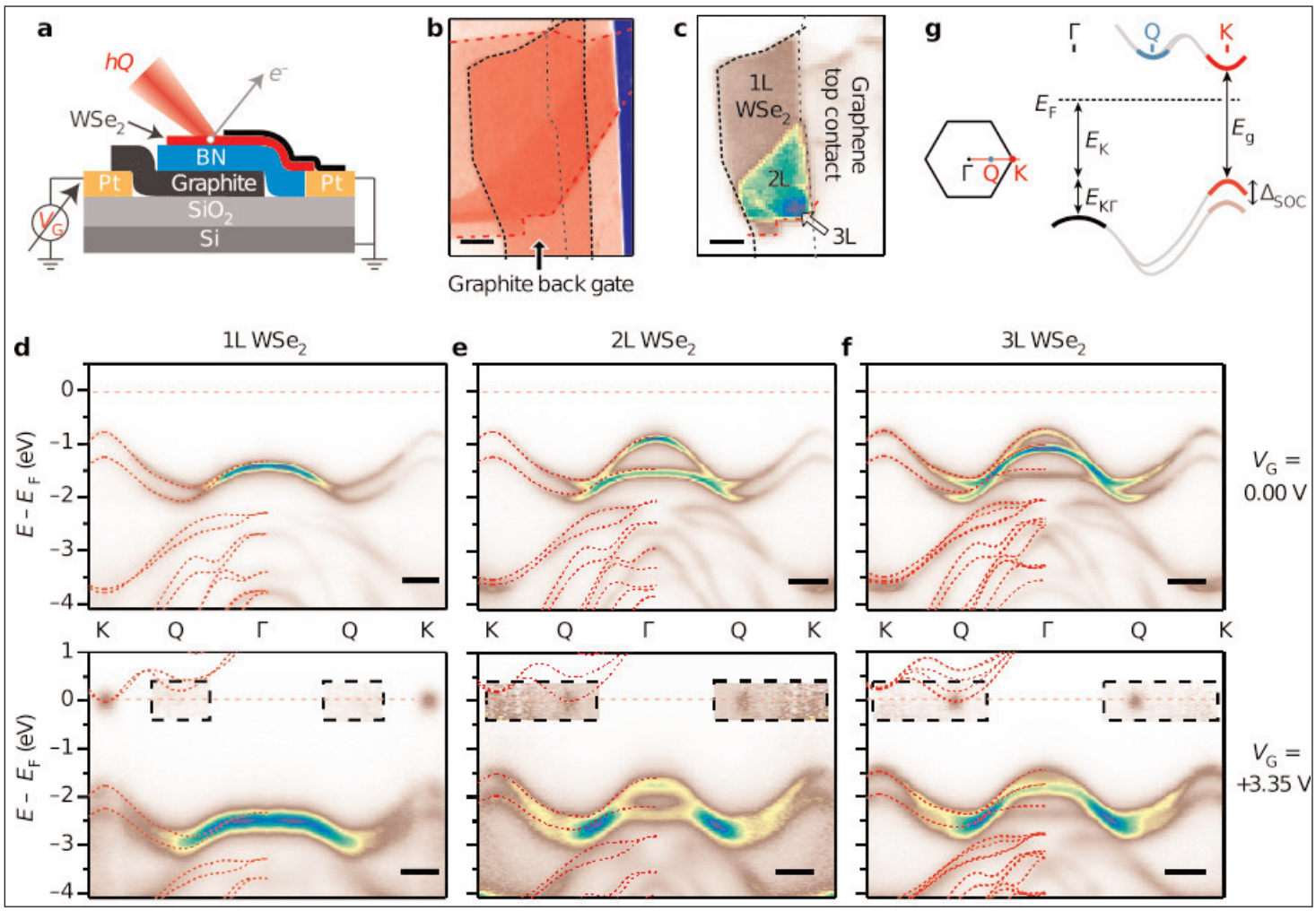

Figure 4. (a) Diagram of device incorporating WSe_2 flake, with overlapping ground graphene top contact and gate voltage applied to graphite back gate. Optical (b) and scanning photoemission microscopy (c) images of WSe_2 device (hBN thickness 7.4nm), with monolayer (1L), bilayer (2L) and trilayer (3L) regions identified. Scale bars, 5μm. (d–f) Energy-momentum slices along Γ–K for 1L, 2L and 3L regions, respectively. Upper panels are at 0V gate and lower ones at +3.35V. Intensity in dashed boxes multiplied by 20. Fuzzy spots signal population of CBE. Scale bars, 0.3/Å. Data reflected about Γ to aid comparison with electronic structure calculations (GW self-energy approximation to first term of Green function (G) and screened Coulomb interaction (W); red dashed lines). (g) Brillouin zone of MX_2 (left) and diagram of bands along Γ–K (right), showing definitions of energy parameters.

Nitrogen-polar GaN current-aperture vertical electron transistor

First demonstration device achieves blocking electric field of 2.9MV/cm.

Researchers based in the USA have reported the 'first demonstration' of a nitrogen-polar (N-polar) gallium nitride (GaN) current-aperture vertical electron transistor (CAVET) [Saba Rajabi et al, IEEE Electron Device Letters, vol40, issue 6 (June 2019), p885]. The device also achieved a blocking electric field of 2.9MV/cm.

The use of N-polar structures allows the use of an aluminium gallium nitride (AlGaN) back-barrier to induce a two-dimensional electron gas (2DEG) in an overlying GaN channel layer. This reverses the usual structure in Ga-polar material where a top AlGaN barrier layer is used.

A back-barrier structure is attractive in radio-frequency power applications such as amplifiers to reduce power losses. Another attractive feature is that Ohmic metal contact is not impeded in the presence of a top barrier.

CAVETs combine a lateral channel and a vertical voltage-blocking structure that allows higher electric fields and eliminates dispersion/current collapse under pulsed operation.

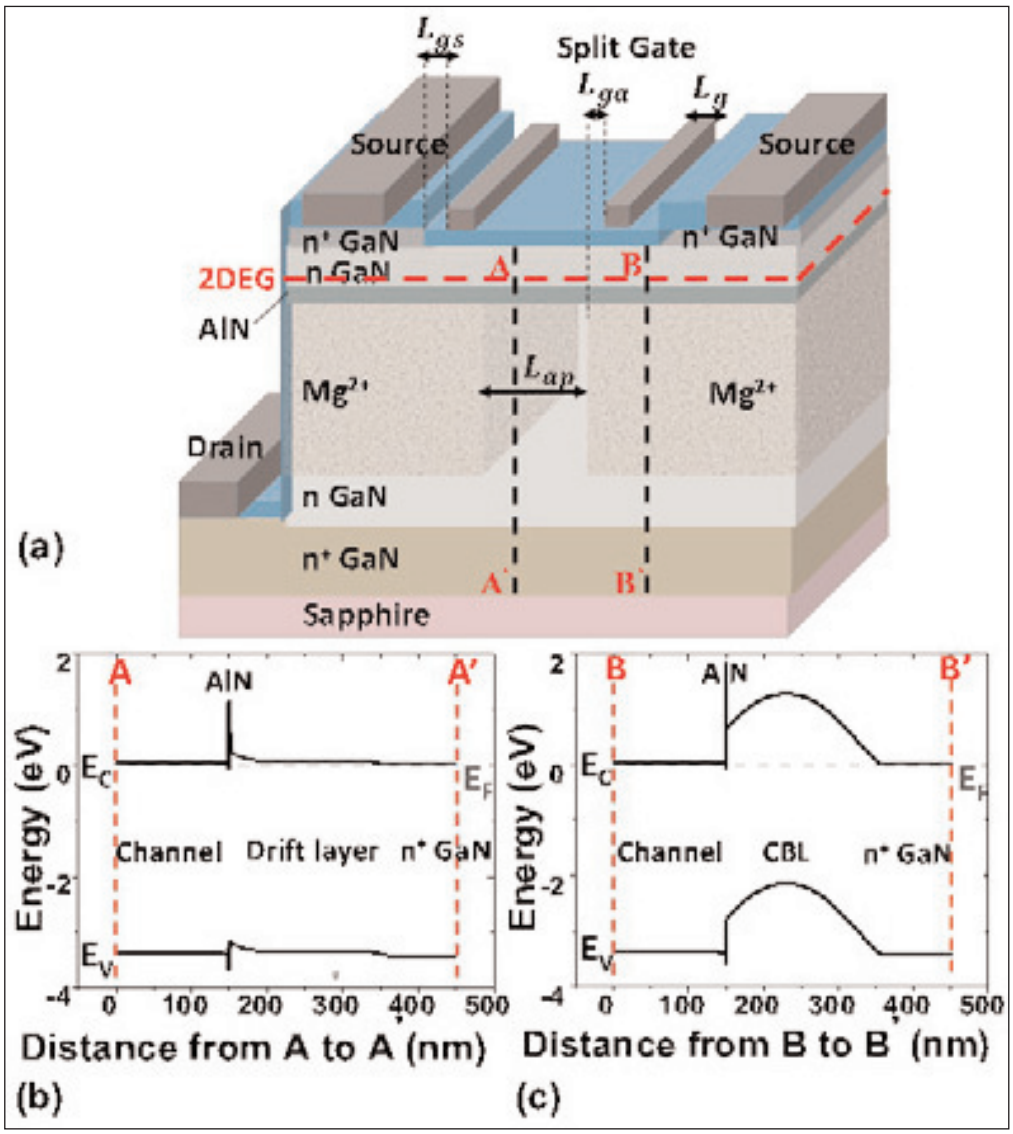

Figure 1. (a) Sketch of N-polar AlN/GaN-based CAVET. (b,c) Band diagrams through aperture (A-A') and CBL (B-B') regions, respectively.

University of California Davis (UCD), University of California Santa Barbara (UCSB) and Stanford University used metal-organic chemical vapor deposition (MOCVD) epitaxial growth on c-plane sapphire, beginning with an unintentionally doped (UID) GaN buffer layer. The structure (Figure 1) continued with 200nm n^+-GaN drain and 200nm UID n-GaN drift layers.

The current-block layer (CBL) regions were formed using selective-area implantation of magnesium ions (Mg^{2+}) into the drift layer. The implantation was followed by annealing at 1280°C for 30s in nitrogen atmosphere.

According to the researchers, the annealing did not need a cap layer due to the thermal stability of the N-polar GaN. Such cap layers can have detrimental effects since they can crystallize, making removal difficult. "This is another advantage of N-polar GaN that can play a very important role in implantation-

Figure 2. Three-terminal breakdown with the gate at pinch-off (-8V). (b) Gate dielectric breakdown test with floating source. (c) n-CBL-n test structure measurement.

based device technology," the researchers write.

After the implantation, further layers were grown at 1160°C: 3nm graded AlGaN, 1nm AlN, 150nm n-GaN, and 40nm n^+-GaN. Secondary-ion mass spectrometry (SIMS) showed that the AlN barrier was effective in blocking out-diffusion of Mg atoms from the CBL into the regrown layers. Such out-diffusion would negatively impact the 2DEG region that forms near the AlN/n-GaN interface in the regrown structure.

Fabrication began with chlorine-based inductively coupled plasma (ICP) etch of isolation 400nm-high mesas. Reactive-ion etch (RIE) exposed the gate and access regions of the transistor. The gate dielectric and surface passivation consisted of 20nm of MOCVD silicon nitride.

The ohmic contact regions were exposed with fluorine-based RIE through the silicon nitride. The source/drain ohmic contact metal stacks were annealed titanium/aluminium/nickel/gold. The gate metal was nickel/gold.

The gate electrode was split in two to minimize gate-drain leakage and to maximize electrostatic control over the source current. The gate length (L_g) and width were 566nm and 150μm, respectively. The gate–source (L_{gs}) distance was 2μm; the gate–aperture (L_{ga}) was 1.3μm. The aperture gap (L_{ap}) was 2μm.

With the gate at 0V, the maximum drain current density was 1.68kA/cm^2; the specific on-resistance was 2.48mΩ-cm^2. The current density and specific on-resistance were normalized according to the source contact lengths and source–source distance (11.3μm) and the device width (150μm), giving an area of 1.7x10^{-5}cm^2. The current pinched-off when the gate was at –8V. The on/off current ratio was 10^6.

Pulsed measurements showed no dispersion from DC performance. The team attributed this to the vertical structure whereby the peak electric field is situated deep the drift region, away from the surface traps that impact pulsed performance.

With the gate pinched-off, the breakdown voltage (Figure 1) was 58V for a leakage of 1mA/cm^2. The researchers estimate the peak electric field at 2.9MV/cm. The researchers claim this as the "first evidence of such a high breakdown field achieved in vertical N-polar GaN transistors."

Experiments on various test structures indicated that the breakdown occurred via punch-through in the current-block layer, not the gate dielectric. The team believes that the CBL could be improved with a more uniform, thicker implantation profile. Thicker, lower-doped drift regions also would enable increased breakdown voltages. The researchers say that there is progress towards growing such thicker drift regions on N-polar GaN with lower dislocation density generation, as needed for high breakdown voltages and low leakage. ■

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Author: Mike Cooke

Silicon carbide power device market growing at 29% CAGR to $1.93bn in 2024, driven by EV market

The automotive sector will rise from 27% of SiC power device market in 2018 to 49% in 2024, says Yole Développement.

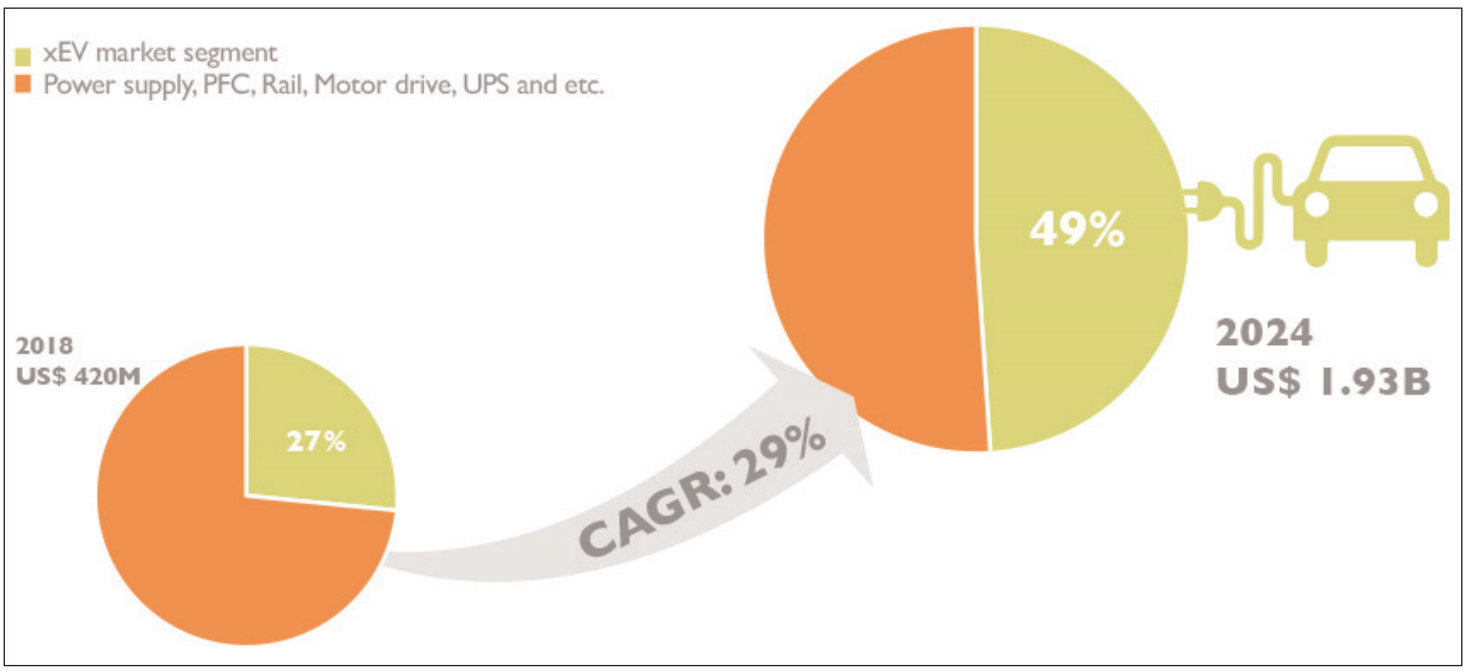
Based on discussions with leading silicon carbide (SiC) players, the Yole Group of companies sees a prospering SiC power device market, according to Yole Développement's technology & market report 'Power SiC: Materials, Devices, and Applications', Knowmade's patent landscape analysis 'Power SiC: MOSFETs, SBDs and Modules' and System Plus Consulting's detailed reverse engineering comparison 'SiC MOSFET Comparison'.

"The SiC power semiconductor market's value will approach $2bn by 2024," says Hong Lin PhD, principal analyst, Compound Semiconductor at Yole. "This market is showing an impressive 29% CAGR [compound annual growth rate] between 2018 and 2024. And, we announced last year, the automotive market is undoubtedly the foremost driver, with around 50% of total device market share in 2024."

The primary market driver is the automotive sector, notes Yole. The total automotive market is expect to reach about $1bn in 2024 (49% market share). Silicon carbide is already used in on-board chargers (OBCs) and such applications will be widely developed in the coming years, it is reckoned.

"The 2018–2019 period is showing a strong shift for SiC adoption by the automotive industry for its main inverter application," comments Yole's Hong Lin. "With the implementation of SiC technology by Tesla, the market has reached the point of no return, and discussions concerning whether other automotive players will also adopt (or not) is THE topic of the year." Following Tesla, BYD will release a SiC invertor in small serial production in 2019. Little by little, the main inverter will begin to adopt SiC, it is expected.

Recently, the automotive industry has committed more than $300bn investment towards hybrid and electric vehicle (xEV) development, causing the xEV market to explode. This is in stark contrast to the traditional combustion engine car market, which is suffering



SiC market evolution, 2018–2024, focusing on the automotive market segment.

through a slowdown. The xEV market is the primary market driver for silicon power devices, and it is a source of excitement for SiC.

Ranging from conservative to optimistic, industrial players offer very different forecasts in terms of market value for SiC in the xEV market, ranging from several hundred million dollars to $3bn in 2025 (the latter estimated by STMicroelectronics).

Everyone agrees that EV is the market with the highest potential but - based on the data that each player has collected and the arguments that derive from their interpretation of the data - perceptions differ regarding how it will grow and how SiC will penetrate into the automotive market.

Behind the adoption of SiC, Yole highlights the packaging issue. The number of automotive-qualified module suppliers is still limited. According to Yole, only STMicroelectronics and Danfoss have expertise, and many challenges are still pending at this level of the SiC supply chain, so that full-SiC module have just begun a long journey.

"The technical panorama of SiC transistors devices is still varying. Concerning die design on the market we still can find different solution such as JFET and MOSFET and, among the latest, trench and planar structures," explains Amine Allouche, costing analyst at System Plus Consulting. "Moreover, in term of packaging, since the standard packaging is not yet optimized for SiC's higher performance, new designs and material are continuously being introduced. This leads to the entrance of new players, especially OSAT [outsourced semiconductor assembly & test], in the packaging' sector."

A study of the SiC patent landscape confirms the leadership of Japanese companies in power SiC devices, as well as significant penetration into the automotive industry.

"In recent years we have seen major players such as GE, Toyota Motor and Rohm accelerating their IP [intellectual property] activity in the field of SiC power devices," notes Rémi Comyn, technology & patent analyst at Knowmade. Knowmade's report also points out the presence of new IP players such as Hestia Power in Taiwan developing planar junction barrier Schottky (JBS) diode-integrated MOSFET technology and, more recently, Danfoss focusing on full-SiC power modules. "Chinese companies have been very active as well lately, with numerous newcomers such as CRRC Times Electric, SGCC and Century Goldray." ■

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Split gate improves octagonal-cell silicon carbide MOSFET performance

Reduced capacitance and charge storage figures of merit show the first 1.2kV silicon carbide devices with better performance than 600V silicon-based power transistors.

Kijeong Han and B. J. Baliga of North Carolina State University (NCSU) in the USA have combined split-gate structures with their 1.2kV-rated octagonal-cell (OCTFET) layout for 4H-polytype silicon carbide metal-oxide-semiconductor field-effect transistors (MOSFETs) "for the first time" [IEEE Electron Device Letters, vol40, issue 7 (July 2019), p1163].

Han and Baliga reported late last year on the advantages of OCTFET over linear-cell layouts in terms of improved high-frequency figures of merit (HF FOMs) [www.semiconductor-today.com/news_items/2019/feb/ncsu_010219.shtml]. The junction field-effect transistors (JFETs) were designed to operate in accumulation-mode rather than inversion-mode due to higher channel mobility.

The split-gate addition in the latest work removes some gate metal from over the JFET region, decreasing capacitance and charge storage due to reduced gate-to-drain overhang, X (Figure 1). Han and Baliga explain: "The minimization of reverse transfer capacitance (C_{rss} or C_{gd}) and gate-to-drain charge (Q_{gd}) of the devices is beneficial for improving high-frequency performance because they are dominant factors that determine switching energy loss."

The split-gate addition in the latest work removes some gate metal from over the JFET region, decreasing capacitance and charge storage due to reduced gate-to-drain overhang

The devices (were fabricated at a 6-inch SiC power MOSFET foundry run by X-FAB in Texas. The 6-inch 4H-SiC substrate included a 10µm n-SiC epitaxial layer. While

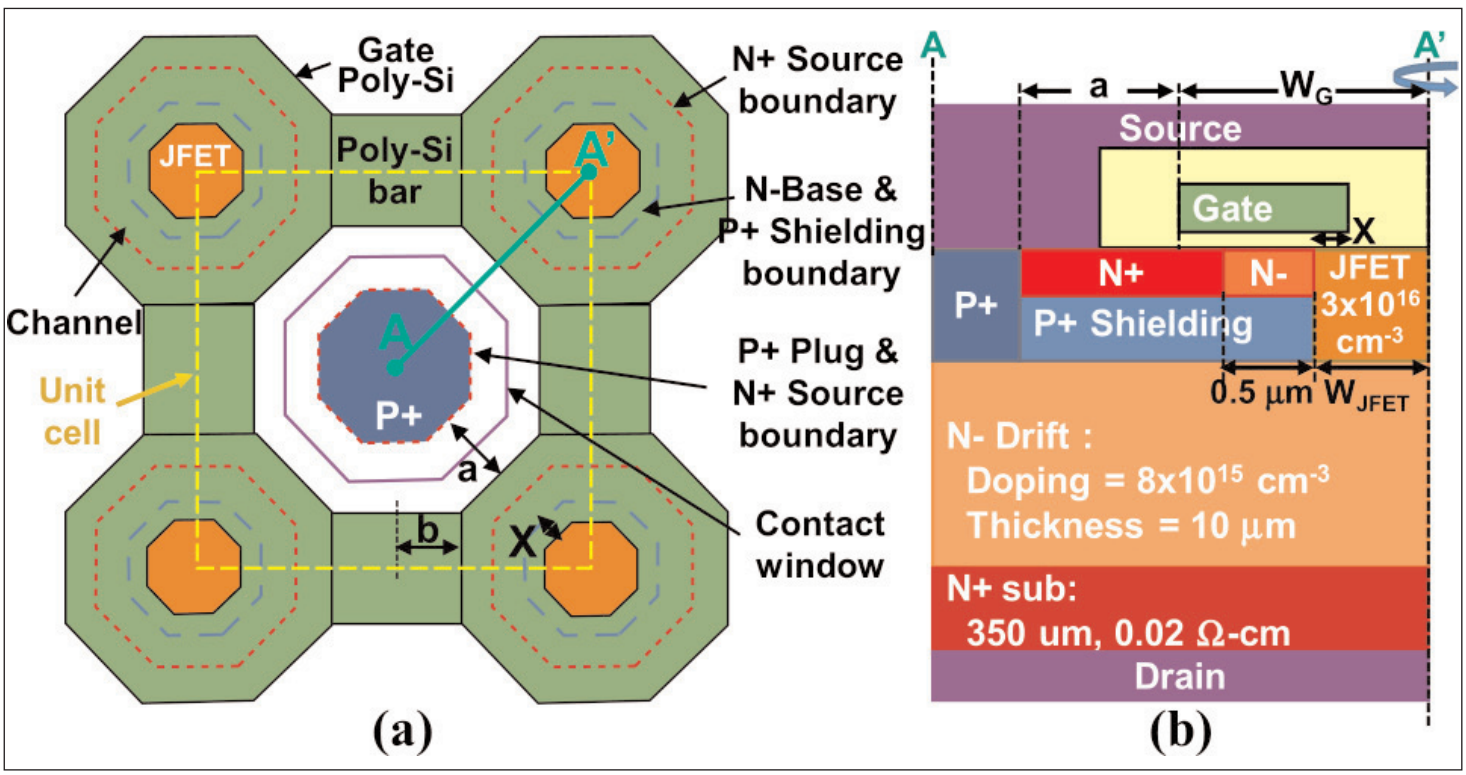

Figure 1. (a) Split-gate OCTFET (SG-OCTFET) cell layout topology. (b) Split-gate MOSFET cell cross-section at A–A' in SG-OCTFET.

the substrate was heavily n-doped, the epitaxial layer was lightly doped to give a drift layer. The gate electrode and MOSFET connecting links consisted of polysilicon (Poly-Si).

Simulations were used to optimize the dimensions of the split-gate OCTFET cell: WJFET=1.5μm, a=1.1μm, X=0.3μm. The trade-offs for X included low on-resistance (large X favored) and low capacitance (low X). To keep the peak electric field down, the X value should also avoid the region 0.7–0.9μm, where the expected peak field was of order 4.4MV/cm. For a peak field of less than 4MV/cm, and low HF-FOM values, the X value should be less than 0.3μm.

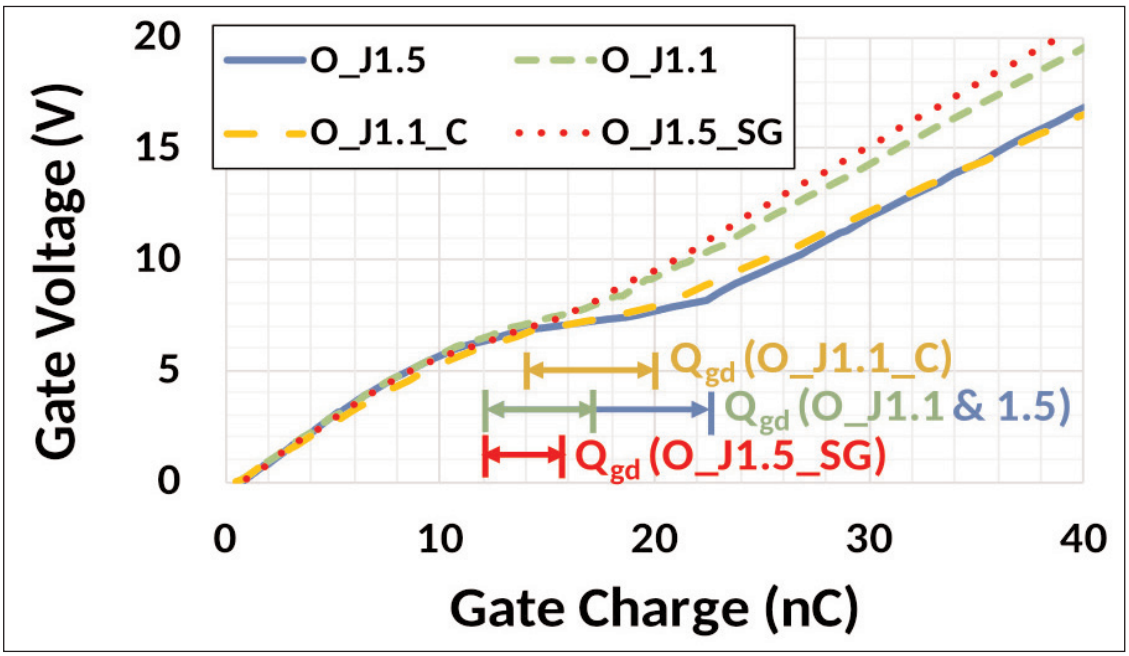

Figure 2. Measured gate charge of fabricated OCTFETs and SG-OCTFET at 800V drain bias and 10A drain current. Active area 0.045cm².

The split-gate OCTFET was found to have reduced gate–drain capacitance-charge storage, as represented in the HF-FOMs combining specific on-resistance with gate–drain capacitance and charge storage ($R_{on}C_{gd}$ and $R_{on}Q_{gd}$, respectively, Table 1 and Figure 2). The reduced capacitance/charge compensated for the increased $R_{on,sp}$ (measured at 20V gate potential, 10A drain current) of the OCTFET layout, relative to linear cells.

Low C_{gd} also boosted the C_{iss}/C_{gd} FOM, where C_{iss} is the input capacitance, i.e. the sum of C_{gd} and C_{gs}. Large values of the C_{iss}/C_{gd} FOM are associated with false-turn-on suppression and low shoot-through current when the voltage changes rapidly. The output capacitance, C_{oss}, is the sum of C_{ds} and C_{gd}.

Han and Baliga also quote the RQ FOM values for Infineon's silicon-based 600V COOLMOS power transistor (IPL60R365P7) at 1240 (310mΩx4nC), and Cree's 'state-of-the-art' 1.2kV SiC power linear cell topology MOSFET (CREE C2M0160120D) at 2240 (160mΩx14nC). The researchers write: "Our work demonstrates for the first time that a HF-FOM [$R_{on}xQ_{gd}$] 1.66-times better than the 600V COOLMOS product can be achieved in a 1.2kV SiC power MOSFET by using the SG-OCTFET topology, which opens new application opportunities for 1.2kV SiC power MOSFETs." ■

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Author: Mike Cooke

Table 1. Experimental results for OCTFETs and split-gate OCFET with varying dimensions: O_J1.5,

	O_J1.5	O_J1.1	O_J1.1_C	O_J1.5_SG
WA–A'	5.10μm	4.53μm	3.75μm	5.10μm
Channel density	0.256/μm	0.259/μm	0.377/μm	0.256/μm
JFET (X) density	0.144	0.098	0.143	0.052
Breakdown	1607V	1605V	1605V	1625V
Vt_h	2.12V	2.02V	2.12V	2.02V
$R_{on,sp}$	8.38mΩ-cm²	12.82mΩ-cm²	8.47mΩ-cm²	8.51mΩ-cm²
$C_{iss,sp}$	32nF/cm²	33nF/cm2	37nF/cm²	33nF/cm²
$C_{oss,sp}$	1073pF/cm²	1067pF/cm²	1069pF/cm²	1076pF/cm²
$C_{gd,sp}$	62pF/cm²	35pF/cm²	48pF/cm²	27pF/cm²
$Qg_{d,sp}$	233nC/cm²	113nC/cm²	144nC/cm²	88nC/cm²
C_{iss}/C_{gd} FOM	516	943	771	1222
$R_{on}xC_{gd}$ HF-FOM	520mΩ-pF	449mΩ-pF	407mΩ-pF	230mΩ-pF
$R_{on}xQ_{gd}$ HF-FOM	1953mΩ-nC	1449mΩ-nC	1220mΩ-nC	749mΩ-nC

Pushing high-frequency transistor performance above 700GHz

Researchers claim the first demonstration of combined cut-off frequency and maximum oscillation frequency above 700GHz in any material system.

Researchers based in South Korea and Japan claim record cut-off frequency performance for high-electron-mobility transistors (HEMTs) with channels constructed from indium gallium arsenide (InGaAs) quantum wells in indium aluminium arsenide (InAlAs) barriers [Hyeon-Bhin Jo et al, Appl. Phys. Express, vol12, p054006, 2019]. The team from Kyungpook National University and University of Ulsan in South Korea and NTT Device Technology Laboratories in Japan state: "To the best of our knowledge, this is the first demonstration of both f_T and f_{max} in excess of 700GHz on any transistor on any material system."

The researchers see such devices as potentially contributing to the 'terahertz' (300–3000GHz) radio-frequency (RF) electromagnetic (EM) sector, where the wavelength is in the sub-millimeter range. Such EM waves are or could be used in security/medical imaging

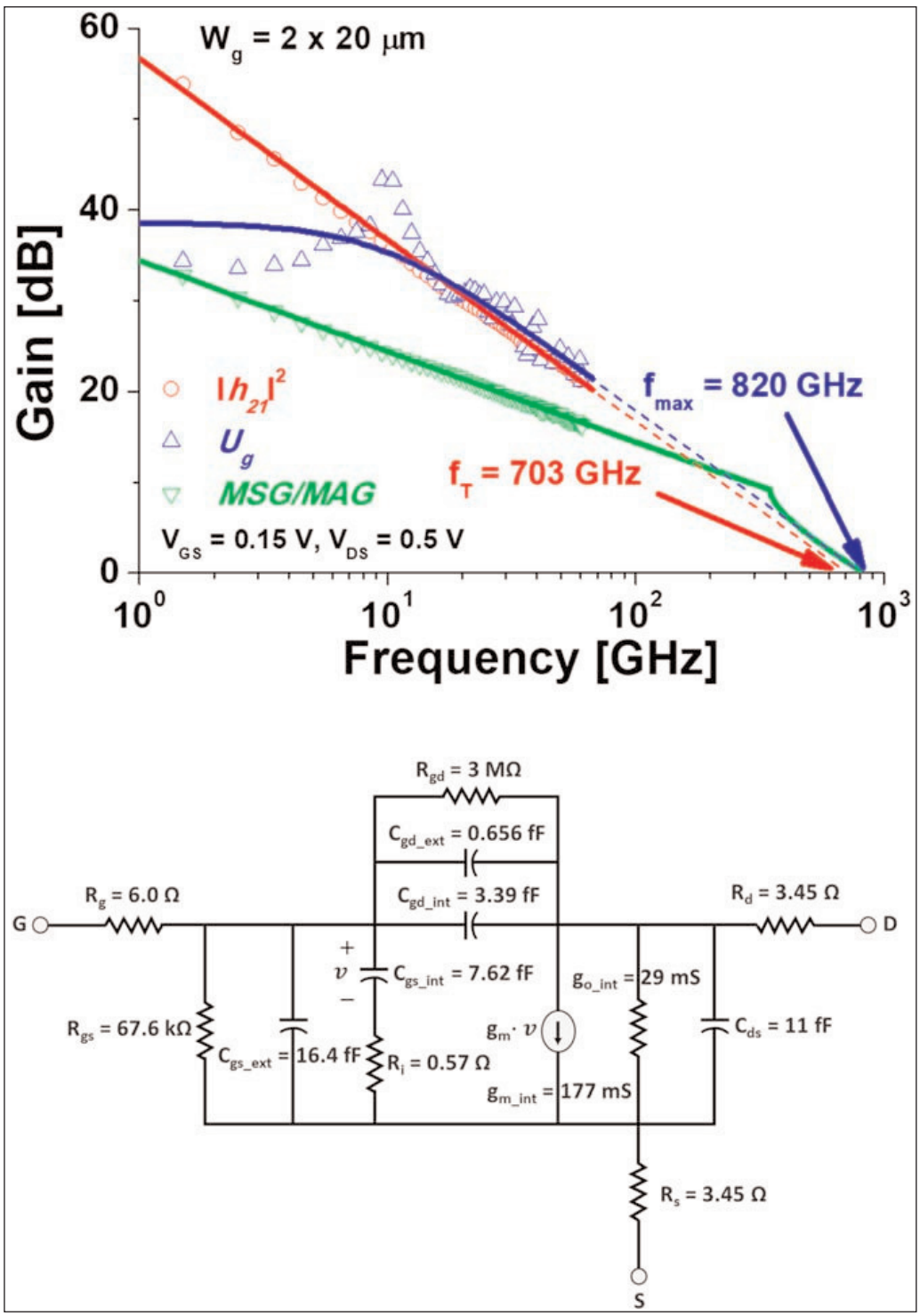

Figure 1. (a) Measured (symbols) and modeled RF gains (solid lines) ($|h_{21}|^2$, U_g, MSG and MAG), and (b) small-signal equivalent circuit model. Dashed lines represent least-squares projections from modeled $|h_{21}|^2$and U_g with –20 dB/decade fall-off.

systems, collision avoidance radars, next-generation transport communications, and wireless-local-area-networks (WLAN). Among the improvements of the researchers' devices was reducing gate lengths to 25nm, boosting frequency performance.

The metal-organic chemical vapor deposition (MOCVD) epitaxial heterostructure was grown on 3-inch semi-insulating indium phosphide (InP) substrate. The layer sequence was 200nm $In_{0.52}Al_{0.48}As$ buffer, 9nm InGaAs quantum well channel, 9nm $In_{0.52}Al_{0.48}As$ barrier/spacer, 3nm InP etch stop, and 30nm heavily doped $In_{0.52}Al_{0.48}As/In_{0.53}Ga_{0.47}As$ multi-layer cap.

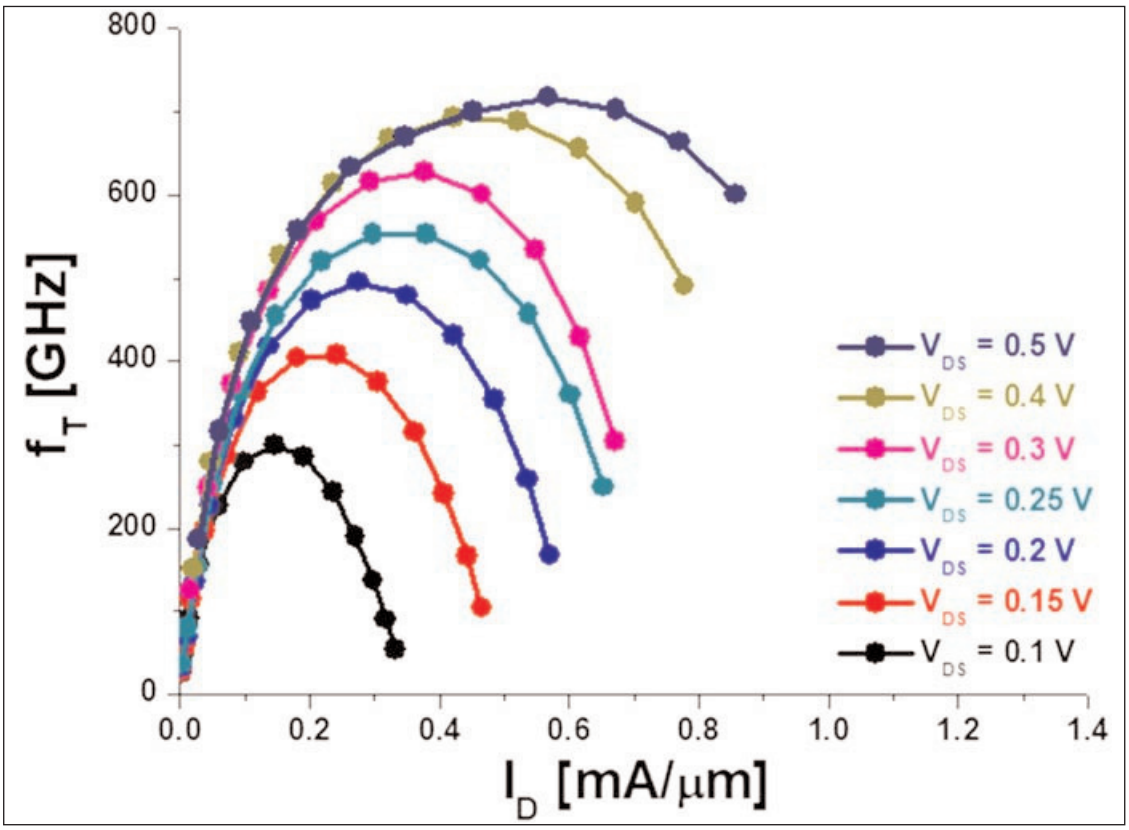

Figure 2. Measured f_T against drain current (I_D) with various V_{DS}.

The barrier/spacer layer was delta-doped with silicon. The cap was designed to reduce source/drain contact resistance. The channel layer had three components — 3nm $In_{0.53}Ga_{0.47}As$, 5nm $In_{0.8}Ga_{0.2}As$, and 1nm $In_{0.53}Ga_{0.47}As$. Hall measurements gave ~$3x10^{12}/cm^2$ two-dimensional electron gas density (2DEG) and mobility of 13,500cm^2/V-s at 300K.

The epitaxial material was fabricated into HEMTs with recessed gates. The gate-to-channel distance was 5nm; the source–drain spacing was 0.8μm. The Ohmic source/drain contacts consisted of titanium/molybdenum/titanium/platinum/gold. The platinum/titanium/platinum/gold T-gates were formed with the help of silicon dioxide. Gate lengths as short as 25nm were achieved.

The 25nm-gate device had a DC on-resistance of 279Ω-μm, while the contact resistance was 40Ω-μm. The peak transconductance was 2.8mS/μm with the drain bias (V_{DS}) at 0.8V. The subthreshold swing was 100mV/decade; the drain-induced barrier lowering (DIBL) was 120mV/V.

Measurements in the range 1–50GHz gave a cut-off frequency (f_T) and a maximum oscillation frequency (f_{max}) of 703GHz and 820GHz, respectively, for 25nm-gate HEMTs with 2x20μm width (Figure 1). The drain and gate (V_{GS}) biases were 0.5V and 0.15V, respectively. These offset values were chosen to put the HEMT near the peak transconductance state.

There were problems in estimating fmax due to "sharp peaky behavior" of Mason's unilateral power gain (U_g) with respect to frequency. The 820GHz f_{max} value was derived through a small-signal model from which a well-behaved gain parameter was extracted.

The researchers comment: "It is true that there exists inconsistency between the measured and the modeled U_g, especially in the low-frequency regime. This is due to the fact that our small-signal model did not take the effect of impact ionizations in the InGaAs QW channel into account. Nevertheless, this kind of the small-signal model has provided a reasonable estimate on f_{max}, since the effect of the impact-ionizations diminishes as the measured frequency goes over 10GHz."

The small-signal model was also used to extrapolate the maximum stable gain (MSG) and maximum available gain (MAG) values. The f_{max} of 820GHz was also consistent with the MSG/MAG behavior. The f_T value was derived from extrapolation of the short-circuit current-gain ($|h_{21}|^2$).

The team point out that the f_T and f_{max} values above 700GHz were obtained using the same bias conditions, unlike in other reports on high-speed transistors.

The researchers also studied the fT_Tvariation with drain current and bias (Figure 2). The team points out that at drain currents typical for low-noise amplifiers (0.1A/μm) the f_{TT}value was still more than 400GHz. ■

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Author: Mike Cooke

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23–25 September 2019
Strategic Materials Conference—SMC 2019
Doubletree by Hilton, San Jose, CA, USA
E-mail: ltso@semi.org
www.semi.org/en/connect/events/strategic-materials-conference-smc

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

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

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www.icscrm2019.org

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www.world-of-photonics-india.com

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

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

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

5–8 November 2019
5th International Conference on Advanced Electromaterials (ICAE 2019) - Symposium 8, 'Materials and Devices for Power Electronics'
Ramada Plaza Jeju Hotel, Jeju Korea
E-mail: secretary@icae.kr
www.icae.kr

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

12–15 November 2019
SEMICON Europa 2019, co-located with productronica
Munich, Germany
E-mail: SEMICONEuropa@semi.org
www.semiconeuropa.org

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65th IEEE International Electron Devices Meeting (IEDM 2019)
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