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NXP opens 6-inch RF GaN fab in Arizona



Cree sells LED business • POET & Sanan IC form Super Photonics
Aledia raises €80m • NeoPhotonics consolidating InP production



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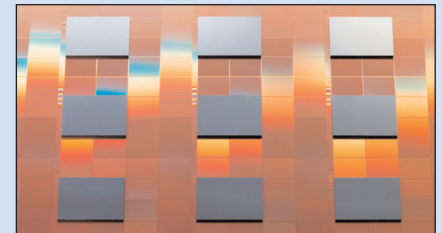
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p11 Microchip has announced its newly qualified 700V and 1200V SiC Schottky barrier diode power devices, targeting electric vehicle systems.



p24 EVG has demonstrated a complete process flow for collective die-to-wafer hybrid and fusion bonding with sub-2µm placement accuracy.



p57 A Swedish development project has installed Midsummer's CIGS solar panels on the side of a truck trailer made by Swedish commercial vehicle manufacturer Scania.



Cover: NXP Semiconductors of The Netherlands has held a grand opening for its 6-inch RF GaN fab in Chandler, Arizona, which is claimed to be the most advanced fab dedicated to 5G RF power amplifiers in the USA. **p15**

Scaling up wafer growth

In late September, Netherlands-based NXP Semiconductors opened its new 150mm-wafer gallium nitride (GaN) fab at its plant in Chandler, Arizona, which is dedicated to 5G RF power amplifiers supporting the expansion of 5G base stations and advanced communication infrastructure in the industrial, aerospace and defense markets (see page 15).

In addition, Singapore-based epiwafer foundry IGaN has reported low conduction losses for its 150mm GaN-on-silicon HEMT epiwafers, while it readies its 200mm RF Epistack wafers for commercial availability by the end of first-quarter 2021, citing 5G network applications in particular (page 20).

Correspondingly, 5G smartphone handset sales are expected to grow at a compound annual growth rate (CAGR) of 122.7% over 2020–2027, according to Polaris Market Research (see page 6).

Meanwhile, after selling its Lighting Products business in May 2019, Cree has now agreed the sale of its LED Products business as it finally focuses exclusively on its Wolfspeed GaN RF device and silicon carbide (SiC) materials & power device business (see page 38).

SiC Schottky diodes and MOSFETs operating up to 1200V continue to be launched for power electronics, e.g. by Toshiba and Microchip (pages 11–12), with the latter being qualified for automotive applications in electric vehicles.

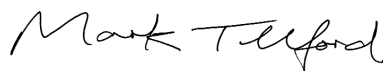
Autonomous vehicles and advanced driver assistance systems (ADAS) comprise automotive applications of light detection & ranging (LiDAR), using vertical-cavity surface-emitting lasers (VCSELs), which are also used for 3D sensing in smartphones (such as for facial recognition). According to market research firm Yole Développement, the VCSEL market will grow at a 18.3% CAGR from \$1bn in 2020 to \$2.7bn in 2025 (see pages 62–63).

Epiwafer foundry IQE has announced the development of IQGeVCSEL 150 technology for growing VCSELs on 150mm germanium substrates. The firm describes this as a “critical step” on the path to growing VCSELs on 200mm and 300mm silicon wafers — rather than smaller-diameter and more costly gallium arsenide (GaAs) substrates — through the use of IQE’s Ge-on-silicon templates (to be detailed next issue).

Engineered materials and optoelectronic component maker II-VI Inc says its 150mm GaAs optoelectronics platform, which it uses for manufacturing 3D sensing and high-speed datacom devices, has now been made available for its full product line of high-power edge-emitting lasers for pumping fiber lasers (page 44). The firm cites the “long-term strategic benefit of developing vertically integrated technology platforms in-house, which is the ability to leverage those investments over time across multiple applications”. So, as mass-market devices like VCSELs for 3D sensing in smartphones drive the economies of scaling up wafer diameter, other device types of higher value but made in smaller numbers can be manufactured with greater economy of scale.

Another example of consumer electronics driving technology development is Apple’s intention to adopt micro-LED displays rather than organic light-emitting diode (OLED) displays in its smart watches, iPhones etc. Furthermore, Apple is planning to forgo thin-film transistor (TFT) backplanes, instead opting for silicon CMOS micro-drivers, reckons Yole. “Implications go far beyond a technological choice. Apple’s micro-LED supply chain would eliminate reliance on display makers such as Samsung or LG,” the firm adds (see www.semiconductor-today.com/news_items/2020/oct/yole-291020.shtml — to be covered in more detail next issue).

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

Regular issues contain:

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

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5G market growing at 122.7% CAGR over 2020–2027 ASP fell in first-half 2020, but recovering during second half

The 5G smartphone market is expected to grow at a CAGR of 122.7% from 2020 to 2027, according to a report '5G Smartphone Market Share, Size, Trends, Industry Analysis Report, By Operating System (iOS, Android, Windows, Others); By Sales Channel (Online, Offline); By SIM Type (Single SIM, Multi SIM); By End User (B2B, B2C); By Regions; Segment Forecast, 2020 – 2027' from Polaris Market Research.

Demand for 5G smartphones in 2019 was 12.42 million units. However, the market saw a precipitous decline in average selling price (ASP) during first-quarter 2020 due mainly to the COVID-19 pandemic, and the price fall continued during second-quarter 2020. Another major reason for the decline was low-priced Chinese 5G devices. However, the overall market is expected to bounce back during Q3–Q4/2020 and is estimated to accelerate and grow during the forecast period, affecting the 5G device ASP.

5G technology is increasingly being commercialized in different parts of the globe, with China leading. Theoretically, 5G is 100 times faster than its predecessor, with estimated speeds up to 10Gbps, but smartphones require 5G-compatible sensors and receivers to support the additional speeds.

The increasing demand for high-speed Internet for both small- and

large-sized businesses and individuals for buffer-free streaming and the prominence of over-the-top (OTT) services such as Netflix, Amazon Prime, Hulu, Disney+ etc are the main factors driving growth.

On-demand content is increasingly being preferred by the younger generation, and the advent of 5G smartphones will provide them with a tool for viewing high-quality content on the go. High-speed Internet is required for hassle-free streaming. Furthermore, with the growth of both residential and industrial Internet of Things (IoT) devices, smartphones will play the role of a personalized authentication device for enhanced security purposes.

Collaboration between smartphone makers, chipset providers and telecom providers will aid the acceleration of commercial 5G services. Furthermore, government bodies around the globe are mulling regulations for the use of 5G spectrum in order to speed up the adoption of 5G.

For example, in China the government has drastically reduced licensing costs to speed up the roll-out of 5G services. On the other hand, the US Federal Communications Commission (FCC) has amended the rules that govern equipment modification. New hardware can be installed on the existing poles to bring down the capital costs and speedup the deployment of 5G.

Since 5G will be built mainly on the

existing 4G infrastructure, the stakeholders will need to provide fool-proof strategies to ensure that the networks are capable of handling the additional data speed and connected devices, notes Polaris.

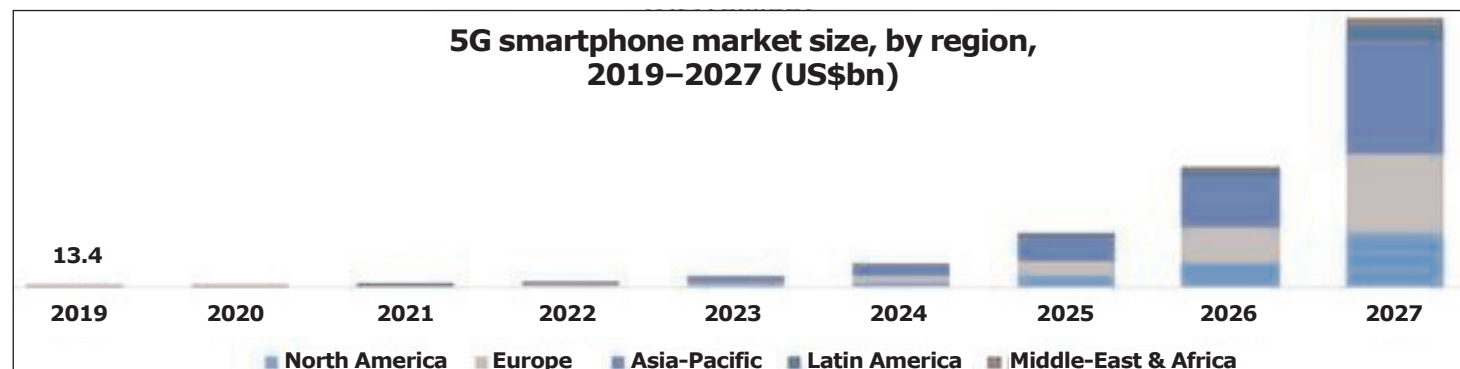
Key players operating in the market include Apple Inc, Ericsson, China Mobile, Huawei Technologies Co Ltd, Motorola Inc, Lenovo Group Ltd, BBK Electronics Corp, Nokia, LG Electronics Inc, TCL Communication Ltd, Xiaomi Corp, Samsung Electronics Co Ltd and Vivo Mobile Communication Co Ltd.

To increase their unit sales, 5G smartphone makers are focusing on indirect sales channels. For example, Xiommi is reducing its operational expenses by partnering with platforms such as Walmart and Amazon for 5G smartphone sales. Also, prominent players such as Samsung and BBK Electronics are aggressively pursuing the mid-range smartphone segment to target the middle and upper echelons of society.

Furthermore, the number of multi-SIM smartphone models are expected to increase in the coming years, as manufacturers are promoting dual-network capability in smartphones. Samsung, for instance, supports dual-SIM technology in its A51 5G smartphone, which was launched in April. These allow consumers to use a local and a roaming SIM in the same device during international travel.

www.polarismarketresearch.com

5G smartphone market size, by region, 2019–2027 (US\$bn)



LED smart street-light revenue growing at 8.2% CAGR to over \$1bn by 2024

Huawei and Tencent to dominate market

The global LED smart street-light market (which includes only luminaires and single lighting control systems) is rising at a compound annual growth rate (CAGR) of 8.2% from 2019 to US\$1.094 in 2024, forecasts TrendForce in its latest investigations.

LED lighting manufacturers such as Signify, Acuity Brands, Zumtobel, Leotec (a subsidiary of Lite-On Group) and Unilumin have each released new outdoor smart lighting products and integrated smart lighting solutions, which are likely to raise the penetration rate of smart LED street lights. However, downstream LED lighting demand is highly correlated with the state of the overall economy, notes TrendForce.

Various governments have attempted to alleviate the industrial impacts of the COVID-19 pandemic through fiscal policies, smart-city construction, and new infrastructure investments, notes analyst Christine Liu. Of these governmental efforts, roadside infrastructure investments in China and North America are the largest in terms of scale. Data from the US Census Bureau shows that the US government had invested \$42.9bn in

roadside infrastructure as of June 2020. This effort to stimulate the economy via governmental spending is expected to bring about growth in demand for outdoor LED street lights.

Chinese firms the primary drivers of smart street-light development, as Huawei and Tencent dominate

Generally, smart light poles fulfill six essential functions: intelligent lighting, information dissemination, security surveillance/monitoring, environmental detection, charging station, and small-scale 5G base station. Smart lighting products ranging from modular LED lamp heads to single light controllers are essential components for fulfilling these six functions. TrendForce's cost analysis of smart street-light construction projects finds that the average selling price (ASP) of the highest spec'd smart street poles is \$6997.90, with 2.6% of it stemming from smart lighting equipment ASP, which stands at \$182.5.

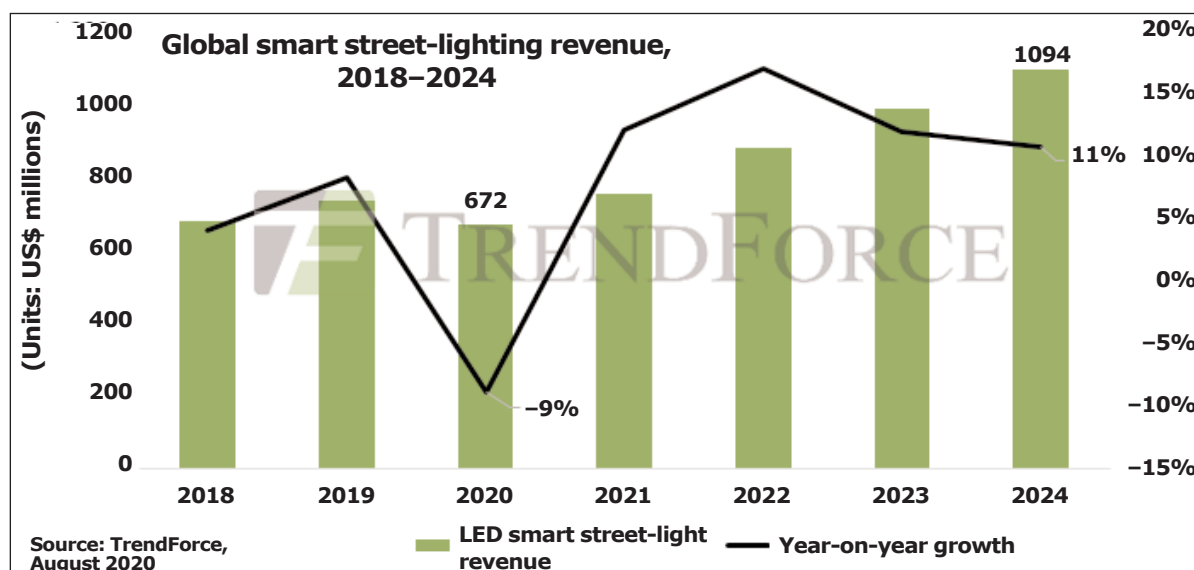
Although China is the primary driver of global smart street-light development, large-scale city-level projects in China are both expensive and time-consuming, mostly due to the country's substantial landmass

as well as the large discrepancies in various local governments' demands. Furthermore, municipal governments generally tend to outsource smart street-light projects to private corporations with sufficient resources, who may not necessarily be well-versed in smart street-light equipment design and manufacturing and therefore must collaborate with other partners to complete these projects. On the other hand, as smart street-light projects involve IoT and telecommunications, LED lighting manufacturers must collaborate with major tech companies in carrying out these projects. As such, companies with strong resource integration capabilities, such as Huawei and Tencent, are expected to take the major share of smart street-light projects in China.

TrendForce believes that more and more commercial opportunities can be found the further downstream one looks in the smart street-light supply chain. To enter the existing supply chain, LED lighting manufacturers must add more value to their existing competitive advantages by strengthening their ability to service systems, streamlining their LED lighting portfolios, and

raising their overall quality of service. At the same time, governments need to institute crystal-clear standards regarding smart street lights and draw a comprehensive smart-city blueprint, ensuring the healthy development of the LED smart street-light industry going forward, TrendForce concludes.

www.trendforce.com



Open RF Association formed

Multi-mode RF front-end and wireless chipset providers to drive interoperability across 5G ecosystem

The Open RF Association has been formed as an industry consortium dedicated to expanding the functional interoperability of hardware and software across multi-mode RF front-end and chipset platforms into the 5G era, responding to customer demand for open architectures. Founding members include Broadcom Inc, Intel Corp, MediaTek Inc, Murata Manufacturing Co Ltd, Qorvo, and Samsung.

OpenRF aims to deliver an open framework that standardizes hardware and software interfaces without limiting innovation, while enabling total flexibility for 5G device original equipment manufacturers (OEMs) to take advantage of time-to-market, cost, performance and supply chain benefits. OEMs will be able to choose interoperable best-of-breed solutions from a multi-vendor ecosystem, while using the same RF front end with any 5G baseband.

"Wireless device manufacturers have historically relied upon a robust ecosystem of best-in-class solutions to differentiate and optimize their products' overall performance," says Eric Creviston, president of Qorvo Mobile Products. "The Open RF Association essentially standardizes this time-proven framework while simultaneously

fostering greater innovation and helping accelerate the delivery of next-generation 5G devices," he adds.

OpenRF is supported by a diverse group of global chipset providers, RF front-end vendors and device manufacturers, all working towards enabling a multi-vendor 5G ecosystem. The organization aims to satisfy customer requests to advance the industry's interests by enhancing the traditional reference design process to drive best-in-class configurable solutions to market faster.

OpenRF plans to:

- create a set of core chipset and RF front-end features and interfaces that will enable interoperability across 5G basebands while allowing innovation across vendors;
- build on industry standards to maximize configurability and effectiveness of the RF front end;
- develop a common hardware abstraction layer enhancing the transceiver/modem and RFFE modules interface; and
- define and develop industry-leading approaches to RF power management.

OpenRF plans to develop a compliance program to support a robust ecosystem of interoperable RFFE and chipset platforms.

Ongoing development of the MIPI RFFE specification, which has become the de-facto interface for control of the radio-frequency front end since its release in 2010, will continue to be coordinated within MIPI Alliance's RFFE Working Group. OpenRF is currently working toward a liaison agreement with the Alliance.

"The RF front-end market has become extremely complex, so the industry increasingly needs structure to deal with the complexity," says Joe Madden, principal analyst at Mobile Experts. "By standardizing some common elements, the Open RF Association will allow RFFE vendors to focus their R&D attention on the sharp point of innovation," he adds. "Making common building blocks in non-competitive areas will also speed up time-to-market, ensure compatibility across generations and between different platforms, and will save millions of dollars through improved economies of scale. All of this is possible without diminishing the fierce competition between vendors."

The OpenRF is open to smartphone chipset, RFFE and OEM vendors and related industry companies.

www.OpenRF.com/join

Qorvo closes \$700m offering of senior notes due 2031

Proceeds being used to redeem 5.50% senior notes due 2026

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has completed its offering of \$700m of its senior notes maturing in 2031.

Issued to qualified institutional buyers and certain non-US persons, the notes will pay interest semi-annually at a rate of 3.375% and mature on 1 April 2031, unless

earlier redeemed in accordance with their terms.

Qorvo expects to use the net proceeds of the offering, together with borrowings under its credit facility, to redeem all of its outstanding 5.50% senior notes due 2026.

The notes are senior unsecured obligations of Qorvo and are initially guaranteed, jointly and severally, by each of Qorvo's existing and future direct and indirect wholly

owned US subsidiaries that guarantee Qorvo's obligations under its credit facility.

The notes have not been and will not be registered under the Securities Act or any state securities laws and may not be offered or sold in the USA absent registration or an applicable exemption from such registration requirements.

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WIN joins semiconductor industry cluster in Southern Taiwan Science Park

New fab in Kaohsiung to mitigate concentration of capacity in northern Taiwan

WIN Semiconductors Corp of Taoyuan City, Taiwan — the largest pure-play compound semiconductor wafer foundry — says that its application to invest in setting up an establishment in the Southern Taiwan Science Park in Kaohsiung was approved by the 64th meeting of the Science Park Review Committee of the Ministry of Science and Technology in August. WIN has now officially joined the semiconductor industry cluster of Southern Taiwan Science Park and it will be another WIN production base in the future.

As of third-quarter 2020, WIN's total capacity in Taoyuan (including Fab A, Fab B and Fab C) has reached 41,000 wafers per month.

WIN says that, looking ahead, it continues to be optimistic about the demand for 5G and Wi-Fi-related handheld devices and infrastructure (e.g. base stations). "Applications of optical devices will increase in popularity over time," the firm believes. "As a result, WIN Semi will continue to invest in capacity expenditure and deepen the development of technologies to serve

customers globally," it adds.

"Establishing this additional fab in Kaohsiung can help mitigate the risk of concentrating all of our capacity expansion in northern Taiwan, and improve the stability of supply to our customers," the firm reckons. "This investment also helps us to enhance our competitiveness and maintain our leadership in the industry, supporting Taiwan as a key player in the next generation of information technology."

www.winfoundry.com

Tower launches RF switch technology with record figure of merit of under 10fs

Multi-project wafer runs available in 2021

Specialty foundry Tower Semiconductor Ltd (which has fabrication plants in Migdal Haemek, Israel, and at its US subsidiaries in Newport Beach, CA and San Antonio, TX, and at TowerJazz Japan Ltd) has launched a radio frequency switch technology with record RF device figure of merit ($R_{on} \times C_{off} < 10fs$ versus 70–100fs in use today for the most advanced applications) targeting the 5G and high-performance RF switch markets.

The switch performs over an extremely wide range of frequencies spanning MHz to all frequency bands discussed for 5G, and further into the mmWave. This results in

extremely low insertion loss and very small device size.

The switch is also non-volatile, so it consumes no energy when in the on-state or off-state, suiting IoT and other power and battery-sensitive product applications.

Tower has demonstrated the versatility of the patented technology by integrating it with some of its other process platforms such as silicon germanium (SiGe) BiCMOS and Power CMOS.

The new switch technology enables more efficient, novel RF system architectures in applications including mobile, base-station and millimeter-wave (mmWave)

communications. Tower says that it is engaged with multiple customers and partners to bring the technology to market for next-generation products. The firm is offering multi-project wafer runs (MPWs) in 2021 for select customers.

The new RF switch was presented in the Tu1G: Innovative RF Switches and Applications session (Tu1G-2 and Tu1G-5) at the IEEE's International Microwave Symposium (IMS 2020) with results from electrical devices, process integration and circuits fabricated at Tower.

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Microchip launches automotive-qualified 700V & 1200V silicon carbide Schottky diodes

Devices targeted at helping EVs achieve high reliability and ruggedness

Microchip Technology Inc of Chandler, AZ, USA has announced its newly qualified 700V and 1200V silicon carbide (SiC) Schottky barrier diode (SBD) power devices, providing electric vehicle (EV) system designers with solutions that meet stringent automotive quality standards across a wide range of voltage, current and package options. As vehicle electrification continues rapid growth worldwide, innovative power technologies such as silicon carbide are required for high-voltage automotive systems ranging from motors to on-board chargers (OBCs) and DC/DC converters.

Microchip says that, for EV power designers who need to increase system efficiency while maintaining high quality, its AEC-Q101-qualified devices maximize system reliability and ruggedness and enable stable and lasting application life. The devices' superior avalanche performance allows designers to reduce the need for external protection circuits, reducing system cost and complexity, adds the firm.

"As a long-time supplier to the automotive industry, Microchip's continued expansion of automotive-capable power solutions is leading the transformation of power systems in vehicle electrification," says Leon Gross, VP of Microchip's discrete product business unit. "Our focus is to provide automotive solutions that help our clients easily transition to SiC while minimizing the risk of quality, supply and support challenges."

Microchip has been a supplier to the automotive industry for more than 25 years. Its SiC technology, as well as its multiple IATF 16949:2016-certified fabrication facilities, provide high-quality devices through flexible manufacturing alternatives, helping to minimize risk in the supply chain, says the firm.



Through Microchip's internal and third-party testing, the firm's devices have demonstrated no degradation in performance (unlike other SiC devices that degrade under extreme conditions), increasing the application life. Microchip's SiC SBD ruggedness testing demonstrates 20% higher energy withstand in unclamped inductive switching (UIS) and among the lowest leakage currents at elevated temperatures, it is claimed, increasing system life and enabling more reliable operation.

Microchip's SiC automotive power devices complement its broad portfolio of controllers, analog and connectivity solutions, providing designers with total system solutions for electric vehicles and charging stations.

Microchip's AEC-Q101-qualified SiC SBD devices are supported with SPICE and PLECS simulation models and MPLAB Mindi Analog Simulator. Also available is a PLECS reference design model that uses the firm's SBDs (1200V, 50A) as part of the power stage

The firm also provides a broad portfolio of 700, 1200 and 1700V SiC SBD and metal-oxide-semiconductor field-effect transistor (MOSFET) power modules utilizing its newest generation of SiC die. In addition, its dsPIC digital signal controllers deliver performance, low power consumption and flexible peripherals.

Microchip's AgileSwitch family of digital programmable gate drivers further accelerates the process of moving from the design stage to production. These solutions also have applications across renewable, grid, industrial, transportation, medical, data-center and aerospace & defense systems.

Microchip's AEC-Q101-qualified SiC SBD devices are supported with SPICE and PLECS simulation models and MPLAB Mindi Analog Simulator. Also available is a PLECS reference design model that uses the firm's SBDs (1200V, 50A) as part of the power stage — the Vienna 3-phase power factor correction (PFC) reference design.

Microchip's AEC-Q101-qualified 700 and 1200V SiC SBD devices (also available as die for power modules) for automotive applications are available now for volume production orders.

www.microchip.com

II-VI completes Ascatron & INNOViON acquisitions, and joins Semiconductor Industry Association

Sohail Khan to lead New Ventures & Wide-Bandgap Electronics Technologies organization

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA — which manufactures silicon carbide (SiC) substrates — says that Sohail Khan has joined it as executive VP of New Ventures & Wide-Bandgap Electronics Technologies.

II-VI has also closed the acquisition of Ascatron AB of Kista, Stockholm, Sweden, and completed the acquisition of the outstanding interests of the owners of the parent firm of INNOViON Corp of Colorado Springs, CO, USA. It has also joined the US-based Semiconductor Industry Association (SIA).

Spun out of research institute Acreo in 2011, Ascatron produces SiC epitaxial wafers and devices that enable a wide range of high-voltage power electronics applications.

INNOViON is said to be the world's largest provider of ion implantation services, with 30 implanters across a global footprint supporting capabilities in semiconductor materials

processing for up to 300mm wafers. The firm's processes enable doping in a wide range of semiconductors, including silicon carbide, gallium arsenide, indium phosphide and silicon.

The New Ventures & Wide-Bandgap Electronics Technologies organization will consolidate II-VI's technology expertise in SiC substrates, wide-bandgap epitaxy, device fabrication, and module design.

"Sohail Khan has my utmost respect as an integrated circuits and optoelectronics technologist, a visionary, and an accomplished business leader," comments II-VI's CEO Dr Vincent D. Matterna Jr.

"Guided by Sohail's leadership and the benefits of our platforms built by our innovations of the last 20 years, we will continue to invest in efficient energy-conversion technology," he adds.

"Using our in-house knowledge and the technology recently

licensed from General Electric, we will establish within II-VI a vertically integrated 150mm SiC technology platform that we expect will produce the world's most advanced SiC devices for power electronics," says Khan. "We will also support the SIA's effort to encourage US policies and regulations that fuel innovation, propel business, and drive international competition."

For the past two years, Sohail was the managing partner for K5 Innovations. His prior positions include: CEO at UHD video solutions semiconductor company ViXS Systems, CEO of fuel-cell company Lilliputian Systems, CEO of SiGe Semiconductor and executive VP of the Infrastructure Group at Agere Systems; and president of the IC Division of Lucent Microelectronics. He has an MBA from the University of California, Berkeley, and a BSEE from the University of Engineering, Lahore.

www.ii-vi.com

www.ascatron.com

Toshiba shipping 1200V SiC MOSFET Second-generation chip design includes built-in Schottky barrier diode

Tokyo-based Toshiba Electronic Devices & Storage Corp (TDSC) — spun off from Toshiba Corp in July 2017 — has begun shipping the TW070J120B, a 1200V silicon carbide MOSFET (available in a TO-3P(N) package) for industrial applications, including large-capacity power supplies.

Compared with conventional silicon (Si) MOSFET and insulated-gate bipolar transistor (IGBT) devices, the new SiC power MOSFET achieves high voltage resistance, high switching speed and low drain-source on-resistance ($R_{DS(ON)}=70m\Omega$, typical), so it will contribute to lower power consumption and system downsizing, the firm says.

Fabricated with Toshiba's second-generation chip design, which includes a built-in SiC Schottky barrier diode (SBD) and improves the reliability of SiC MOSFETs, the new device realizes low input capacitance, a low gate-input charge, and low drain-to-source on-resistance. Compared with Toshiba's GT40QR21 1200V silicon IGBT, it cuts turn-off switching loss by about 80% and switching time (fall time) by 70%, while delivering low on-voltage characteristics with a drain current of 20A or less (at 25°C ambient).

Gate threshold voltage is set in the high range of 4.2–5.8V, which reduces malfunction risk (unintended turn-on or -off). Incorporation of an

SiC Schottky barrier diode with low forward voltage also helps to reduce power loss. As well as its high drain-source voltage (V_{DSS}) of 1200V, features also include low input capacitance ($C_{iss}=1680pF$, typical), low total gate charge ($Q_g=67nC$, typical), low diode forward voltage ($V_{DSF}=-1.35V$, typical).

Toshiba says that the new MOSFET will contribute to higher efficiency by reducing power loss in industrial applications, such as large-capacity AC-DC converters, photovoltaic inverters, and large-capacity bidirectional DC-DC converters, and will also contribute to reduced equipment size.

www.toshiba.semicon-storage.com

GeneSiC releases 6.5kV SiC MOSFET bare chips

Medium-voltage power conversion applications include traction, pulsed power and smart grid infrastructure

Silicon carbide (SiC) power semiconductor supplier GeneSiC Semiconductor Inc of Dulles, VA, USA has announced the immediate availability of 6.5kV SiC MOSFET bare chips, namely the 300mΩ G2R300MT65-CAL and the 325mΩ G2R325MS65-CAL (with an integrated Schottky diode), joining the 100mΩ G2R100MT65-CAL. Full-SiC modules utilizing the technology will soon be released. Applications are expected to include traction, pulsed power, smart grid infrastructure and other medium-voltage power converters.

The chips features a silicon carbide double-implanted metal-oxide-semiconductor field-effect transistor (DMOSFET) device structure with a

junction barrier Schottky (JBS) rectifier integrated into the SiC DMOSFET unit cell.

The power device can be used in a variety of power conversion circuits in the next generation of power conversion systems. Other advantages are said to include more efficient bi-directional performance, temperature-independent switching, low switching and conduction losses, reduced cooling requirements, superior long-term reliability, ease of paralleling devices, and cost benefits. Other features are listed as: high avalanche (UIS) and short-circuit ruggedness; superior $Q_G \times R_{DS(ON)}$ figure of merit; low capacitances and low gate charge; normally-off stable operation up to

175°C; and +20V/-5V gate drive.

GeneSiC says that its technology also has the potential to reduce the net SiC material footprint in power converters.

"GeneSiC's 6.5kV SiC MOSFETs are designed and fabricated on 6-inch wafers to realize low on-state resistance, highest quality, and superior price-performance index," says VP of technology Dr Siddarth Sundaresan. "This next-generation MOSFET technology promises exemplar performance, superior ruggedness and long-term reliability in medium-voltage power conversion applications," he adds.

www.genesicsemi.com/sic-mosfet/bare-chip/G2R300MT65-CAL/G2R300MT65-CAL.pdf

Infineon's CoolSiC MOSFETs used by EA

Bidirectional lab power supply used for testing electric drive-trains

While it is great news for the goal of reducing CO₂ emissions, the global acceleration in sales of hybrid and fully electric vehicle is challenging for the testing capacities of electronic components (namely the motor, control, and battery). Testing, however, is a critical part of bringing any electric drivetrain into production. Traditional test setups require a dedicated DC source and electronic load in parallel to deal with bidirectional energy flow.

The PSB 10000 power supply of EA Elektro-Automatik GmbH in Viersen, Germany (which makes laboratory power supplies and electronic loads) offers a bidirectional solution for this application. It simplifies the test setup and reduces test time. Additionally, it offers the potential for savings in both acquisition and maintenance costs. Due to discrete 1200V CoolSiC silicon carbide metal-oxide-semiconductor field-effect transistors (MOSFETs)



EA's PSB 10000 4U bidirectional laboratory power supply.

from Infineon Technologies AG of Munich, Germany, the system operates with efficiencies of over 96%. Used as an electronic load, the energy is fed back into the power grid, and only a small amount of energy is dissipated in the form of heat. The power density is claimed to be industry leading, with 30kW in a single 4U 19" housing.

The PSB 10000 device series features an output stage with an extended scope of operation. Typical programmable DC sources offer full output power only at maximum voltage and current. In contrast, EA's devices offer full power from

as little as one-third of the output voltage or output current. Charging or discharging a vehicle battery can serve as a good example. Even if the battery voltage rises or falls, the current automatically adjusts and thus provides full power. The flexibility of the devices can save a lot of equipment when testing different electronic components.

The PSB 10000 4U bidirectional laboratory power supplies can be configured from 30kW to 1920kW to form a complete system. Voltages from 60V to 2000V and currents up to several thousand amperes are available. To facilitate the integration into a test stand, the units are equipped with analog and digital interfaces. All power supplies are equipped with Ethernet and USB; CAN, CANopen, Profibus, ProfiNet, Ethercat, ModBus, and RS232 are optionally available.

www.infineon.com/coolbic
www.elektroautomatik.com

ST launches first silicon-based driver & GaN transistors integrated in one package

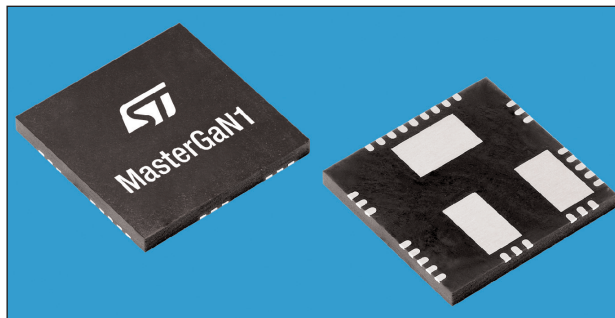
Chargers and adapters 80% smaller and 70% lighter while charging three times faster than silicon

STMicroelectronics of Geneva, Switzerland has unveiled MasterGaN, which is claimed to be the first platform embedding a half-bridge driver based on silicon technology along with a pair of gallium nitride (GaN) transistors. The combination is aimed at accelerating the creation of next-generation compact and efficient chargers and power adapters for consumer and industrial applications up to 400W.

GaN technology enables these devices to handle more power even as they become smaller, more lightweight, and more energy efficient. Such improvements can make a difference for smartphone ultra-fast chargers and wireless chargers, USB-PD compact adapters for PCs and gaming, as well as in industrial applications like solar-energy storage systems, uninterruptible power supplies (UPS), or high-end organic light-emitting diode (OLED) TVs and the server cloud.

The existing GaN market is typically served by discrete power transistors and driver ICs that require designers to learn how to make them work together for best performance. ST says that its MasterGaN approach bypasses that challenge, resulting in faster time to market and assured performance, together with a smaller footprint, simplified assembly and increased reliability with fewer components. With GaN technology and ST's integrated products, chargers and adapters can cut 80% of the size and 70% of the weight of ordinary silicon-based solutions, it is reckoned.

"ST's market-unique MasterGaN platform builds on our proven expertise and power-design skills to combine high-voltage smart-power BCD [bipolar-CMOS-DMOS]



process with GaN technology, to accelerate the creation of space-saving and power-efficient products that are kinder to the environment," says Matteo Lo Presti, executive VP & general manager Analog Sub-Group.

The MasterGaN platform leverages STDRIVE 600V gate drivers and GaN high-electron-mobility transistors (HEMTs). The 9mm x 9mm low-profile GQFN package ensures high power density and is designed for high-voltage applications with over 2mm creepage distance between high-voltage and low-voltage pads.

MasterGaN leverages STDRIVE 600V gate drivers and GaN HEMTs. The 9mm x 9mm low-profile GQFN package ensures high power density and is designed for high-voltage applications with over 2mm creepage distance between high-voltage and low-voltage pads. The family of devices will span different GaN transistor sizes ($R_{DS(ON)}$) and will be offered as pin-compatible half-bridge products that let engineers scale designs with minimal hardware changes

The family of devices will span different GaN transistor sizes ($R_{DS(ON)}$) and will be offered as pin-compatible half-bridge products that let engineers scale designs with minimal hardware changes. Leveraging the low turn-on losses and

absence of body-diode recovery that characterize GaN transistors, the products offer what is claimed to be superior efficiency and overall performance enhancement in high-end, high-efficiency topologies such as flyback or forward with active clamp, resonant, bridgeless totem pole PFC (power factor corrector) and other soft- and hard-switching topologies used in AC/DC and DC/DC converters and DC/AC inverters.

ST is launching the new platform with MasterGaN1, which contains two GaN power transistors connected as a half bridge with integrated high-side and low-side drivers. Specifically, MasterGaN1 contains two normally-off transistors that feature closely matched timing parameters, 10A maximum current rating, and 150m Ω on-resistance ($R_{DS(ON)}$). The logic inputs are compatible with signals from 3.3V to 15V. Comprehensive protection features are also built in, including low-side and high-side UVLO protection, interlocking, a dedicated shutdown pin, and over-temperature protection.

MasterGaN1 is in production now, in a 9mm x 9mm GQFN package only 1mm high. Priced at \$7 for orders of 1000 units, it is available from distributors. An evaluation board is also available to help jump-start customers' power projects.

www.st.com/en/power-transistors.html

NXP opens new 6" RF GaN fab in Arizona

RF power amplifiers targeted at 5G cellular infrastructure expansion

NXP Semiconductors N.V. of Eindhoven, The Netherlands has held a grand opening for its 150mm (6-inch) RF gallium nitride (GaN) fab in Chandler, Arizona, which is claimed to be the most advanced fab dedicated to 5G RF power amplifiers in the USA.

Combining NXP's expertise in RF power and high-volume manufacturing, the new internal factory supports the expansion of 5G base stations and advanced communication infrastructure in the industrial, aerospace and defense markets.

The virtual opening ceremony was marked by keynote addresses and remarks by NXP executives plus federal, state and local government officials, including Arizona Senators Kyrsten Sinema and Martha McSally, US Representative Greg Stanton, Arizona Governor Doug Ducey, City of Chandler Mayor Kevin Hartke, US Department of Commerce Deputy Under Secretary for International Trade Joseph Semsar, and Ambassador of the Kingdom of the Netherlands to the United States Andre Haspels.

"Today marks a critical milestone for NXP," said CEO Kurt Sievers in his keynote address. "By building this incredible facility and tapping key talent in Arizona, we are able to bring focus to GaN technology as part of driving the next generation of 5G base-station infrastructure."

With 5G, the density of RF solutions required per antenna has increased exponentially, but maintaining the same box size and reducing power consumption is mandatory, notes NXP. To address these conflicting requirements, GaN power transistors have emerged, as they deliver significant improvements in both power density and efficiency.

NXP reckons that nearly 20 years of GaN development expertise and wireless communication industry knowledge position it well in this next wave of cellular expansion for 5G. The firm says that it has



NXP's new 6-inch RF gallium nitride fab in Chandler, Arizona.

optimized its GaN technology to improve the electron trapping in the semiconductor to deliver high efficiency and gain with what is claimed to be best-in-class linearity.

"Power amplifiers play an important part of the radio technology," comments Joakim Sorelius, head of Development Unit Networks at longstanding customer Ericsson. "Similar to Ericsson's recent US investments, we are pleased to see NXP's investments in the US semiconductor process development with the continuous focus on improving RF system performance for future high-demanding radio networks."

NXP says that its strategic move to build an internal GaN fab was driven by its ability to achieve higher performance benefits through leveraging its core competency in cellular infrastructure design, its track record in high-volume manufacturing, and its consistency in quality processes.

The internal factory will serve as an innovation hub that facilitates collaboration between the fab and NXP's on-site R&D team

The new facility in Chandler "underscores NXP's decades-long commitment to GaN and the communications infrastructure market," says Paul Hart, executive VP & general manager of the Radio Power Group at NXP. The new RF GaN fab is "ready to scale to 6G and beyond".

The fab is set to ramp quickly, with NXP leveraging its Chandler-based team and its long-standing expertise in compound semiconductor manufacturing.

"With this new state-of-the-art manufacturing facility in Chandler, Arizona is set to expand its reputation as a high-tech manufacturing hub and a pioneer in 5G innovation," comments Arizona Governor Doug Ducey.

The internal factory will serve as an innovation hub that facilitates collaboration between the fab and NXP's on-site R&D team. NXP engineers can now more rapidly develop, validate and protect inventions for current and future generations of GaN devices, resulting in shorter cycle times for NXP GaN innovations, it is reckoned.

The new GaN fab is now qualified, with initial products ramping in the market and expected to reach full capacity by the end of 2020.

www.nxp.com

EPC Space launches 40–300V radiation-hard eGaN power transistors

Discrete devices targeted at high-reliability or commercial satellite space environments

EPC Space LLC of Haverhill, MA, USA has launched a family of rad-hard enhancement-mode power transistors spanning a range of 40–300V and 4–30A, and demonstrating what are said to be significant performance advantages over competing silicon-based rad-hard power MOSFETs.

EPC Space was established in June as a joint venture between Efficient Power Conversion Corp of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications — and VPT Inc of Blacksburg, VA, USA (part of the HEICO Corp subsidiary HEICO Electronic Technologies Group). The JV is focused on designing and manufacturing high-reliability, radiation-hardened enhancement-mode GaN-based power conversion devices for space and other harsh environments.

“We are able to offer designers a superior technology with significant space heritage, as thousands of our rad-hard GaN devices have been in



orbit since January of 2019,” says CEO Bel Lazar.

EPC Space says that its technology produces devices that are smaller, have lower resistance, and have many times superior switching performance compared with silicon solutions.

Critical spaceborne applications that benefit from this newly available performance include power supplies for satellites and mission

orientation and positioning as well as interplanetary propulsion of low-mass robotic vehicles.

Beyond the performance improvement, the devices are said to offer superior radiation hardness under heavy ions (SEE) and gamma radiation (TID). SEE immunity is guaranteed at the wafer level and EPC Space devices are manufactured in an AS9100D-certified facility in the greater Boston area.

equipment, light detection & ranging (LiDAR) for robotics and autonomous navigation and rendezvous docking, motor drives for robotics and instrumentation, and ion thrusters for satellite

EPC Space launches rad-hard eGaN drivers and power stages

EPC Space has announced a family of radiation-hardened enhancement-mode GaN drivers and power stages. Rad Hard GaN drivers are optimized to drive Rad Hard GaN transistors in critical spaceborne systems. Rad Hard power stages integrate a high-speed gate drive circuit with power switches to provide a complete power stage in a tiny footprint for smaller, lower-weight systems.

The new product line of drivers and power stages includes ultra-fast low-side eGaN drivers, ultra-fast dual low-side eGaN drivers, and half-bridge drivers with integ-

rated eGaN power switches. The devices are suitable for high-speed DC–DC conversion, synchronous rectification, commercial satellite electrical power systems (EPS) and avionics, and multi-phase motor drives. Thousands of these devices are currently flying in orbit as motor drivers for satellite reaction wheels.

EPC Space says that, beyond the performance improvement inherent from using GaN-based devices, these products offer superior radiation hardness under heavy ions (SEE) and gamma radiation (TID). The firm’s devices

are manufactured in an AS9100D-certified facility in the greater Boston area.

“These devices provide engineers with a higher-performance, modular solution with guaranteed electrical, thermal, and radiation performance,” says chief technology officer Max Zafrani. “In addition to very high efficiencies and extremely low parts count, operation above 1MHz enables smaller magnetics for smaller, lower-weight designs and an extremely cost-competitive solution.”

www.epc.space/products/drivers-and-power-stages

EPC signs Micross as global distributor of bare die GaN technology targeted at hi-rel customers

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) and integrated circuits for power management applications — has signed a new agreement establishing Micross Components Inc of Orlando, FL, USA (a provider of bare die and a mission-critical microelectronic components and services for high-reliability mar-

kets) as an authorized worldwide supplier of its GaN products offered in die form.

The new agreement combines the performance and reliability of EPC's GaN technology with Micross' portfolio of capabilities that will further strengthen Micross' one-source service for customers requiring microelectronic components or custom packaging solutions.

"EPC's GaN technology solutions are a perfect complement to

Micross' global expertise in providing mission-critical component and services to our hi-reliability customers," comments Tony Hamby, Micross' senior VP of global die, who adds that the agreement is "bringing together our combined expertise to further meet customer applications that require higher frequency, efficiency and greater power density solutions."

www.micross.com

www.epc-co.com

MediaTek invests in VisIC's Series E funding round to support growing EV market

D3GaN-based product portfolio to be enlarged for EV applications

VisIC Technologies Ltd of Ness Ziona, Israel — a fabless supplier of power conversion devices based on gallium nitride (GaN) transistor devices for automotive high-voltage applications — has raised a Series E financing round with participation from MediaTek Inc, the world's fourth largest global fabless semiconductor company, which develops systems-on-chip (SoC) for a mobile device, home entertainment, connectivity, and IoT products. The new funding will help the firm to enlarge its portfolio of products based on its proprietary D3GaN (Depletion-mode Direct Drive GaN)

process for high-power systems in electrical vehicles (EVs).

"This round of financing will help us to enlarge our portfolio and continue to develop a solid manufacturing foundation for existing products," says CEO Dr Tamara Baksht. "As a great innovative fabless company, MediaTek is a constant source of inspiration for us to work harder and to deliver new technological solutions," she adds. "We have a lot to learn from MediaTek how to grow innovation and make a difference in the mutual automotive market."

MediaTek, which addresses several key technology areas including

highly power-efficient mobile technologies, automotive solutions and a broad range of advanced multimedia products, aims to contribute its experience to accelerate VisIC's innovation and sales.

"VisIC has impressive innovation and development around GaN for high-power electric vehicles that improves the efficiency and performance, from hybrid up to full-electric applications," says Dr Lawrence Loh, senior VP of MediaTek. "This technology is key to improve electric vehicle performance and affordability."

www.visic-tech.com

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Transphorm appoints former Nexperia general manager as independent director

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified 650V and 900V gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — has appointed Dr Julian Humphreys as a new independent director on its board, effective 14 October.

The firm says that Humphreys has substantial knowledge in all aspects of the power semiconductor business including profit & loss (P&L), sales & marketing, development,

and design of power semiconductor technologies. He most recently served as senior VP & general manager at Nexperia B.V., a long-term cooperation partner to Transphorm in the global automotive market. Prior to Nexperia, he was VP & general manager of Nexperia's predecessor NXP Semiconductors N.V. Standard Products Division. Humphreys holds a Bachelor of Engineering in electronics and a Ph.D. in semiconductor physics, both from the University of Liverpool.

"Dr Humphreys brings exceptional

experience and highly relevant industry knowledge, specifically within power semiconductor technology," comments CEO Mario Rivas. "At this stage in the company's growth, it is imperative that the leadership and expertise of our board continues to expand," he adds. "With the addition of Julian, we have added an independent director who can offer the company well informed guidance, perspective and oversight as we continue to execute on Transphorm's long-term strategic plan."

www.transphormusa.com

Transphorm releases 4kW analog-controlled bridgeless totem-pole GaN evaluation board

Transphorm has made available its newest evaluation board.

Designed for single-phase AC-to-DC power conversion up to 4kW, the TDTP4000W065AN uses the bridgeless totem-pole power factor correction (PFC) topology with a traditional analog control. This pairing provides fast and easy access to the conversion efficiency made possible by Transphorm's latest SuperGaN FETs without the need for firmware development required when using digital signal controllers (DSCs).

The TDTP4000W065AN offers power systems engineers an upgrade in efficiency over standard CCM boost PFC designs that use superjunction MOSFETs.

The evaluation kit is rated at 4kW highline (180–260V) and 2kW lowline (90–120V). The main advantages of the analog totem-pole solution are said to be as follows:

- Maintenance power — power required to support basic functionality such as powering up and supplying chipsets — is a relatively fixed amount in any system. Therefore, as an application's power level decreases, the main-

tenance power becomes a larger percentage of the system's overall power loss. Compared with a DSP solution, Transphorm's analog board requires lower maintenance power at the onset, increasing overall system efficiency.

- No DSP firmware programming is needed, suitable for standard CCM boost AC-to-DC PFC power stages.

For engineers requiring more design flexibility, Transphorm released the TDTP4000W066C in April. This DSC-based 4kW AC-to-DC board also uses the bridgeless totem-pole PFC with the company's SuperGaN FETs. However, it integrates a dsPIC33CK DSC board from Microchip that has been pre-programmed and is backed by dedicated firmware support.

"Transphorm's analog evaluation board provides an unprecedented opportunity to access our highly efficient GaN in the easiest way possible," says Philip Zuk, VP of worldwide technical marketing & NA sales. "Much like the preceding digital board, it gives power system engineers a choice that the high-voltage device market was

previously lacking," he adds.

"Regardless of the end-application's targeted value proposition, we have the diverse toolset and the most robust GaN possible."

The TDTP4000W065AN employs Transphorm's SuperGaN Gen IV TP65H035G4WS FETs in the board as the fast-switching leg with low-resistance silicon MOSFETs in the slow-switching leg. The resulting performance is similar to that of its digitally controlled counterpart, the TDTP4000W066C.

The TP65H035G4WS is a 650V device with a 35m Ω on-resistance in a TO-247 through-hole package with an inherently high thermal dissipation ability. This feature eliminates the need to parallel devices for higher power output, a design method required by competitive surface-mount GaN solutions. Also, as with all other Transphorm GaN devices, the SuperGaN FETs can be driven with a threshold voltage (V_{th}) of 4V and standard off-the-shelf gate driver operating from 0V to 12V.

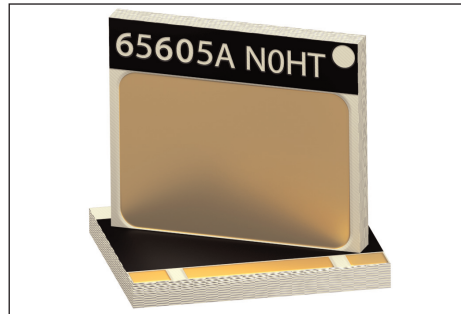
The TDTP4000W065AN evaluation board is available through distributors Digi-Key and Mouser.

GaN Systems launches family of AEC-Q101-qualified 650V, 60A transistors

Enhanced AEC-Q test AutoQual+ developed with automotive partners

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has announced the release and availability of the first product in a family of new 650V, 60A transistors for the automotive market. The GS-065-060-5-T-A is designed to meet automotive reliability standards including AEC-Q101 qualification and GaN Systems' AutoQual+ testing and qualification. AutoQual+ is an enhanced AEC-Q test sequence based on the firm's collaboration with automotive partners to prove its transistors lifetimes exceed market requirements.

The new GaN transistor provides low drain-source on-resistance ($R_{DS(on)}$ of 25m Ω) and features a 60A drain current (I_{DS}) rating and GaN Systems' high-performance GaNPX packaging, which enables ultra-low inductance and what is claimed to be the best thermal resistance in a compact form factor.



Leveraging these transistors, wide-ranging automotive applications from onboard battery chargers (OBCs), DC-DC converters, electric vehicle (EV) traction inverters, electronic power steering, and motor drives can benefit from high reliability and reductions in volume, weight and cost.

Meeting automotive reliability requirements with AutoQual+ GaN Systems' methodology for the qualification of its transistors is based on a collaboration with select customers in the global automotive industry. This joint effort resulted in an enhanced test methodology, AutoQual+, using AEC-Q101 tests as a baseline and then adding addi-

tional tests that address GaN-specific wear-out mechanisms. The additional testing of AutoQual+ ensures that GaN Systems' power semiconductors are reliable and robust in the rigors of the automotive environment. As a result, the firm's products meet the lifetime requirements the automotive industry requires with demonstrated failure-in-time (FIT) rates much less than 1, setting what are said to be new GaN industry benchmarks.

"GaN Systems transistors have been tried and tested through the AutoQual+ test methods, a testing regimen that stemmed from our many workshops with automotive partners," says Dr Maryam Abouie, director of reliability engineering. "The knowledge these experts provided, including sharing decades of experience of silicon failure mechanisms identified in field-based applications, was critical in the development of our qualification strategy and process."

www.gansystems.com/gan-transistors/gs-065-060-5-t-a

GaN Systems issues 12V Class-D audio amplifier reference designs

GaN Systems has issued its latest technical manual '12V High-Efficiency Audio Reference Designs using GaN Power Transistors'.

The technical manual was developed in response to the launch of its Class-D audio amplifier evaluation kit in May and from growing customer interest for designs in the 12V market for automotive, marine, powersports and other applications from power system design engineers.

High-quality audio is now a 'must have' across all segments from pro-audio, home-audio and portable audio, says the firm. Class-D audio systems using GaN are not only smaller and lighter but provide better sound quality, it

adds.

The new technical manual provides several amplifier designs for 12V input systems using GaN Systems' Class-D audio amplifier evaluation kit, which includes a 2-channel, 200W-per-channel (8 Ω) Class-D audio amplifier and companion 400W continuous power audio-grade switch-mode power supply (SMPS), including:

- Single-Phase and Dual-Phase 12V Boost Converter design supports both a 'direct' +12V to +18V single-rail power supply and a 'boosted' +12V to +18V single-rail power supply configuration;
- Direct +12V to +18V V_{IN} Supply to $\pm 32V$ V_{OUT} Boost Converter design supports a 'direct' +12V to

+18V V_{IN} supply and allows for the best cost versus power output trade-off, while maintaining the desired audio performance.

In audio systems, delivering more power and more channels has typically meant driving up size and weight and sacrificing sound quality. With GaN, designers can provide more power, more channels and better sound quality in small, lightweight solutions, says GaN Systems.

The technical manual, as well as the Class D amplifier and power supply kit and white paper 'See, Feel, and Hear the Difference with GaN Class-D Amplifier and Companion SMPS', are available at: www.gansystems.com/class-d.

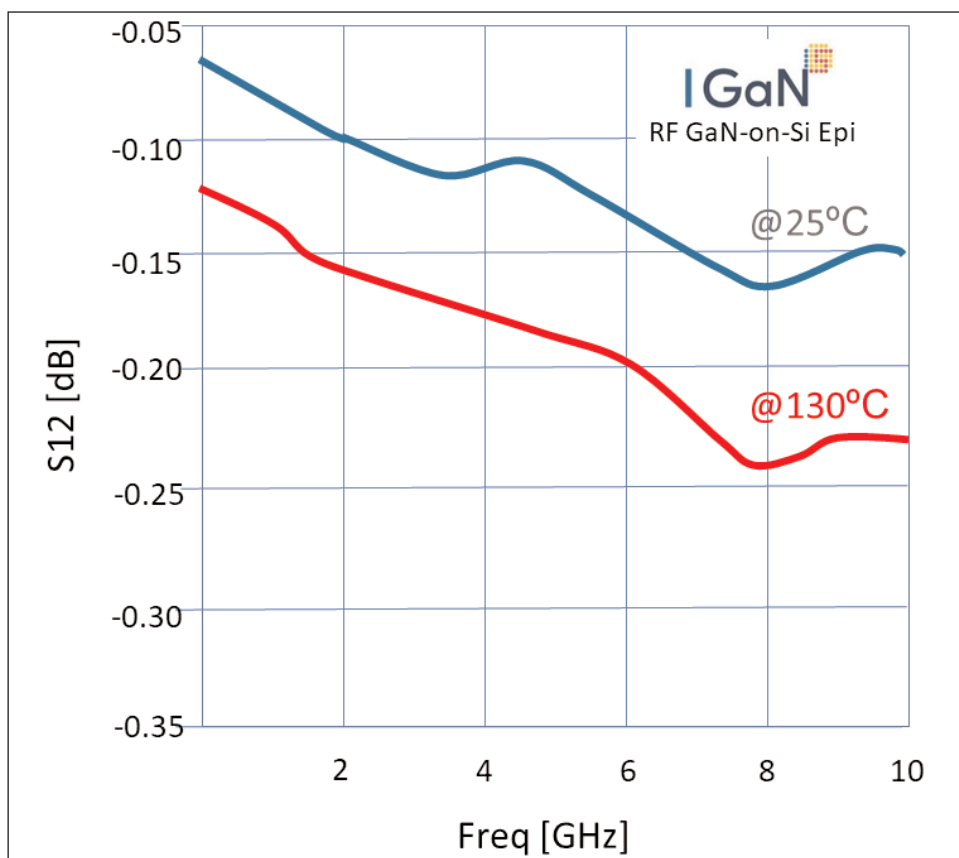
IGaN achieves low conduction loss with 150mm GaN-on-Si epi for RF applications

RF Epistack on 200mm substrates available by end-Q1/2021

In recent years, there has been growing demand for GaN-based products stemming from the increased adoption of GaN power and RF devices in a variety of applications, notes Singapore-based IGSS GaN Pte Ltd (IGaN) – which develops and commercializes gallium nitride-on-silicon/silicon carbide (GaN-on-Si/SiC) epitaxial wafers and proprietary 8" (200mm) GaN fabrication technologies for power, RF and sensor applications. From military, defence, aerospace and next-generation telecoms (particularly with 5G networks), the wide bandgap of GaN-based materials offers remarkable breakdown electric field and high drift velocity suitable for the fabrication of high-power and high-frequency devices.

In terms of applications, III-nitride materials such as GaN are generally grown heteroepitaxially on a substrate. Among various substrate materials, silicon is widely selected for the growth of an epitaxial stack comprising III-nitride materials due to the lower substrate cost and flexible scalability on substrate size. Differences in material properties such as thermal expansion coefficient and lattice constant between III-nitride materials and the silicon substrate can pose technological challenges (i.e. cracks, defects, wafer bow and crystal quality) for practical applications. However, despite the great promise shown by GaN-on-Si RF electronics, there remain a few issues to be resolved.

One such issue is the presence of a parasitic channel formed at the III-nitride/silicon interface, which leads to parasitic loss, severely degrading the output power, power gain and efficiency of devices especially when they are operating at high frequency. A key requirement in GaN high-electron-mobility transistors (HEMTs) on silicon for RF



Conduction loss measurement at room temperature and high temperature up to an operating frequency of 10GHz on IGaN's 150mm GaN-on-Si HEMT wafers.

applications is the reduction in conduction loss at the AlN/Si interface. As the AlN/Si interface can become conductive due to the doping of Al and Ga residuals in the reactor, preconditioning of the reactor and the growth conditions of the first AlN layers on the silicon substrate will be crucial for the suppression of conduction loss.

IGaN claims that its technology has the unique advantage of achieving very low conduction loss, meeting the industry standards for GaN HEMTs on silicon for RF applications. Recently processed IGaN 150mm GaN-on-Si HEMT wafers have achieved a conduction loss of 0.15dB at room temperature and 0.23dB at high temperature for an operating frequency of 10GHz. The Figure shows measurements of conduction loss up to an operating

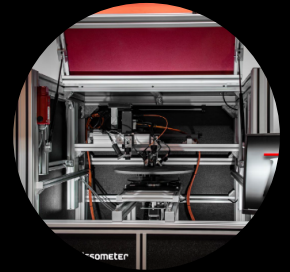
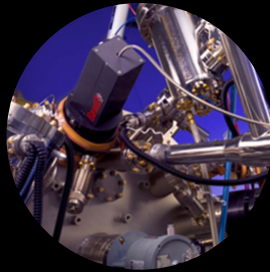
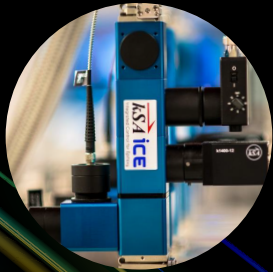
frequency of 10GHz at room temperature and high temperature. Low conduction loss is a key factor for achieving low RF loss, which is critical for RF devices.

Besides the conduction loss test, IGaN has implemented a quick method for screening-out poor-performing GaN epiwafers before fab processing that can save customers expensive scrappage and help to avert potential wastage of processed wafers and packaged devices downstream if the epiwafer substrates has high conduction losses. Early detection of high-conduction-loss epiwafers is critical for mass producing RF GaN devices, says IGaN.

RF Epistack on 200mm substrates is under development and will be available to customers by the end of first-quarter 2021.

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CSconnected supporting Royce's materials roadmap for low-loss electronics

Call for UK initiative to address net-zero-carbon future of electronic systems

CSconnected (the world's first compound semiconductor cluster) based in South Wales, UK is supporting the new roadmap on the future of materials for low-loss electronics published by the Henry Royce Institute for advanced materials. The roadmap sets out recommendations to support the demands of future ultra-efficient electronic systems.

Operating with its Hub at The University of Manchester, the Henry Royce Institute for advanced materials research and innovation is a partnership of nine leading institutions — the universities of Cambridge, Imperial College London, Liverpool, Leeds, Oxford, Sheffield, the National Nuclear Laboratory, and UKAEA. Royce aims to support and grow excellence in UK materials research, accelerating commercial exploitation and delivering positive economic and societal impact for the UK. Royce is funded by the Engineering & Physical Sciences Research Council (EPSRC), part of UK Research & Innovation.

CSconnected and Royce are working together to call for a UK-wide initiative to capitalize on the UK's established semiconductor materials research base, to fund the development of materials solutions that deliver the next generation of efficient electronic devices and components, and to address the UK Government's target of net-zero carbon emissions by 2050.

The low-loss electronics roadmap sets out the priorities, targets and enablers that have been identified by the UK materials community to help to achieve more efficient electronics in the context of power electronics and computing. Its recommendations reflect the growth in the electrification of vehicles, the increased use of renewable energy sources, and the development of 'smart grids'.

They also reflect the ever-growing global demand for digital technologies that is rapidly accelerating due to the evolution of established trends such as smartphone usage, the rise of social media and digital entertainment on demand.

This increasing global demand for digital technologies is now overlaid with new opportunities including mass-market adoption of the Internet of Things (IoT), practical applications of artificial intelligence (AI), the emergence of autonomous vehicle technology, Industry4.0 and, more recently, a step change in the connectivity demands of home working and online retailing.

Such a ubiquitous upward trend in digital technologies comes inevitably with an energy consumption penalty. There will be 29.3 billion networked devices by 2023, up from 18.4 billion in 2018, with Internet access penetration reaching 66% of the global population. Consequently, Internet (IP) traffic volumes will continue to see a massive rise, from 100 Exabytes per month in 2017 to a forecasted >330 Exabytes per month in 2022. This translates to 'digital electricity consumption' growth of 7% per year, which is outstripping global electricity demand at 3% per year. Estimates suggest that the production and operation of Information and Communication Technology (ICT) systems will demand over 21% of global electricity consumption by 2030.

Overall, an estimated 40% of natural resources are converted to electrical energy. This is expected to grow to 60% by 2040. Given the UK's target to bring all greenhouse-gas emissions to net-zero by 2050, the development and adoption of more energy-efficient electronic systems are essential for the UK to achieve this goal.

"Reducing the energy consumption of future electronic systems cannot be achieved by optimization of existing ICT hardware solutions alone," notes Dr Wyn Meredith, director of the Compound Semiconductor Centre Ltd (CSC), a joint venture founded in 2015 between Cardiff-based epi-wafer foundry and substrate maker IQE plc and Cardiff University focused on the commercialization of compound semiconductor innovation. "The UK needs to harness its extensive, world-class semiconductor materials research base to focus on developing solutions which take a holistic approach from novel materials to electronic devices and components," he adds.

"We need ambitious new impact-driven initiatives to enable the UK materials science research community to accelerate dramatically the commercialization of their research and innovation against our national imperatives," believes Royce CEO professor David Knowles. "This focus on future electronic systems will provide a sovereign manufacturing capability for the UK, underpinned by world-leading research. Applied collaborative research programs designed to accelerate industry adoption are needed, together with UK-based pilot-foundry semiconductor facilities," he adds.

"Establishing policies that set power consumption targets, and support the circular economy through end-of-life considerations, will also be a critical factor in establishing an environment where the UK takes a leading position in the development of low-loss electronics," reckons professor Edmund Linfield, director of the Bragg Centre for Materials Research at Royce partner the University of Leeds.

www.royce.ac.uk

www.iqep.com

Picosun's cluster ALD thin-film coating solutions enable next-generation power electronics

Several cluster systems sold to manufacturers in Europe, USA & Asia

Picosun Group of Espoo, Finland, the leading supplier of AGILE ALD (atomic layer deposition) thin-film coating solutions for global industries, has strengthened its position in power electronics market with several cluster ALD system sales to prominent manufacturers in Europe, USA and Asia.

"Power electronics is an important, fast-growing market for Picosun. ALD has potential to solve various challenges manufacturers are facing in this field, and our solutions have enabled our customers to create significant added value in terms of device quality and throughput," says Juhana Kostamo, head of Customer Solutions/deputy CEO of Picosun. "At Picosun, we have developed several turn-key production ALD solutions specifically for 4–8 inch wafer markets such as power devices. Especially our cluster ALD systems, such as the PICOSUN Morpher which we launched last year, have been extremely well received by our customers."

Power components are crucial in a wide range of applications from consumer electronics to transportation, energy production and distribution, including renewables such as wind and solar power generation. These components are typically manufactured on 4–8 inch compound semiconductor wafers such as gallium nitride (GaN) and silicon carbide (SiC). These materials provide various benefits com-

pared with pure silicon, for example higher electron mobility, higher threshold voltage, and ability to operate at higher temperatures. Challenges do exist, however, as GaN and SiC power devices are prone to high interface trap density (leading to parasitic currents and reduced electron mobility) and gate leakage current, and poor threshold voltage stability.

Interface trap density can be reduced by combining pre-cleaning methods with high-permittivity, large-bandgap insulators. High-quality, defect-free high-k dielectric layers such as Al_2O_3 , AlN or ZrO_2 etc are key in reducing power devices' gate leakage current and to improve electron mobility and threshold voltage stability. A good example here is GaN-based HEMTs (high-electron-mobility transistors), which are important in various large-scale practical applications, and which require efficient gate insulation and surface passivation to achieve optimal functionality.

Picosun says that ALD stands as a superior deposition method here compared with other thin-film coating technologies such as PECVD (plasma-enhanced chemical vapor deposition) as ALD produces the most conformal, uniform and defect-free films with accurate, digitally repeatable thickness control and sharp interfaces. With the right selection of ALD deposition equipment, even multi-layer processing

is possible, i.e. various functional material layers and/or stacked films/nanolaminates can be manufactured in one process run.

PICOSUN Morpher is a disruptive ALD production platform designed for up to 8-inch wafer industries such as power electronics, MEMS, sensors, LEDs, lasers, optics and 5G components. Morpher's operational agility makes the system adaptable to various and changing manufacturing needs, on all business verticals from corporate internal R&D to production and foundry manufacturing, where both the end products and/or customers' requirements may change rapidly. Morpher can handle several substrate materials, batch and substrate sizes, and ALD materials with leading process quality. Multi-layer deposition is possible, and cluster design allows integration also of other processing units such as pre-clean, RIE (reactive ion etch) etc for fully automated, high-throughput continuous vacuum operation.

"In its versatility and transformability, Morpher is the epitome of our principle 'Agile ALD'," says Kostamo. "Innovation, constant development and improvement of our ALD solutions to enable our customers' success is our driving force at Picosun," he adds. "This applies also to the Morpher platform and we have some truly exciting additions to this product family coming in the near future."

www.picosun.com/product/

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EVG demonstrates end-to-end process flow for collective die-to-wafer bonding

Heterogeneous Integration Competence Center targets next-generation 2.5D and 3D semiconductor packaging

EV Group — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — has demonstrated a complete process flow for collective die-to-wafer (D2W) hybrid and fusion bonding with sub-2 μ m placement accuracy utilizing existing EVG wafer bonding technology and processes, as well as existing bond interface materials.

Demonstrated at EVG's Heterogeneous Integration Competence Center, this represents a milestone in accelerating the deployment of heterogeneous integration (HI) in next-generation 2.5D and 3D semiconductor packaging, the firm says.

Located at EVG's headquarters, the Heterogeneous Integration Competence Center offers consultancy services, feasibility studies and demonstrations, process development support and pilot-production services. Serving as an open-access innovation incubator, it is designed to help customers accelerate technology development, minimize risk and develop differentiating technologies and products through HI/advanced packaging, all while guaranteeing the highest IP protection standards that are required for working on pre-release products. All process and integration aspects of both wafer-to-wafer and different D2W integration approaches are focus technologies at the center.

Leading-edge applications such as artificial intelligence (AI), autonomous driving, augmented/virtual reality (AR/VR) and 5G all require the development of high-bandwidth, high-performance and low-power-consumption devices without increasing production cost. As traditional 2D silicon scaling reaches its cost limits, the semiconductor industry is turning



Individual dies on a wafer after collective D2W bonding.

to heterogeneous integration — the manufacturing, assembly and packaging of multiple different components or dies with different feature sizes and materials onto a single device or package — in order to increase performance on new device generations. Collective D2W bonding is an essential HI process step that enables functional layer and known good die (KGD) transfer to support cost-efficient manufacturing of new types of 3D-ICs, chiplets, and segmented and 3D system-on-chip (SoC) devices, says EVG.

"For more than 20 years, EVG has provided process solutions and expertise to support the advancement of HI, including D2W bonding, where our technology has been successfully implemented in high-volume manufacturing applications," says Markus Wimplinger, corporate technology development & IP director. "Our Heterogeneous Integration Competence Center, which is supported by our worldwide network of process technology teams, enhances our capabilities in this critical area by providing a foundation for customers and partners working with EVG to develop

new 3D/HI solutions and products. Among these is our new collective D2W bonding approach, where we have demonstrated the ability to perform all key process steps in-house with high placement accuracy and transfer rate using our existing wafer bonding and debonding, metrology and cleaning process equipment along with select third-party systems from our development partners," he adds. "We'd like to thank our partners for their role and support in enabling this important achievement.

A special thanks goes to IRT Nanoelec and CEA-Leti, which both provided the substrates that were used in this demonstration," says Wimplinger.

Results of collective die-to-wafer bonding demonstration

A technical paper highlighting the results of EVG's collective D2W bonding process was presented at the Electrochemical Society (ECS) PRiME 2020 Conference (4–9 October) and can be downloaded from the ECS PRiME website at <https://ecs.confex.com/ecs/prime2020/meetingapp.cgi/Paper/142631>.

www.evgroup.com/technologies/fusion-and-hybrid-bonding



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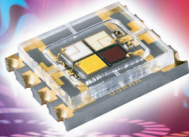


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Riber and Comptek partner to commercialize Kontrox passivation process technology

Riber S.A. of Bezons, France — which makes molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — and Comptek Solutions (which specializes in III–V compound semiconductor quantum surface engineering) have signed a commercial partnership to develop joint technological solutions.

Spun off from Finland's University of Turku in 2017, Comptek addresses the oxidation issue in III–Vs with its patented Kontrox technology.

III–V-based devices have a natural tendency to oxidize almost instantly once exposed to air, which results in the formation of an amorphous oxide layer leading to a range of defects that limit their performance and manufacturing yields. To tackle this, the Kontrox passivation process creates a thin layer of stable crystalline oxide with a dry vacuum approach, preventing the amor-

phous oxidation layer from forming. Compared with existing methods, Kontrox is said to drastically reduce the density of interface defects and increase efficiency and manufacturing yields for III–V devices, including high-electron-mobility transistors (pHEMTs) and heterojunction bipolar transistors (HBTs). This can result in devices that are increasingly efficient, smaller and more reliable for applications such as 5G, facial recognition (3D sensors), augmented reality, virtual reality and autonomous vehicles.

Kontrox can also aid the development of next-generation CMOS processors, where the quality of the interface between the gate oxide insulator and the III–V materials in transistors has a crucial role in CMOS operations.

The technology also boosts the performance of optoelectronic

devices such as mini- and micro-LEDs, high-power lasers, vertical-cavity surface-emitting lasers (VCSELs) and infrared sensors, improving their efficiency, brightness and lifespan.

The partnership between Riber and Comptek aims to build a long-term collaboration to support and accelerate Kontrox technology transfer to industrial clients by delivering customized, highly efficient ultra-high-vacuum equipment along with expert technical support and lifecycle management services.

The collaboration makes it possible to customize and optimize the specifications for equipment to deploy Kontrox technology according to user needs. It is reckoned that this will enhance technology industrialization, featuring process control developed specifically for Kontrox.

www.comptek-solutions.com

Riber's net loss rises year-on-year in first-half 2020 Pandemic-related sourcing difficulties delay system delivery to Q3

Riber has confirmed revenue of €11.6m for first-half 2020, down 17% on first-half 2019's €13.9m.

MBE Systems revenue fell by 35% from €8.6m to €5.6m, with deliveries falling from four reactors to three, as one production system was deferred to third-quarter 2020 due to sourcing difficulties linked to the coronavirus pandemic.

Revenue from evaporation sources and effusion cells fell further, by 95% from €1m to just €0.1m, as the market remains sluggish due to the current lack of investment in the organic light-emitting diode (OLED) screen industry.

Services & Accessories revenue grew strongly by 39% from €4.3m to €6m, in line with the plan to develop the business.

Gross margin was 28.9%, stable with first-half 2019's 29.1%.

Operating expenditure is down by 5%, due mainly to the reduction in

sales & marketing costs. Administrative costs rose slightly by 7%, while R&D investment was maintained at a high level of €1.5m.

Net loss has risen from €0.4m to €1.1m, rising from –2.9% to –9.6% of revenue.

Due to the first-half loss and the distribution of amounts drawn against the issue premium to shareholders for 2019 (€0.6m), shareholders' equity has fallen from €19.2m at end-December 2019 to €17.4m at end-June 2020.

Net cash at end-June 2020 was €6.1m, up from €2.5m at end-June 2019, aided by a €6m government-backed loan that the firm has put in place with its banks to consolidate its working capital and mitigate the postponement of order-taking decisions (and the resulting decrease in deposits paid when ordering) due to the pandemic.

The order book at end-June has

fallen by 36% from 2019's €28.4m to 2020's €18.2m.

Specifically, the Systems business is marked by the wait-and-see approach adopted by clients, with its order book contracting by 42% from €21.5m (13 systems to be delivered in 2019, including six production units) to €12.5m (seven systems to be delivered in 2020, including two production systems). However, Riber expects its system orders to improve in fourth-quarter 2020 due to a strong portfolio of prospects.

Services & Accessories orders have fallen from €6.9m at end-June 2019 to €5.7m at end-June 2020. However, this excludes the major order for MBE services in the USA signed up in September.

For full-year revenue, Riber is forecasting about €30m for 2020, down from 2019's €33.5m.

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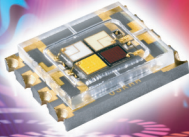


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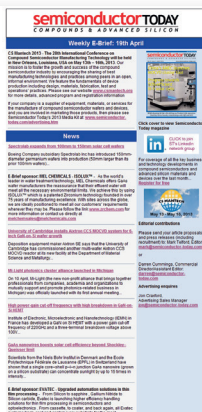


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IQE acquires outstanding stake in IQE Taiwan

UK-based epi foundry makes Asia production subsidiary wholly owned

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has acquired third-party shareholdings in its majority-owned subsidiary IQE Taiwan Corp, taking its ownership from 90.18% to 100%.

The acquisition was effected using a statutory share swap arrangement under Taiwan's Business Mergers and Acquisitions Law. Selling shareholders who accepted the share swap will be issued with shares in IQE on the basis of the average closing price of IQE's ordinary shares of 1p on AIM (the Alternative Investment Market of the London Stock Exchange) in the 30-day period prior to the acquisition. Selling shareholders who rejected the share swap will have their shares in IQE Taiwan purchased for cash.

Selling shareholders representing 5.04% of the shares in IQE Taiwan (and 51% of the third-party shareholdings) accepted the share swap. The total payable to those shareholders is £1,437,646, which will be settled through the issue of 2,606,689 ordinary shares at an issue price of 55.15p per ordinary share (the consideration shares). Selling shareholders representing 4.78% of the shares in IQE Taiwan (and 49% of the third-party shareholdings) rejected the share swap and will have their shares in IQE Taiwan purchased for cash. IQE has agreed a cash price with a number of those shareholders but is waiting for the Taiwan Court to determine the price payable to the others, as part of the normal process to be followed under Taiwan's Business

Mergers and Acquisitions Law. IQE will therefore update the market once the total consideration has been determined.

The consideration shares rank 'pari passu' (on an equal footing) with the existing ordinary shares. The total number of ordinary shares in issue is hence 799,889,941 and the total number of voting rights is also 799,889,941.

"IQE's Taiwan subsidiary is of strategic importance to the group as a base for epitaxy production in the Asia region," says IQE's chief financial officer Tim Pullen. "Having invested in the expansion of the facility in 2019 and looking forward to further growth in the future, I'm delighted to be bringing the entity under wholly owned status."

www.iqep.com

Mitsubishi Chemical America completes acquisition of metal-organic supplier Gelest

Gelest promotes Jonathan Goff to chief technology officer

Gelest Inc of Morrisville, PA, USA has completed the sale of Gelest Intermediate Holdings to New York-based Mitsubishi Chemical America Inc (MCA), the US subsidiary of Tokyo-based Mitsubishi Chemical Corp (MCC). Gelest Intermediate Holdings is the parent company of Gelest Inc and Bimax Inc. The transaction, which was announced on 30 April, has cleared all regulatory approvals.

Founded in 1990 by Dr Barry Arkles and Kevin King, Gelest manufactures silicones, organosilanes, metal-organics (MOs) and specialty monomers for end markets including medical devices, life sciences, microelectronics and personal care. In March 2017, New York-based New Mountain Capital LLC (NMC) made a majority investment in Gelest and has worked with the founders and management to scale the company through

organic initiatives and M&A.

"New Mountain Capital has been a terrific partner and helped us to significantly grow the company over the past three years," says Gelest's CEO Ken Gayer. "We now look forward to joining MCC, where their capabilities and breadth will allow Gelest to create even more value for customers and opportunities for employees," he adds.

"Since partnering with Gelest in 2017, we have been extremely impressed by the management team and Gelest's ability to innovate continuously to serve the evolving needs of its demanding customers," comments Andre Moura, NMC's managing director and lead director at Gelest. "We are proud to have supported Gelest's execution of an organic and inorganic growth strategy," he adds.

"Gelest fits well with MCC's strategy," reckons Mitsubishi Chemical

America's president Steve Yurich. "MCC's operating resources and customer network will enhance the ability to bring Gelest's cutting-edge technologies to market and accelerate the development of new customer solutions."

Also, Gelest has promoted Dr Jonathan Goff to chief technology officer (CTO). He joined Gelest in 2009 and currently manages the Polymer Development, Technical Services, Silanes & Metal-Organic, Research Engineering and Quality Control groups. Goff received his Ph.D. in Macromolecular Science & Engineering from Virginia Tech, is cited as inventor on 12 patents, and has published over 40 technical articles. Arkles will continue serving both Gelest and Mitsubishi Chemical Corp in the role of senior executive fellow.

www.gelest.com

www.bimax.com

Aixtron participating in AdaptAR project

Augmented reality to be used in technical documentation

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that it intends to take advantage of the opportunities offered by digitization to further optimize the production and continuous updating of machine and technical equipment manuals, especially (assembly) instructions. The firm is hence participating in research into possible applications of augmented reality (AR) in product documentation for customers.

Under the leadership of the Fraunhofer Institute for Production Technology (IPT), 11 project partners plus Aixtron (as an associated partner) are developing an augmented reality system with digital twin as the data basis within the AdaptAR research project. The three-year project AdaptAR is funded by Germany's Federal Ministry of Education and Research (BMBF) in the program 'Innovations for tomorrow's production, services and work' (funding code 02K18D070).

AR and Digital Twin

"Specific, always up-to-date and user-friendly technical documentation is indispensable for the successful operation of high-tech equipment," says Thomas Leipold, project manager Digitalization, at Aixtron. "We want to make even more consistent use of the opportunities offered by digitization for further development in this area for

our customers by contributing our know-how and experience to this Fraunhofer IPT research project," he adds. "We, as users, want to use the project results to lay the foundation for system documentation that even extends over the entire life cycle of a system."

With AdaptAR new ground is broken in product documentation. Augmented reality offers an interactive representation of the real environment in which, for example, a system in a factory is supplemented by computer-generated information and enriched with auditory and visual information of the processes. Every product in the factory is given a so-called Digital Twin, or digital shadow.

Digital uncharted territory in documentation

This virtual image of a system, for example, is to contain all the associated job, product, process and resource data in a local database. The Digital Twin is to be continuously enriched with additional data from connected IT systems while the system is in use. This connection will optimize decision making and knowledge management. For the complete synchronization of the virtual world (Digital Twin) and the real world, the data must be continuously collected, stored and processed.

Progress

Aixtron expects that a solution combining AR and Digital Twin will make it easier and more intelligent

to create, use and maintain technical manuals than before. The possible visualization also allows a better understanding of complex processes. The AR-supported technology is to be linked with a remote service offering.

An externally called-in expert can solve tasks together with the customer. User-friendliness can hence be further improved and time and effort significantly reduced. According to Fraunhofer IPT, savings of up to 70% in the time and effort required to create technical instructions are estimated.

"The continuous updating of the information in the database gives us the opportunity to ensure that the system is always up to date and contains all relevant product data, throughout the entire product life-cycle," says Aixtron's Thomas Leipold. "Our vision is that the customer can then call up instructions for solving a task directly on site using a smart device such as a tablet or smart glasses and receive guidance from external specialists via a remote service," he adds. The firm is already taking a first step in this direction.

Aixtron says that it is leveraging the benefits of digitalization for its customers by using remote services via smart glasses in close cooperation with first clients.

www.ipt.fraunhofer.de

www.aixtron.com

Gelest's chairman Arkles resumes position as CEO

Gelest Inc of Morrisville, PA, USA says that Dr Barry Arkles has been appointed chief executive officer, following the resignation of Ken Gayer as CEO. Arkles is also chairman of the board of Gelest, which he co-founded in 1991.

On 1 October, Gelest was acquired by New York-based Mitsubishi Chemical America Inc (MCA), the US subsidiary of Tokyo-based Mitsubishi Chemical Corp (MCC).

"Dr Arkles' comprehensive knowledge of the business and technology of Gelest provides excellent continuity as members of the talented leadership team join to support the continued growth of the company in the key markets served: medical device, semiconductor, personal care, pharmaceutical and diagnostic science," says Mitsubishi Chemical America's president Steve Yurich.

"My primary objective will be to deploy the technological strengths of Gelest and its parent Mitsubishi Chemical in service to the customer base that depends on us and the communities that we serve," says Arkles. "With the support of our reliable and talented employees, I anticipate a smooth transition into the Mitsubishi Chemical organization while sustaining the continued growth of Gelest."

www.gelest.com

Modulight adds Aixtron AIX 2800G4-TM system Biomedical laser maker scales up epi production, enabling tailor-made solutions

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that Modulight Inc of Tampere, Finland (an ISO-certified manufacturer of biomedical lasers and systems for genetics, oncology and ophthalmology) has added an AIX 2800G4-TM metal-organic chemical vapor deposition (MOCVD) system to its existing in-house epitaxial wafer production capabilities.

The system will be installed in Modulight's fully owned fab, where the firm conducts high-volume manufacturing of gallium arsenide (GaAs)- and indium phosphide (InP)-based devices. Modulight is currently expanding the fab's production space by 1000m². The new system will allow it to guarantee supply, and give it the control to provide tailor-made solutions.

"The quality requirements in this sensitive application sector are extremely high. Therefore, the epiwafers must have highest deposition uniformity control, lowest particle count, best yield,

and lowest production cost," says Modulight's chairman & CEO Seppo Orsila. "The MOCVD technology of Aixtron guarantees us the fulfilment of these high demands on epiwafers, and helps us to benefit from higher scalability," he comments.

Modulight's product range includes various types of lasers from visible to infrared (400–2000nm) with output power levels from milliwatts to hundreds of watts. The firm has over 20 years' experience in designing and manufacturing FDA- and CE-approved lasers and providing value-added solutions to optical applications. Its lasers are used for medical, industrial and environmental applications due to their high efficiency and brightness compared with conventional light sources, the possibility of contactless material processing and monitoring from a distance, and shorter cycle times due to fast processing.

The lasers are also used in the automotive industry, for example

for reliable distance measurement and autonomous driving.

Modulight's lasers are also used in medical applications ranging from surgery to non-invasive therapeutic procedures, particularly in oncology, ophthalmology and genetics. Tailoring the wavelength adds versatility and offers a high degree of customization of output power and beam delivery. The firm says that its laser platform is favored by institutes and companies working in oncology due to its extreme versatility and simplicity of use.

"Due to the advantages of medical lasers, this market is growing very strongly," notes Aixtron president Dr Bernd Schulte. "In the coming years, the billion-dollar mark is expected to be exceeded," he adds. "However, excellent laser quality is essential for medical lasers. Modulight is one of the world's leading specialists in the laser market, especially for medical applications," he comments.

www.modulight.com
www.aixtron.com

Osram qualifies Veeco's Lumina MOCVD system To be used for high-end LED production and to drive next-gen products

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that Osram Opto Semiconductors GmbH of Regensburg, Germany has qualified its Lumina metal-organic chemical vapor deposition (MOCVD) system for production of high-end LEDs and to drive the next generation of advanced photonic devices.

"The Lumina system has proven to set new standards in terms of productivity that will meet and exceed market requirements," comments Osram Opto Semiconductors' chief operating officer Lothar Mergili. "Veeco's best-in-class MOCVD technology has been, and

will continue to be, an enabling technology for us," he adds.

"The new Lumina system is built on over 20 years of high-volume MOCVD expertise and carries on the proven performance of our core TurboDisc technology," says Veeco's chief marketing officer Scott Kroeger. "To enable the next generation of devices, leading-edge companies like Osram depend on superior film quality, exceptional uniformity and repeatability with unmatched cost of ownership."

At the heart of the Lumina system is Veeco's MOCVD TurboDisc technology, which is said to feature excellent uniformity and low defectivity over long campaigns for

exceptional yield and flexibility. In addition, the firm's proprietary technology drives uniform injection and thermal control for thickness and compositional uniformity. Providing a seamless wafer size transition, the system is capable of depositing high-quality arsenic phosphide (As/P) epitaxial layers on wafers up to 8-inches in diameter.

The Lumina system allows users to customize their systems for maximum value in delivering IRED, LED, edge-emitting lasers and VCSELs in high-volume production, says Veeco.

www.osram-os.com
www.veeco.com

Aledia chooses Veeco's Propel 300 HVM MOCVD platform for micro-LED display applications

First 300mm system with EFEM designed for display applications

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that its Propel 300 HVM metal-organic chemical vapor deposition (MOCVD) system has been selected Aledia S.A of Echirrolles, near Grenoble, France (a developer and manufacturer of 3D micro-LEDs for display applications based on its gallium nitride nanowires-on-silicon platform) for high-resolution μ LED display applications. Featuring a SEMI-compliant equipment front-end module (EFEM) with cassette-to-cassette automation, the Propel system was chosen due to its highest productivity with the lowest defectivity compared to alternatives, according to Aledia.

"Brightness, contrast, switching speed and power efficiency in display panels for smartwatches, mobile devices, AR/VR [augmented reality/virtual reality] applications and large TVs are driving increased

demand for μ LED solutions," notes Aledia's chief operating officer Francis Taroni. "As our process tool of record, we believe Veeco's Propel 300 HVM platform is uniquely positioned to deliver outstanding process yields while achieving the world's highest-volume production," he adds. "Their history of supporting our innovation was a driving force in our selection."

Micro-LEDs are emerging as a next-generation display technology due to the potential for higher resolution, brightness and reliability. Market research firm TrendForce expects micro-LED wafer production to increase from 74,000 wafers in 2021 to over 5 million wafers in 2024.

"We are proud to be selected again by Aledia, a true pioneer in advanced display technologies, to deliver the industry's first 300mm MOCVD tool to support their micro-LED production ramp," says Veeco's chief marketing officer Scott Kroeger.

"Veeco's dedication to combining compound semiconductor expertise with semiconductor-scale manufacturing is evident in this EFEM-enabled, 300mm-wafer-capable platform," he adds. "It's embedded in our DNA to work closely with leading-edge companies like Aledia to develop the right solutions at production scale."

Veeco says that its single-wafer Propel 300 HVM GaN MOCVD system is designed as a unique, high-volume-manufacturing single-wafer-reactor cluster system for GaN-based advanced displays, power, RF and photonics devices. Featuring a single-wafer reactor platform, the system is capable of producing high-quality epitaxy film performance on 300mm wafers for optimal uniformity, repeatability and yield. The Propel 300 HVM is configurable with modular cluster chambers for maximum productivity and flexibility.

www.aledia.com

Propel HVM MOCVD platform chosen by Korea's A-Pro

A-Pro Semicon Co Ltd, a subsidiary of South Korea-based A-Pro's semiconductor business, has chosen Veeco's Propel HVM MOCVD system for the development and production of gallium nitride (GaN)-based power semiconductor and 5G RF devices. The system was selected for its excellent uniformity, operational efficiency and proven performance for high-volume production, says Veeco.

"A-Pro Semicon is well positioned to grow in the diverse power semiconductor device market as well as expand and commercialize 5G RF technologies using GaN MOCVD technology," reckons A-Pro Semicon's CEO Jong-Hyun Lim Ph.D. "Veeco's single-wafer Propel HVM platform has demonstrated the technical performance, flexibility and versatility we require to go after these markets. Furthermore,

the Veeco team has shown outstanding collaboration and support throughout the buying process."

The global GaN power device market was \$100m in 2019 and is rising at a compound annual growth rate (CAGR) of 35% from 2020 to \$1.2bn in 2027, reckons Allied Market Research. The decrease in prices of GaN devices, increase in demand for GaN devices for wireless charging, and rise in adoption of GaN devices in electric vehicles (EVs) have boosted growth, it adds. Additionally, an increase in GaN devices for commercial RF applications is augmenting the growth.

"A-Pro Semicon has selected our Propel HVM platform as their first MOCVD system to help grow their footprint in the GaN power semiconductor and 5G markets," notes Veeco's chief marketing officer

Scott Kroeger. "Our Propel suite of systems has been well received by leading and ambitious technology companies such as A-Pro Semicon for its proven, high-performance capability and yield to drive critical technology megatrends such as power, 5G RF and photonics applications that are driving the future."

Veeco says its Propel HVM system offers a high-volume, single-wafer reactor configuration for GaN-based applications, with uniformity, repeatability and yield performance resulting from decades of production-scale expertise in GaN MOCVD technology. The system offers 200mm and 300mm configurations with up to six modular cluster chambers for maximum productivity and flexibility, suitable for foundries and integrated device manufacturers (IDMs).

<http://en.aproele.com>

Axis and CP to co-develop CMP for bonding micro-LED wafers to CMOS backplanes

Partnership to accelerate monolithic 1080p micro-LED displays to mainstream augmented reality

Axis Technology of Chandler, AZ, USA — a provider of chemical-mechanical polishing/planarization (CMP), wafer thinning and wafer cleaning surface-processing equipment and process solutions) — has announced a partnership with Compound Photonics US Corp (CP Display) of Vancouver, WA, USA — a provider of compact high-resolution micro-display technologies for augmented- and mixed-reality (AR/MR) applications — to accelerate sub-5 μ m-pixel micro-LED development to the mass market.

Axis and CP are partnering to integrate critical wafer-scale processes needed for mass-production scale up of CP's 2 μ m-pixel, 1080p micro-LED displays for next-generation AR glasses. Specifically, Axis will deploy its Capstone CMP system with integrated post-CMP clean to enable wafer planarization and surface preparation process solutions for wafer-scale bonding of micro-LED wafers to high-performance CMOS backplanes.

To accelerate development, Axis and CP will set up in CP's MicroLED Innovation Center for Augmented Reality Acceleration (MiARA) in Chandler. The approximately 15,000ft², Class 100 cleanroom facility provides the infrastructure for Axis, CP and other capital equipment suppliers to conduct advanced process development in Silicon Desert within proximity to global semiconductor manufacturers.

Axis' CMP processing capability is key to enabling CP's proprietary small-pixel, epi-substrate-agnostic micro-LED integration process scheme. The Capstone CMP system provides the repeatability over multiple wafers and planarity performance within die/wafer to reliably enable bonding of multiple-million micron-scale electrical contacts



The Axis Capstone CMP system.

between micro-LED and CMOS backplane wafers. This addresses a critical mass-production process requirement for consistently yielding micro-display modules with the required visual uniformity, which is needed for compact, low-power, high-brightness AR/MR near-eye applications.

Axis and CP have collaborated since early 2020 to develop wafer-scale bonding process integration between micro-LED array and CMOS backplane wafers. The firms says that their latest partnership demonstrates their commitment from to advance micro-LED display fab processes and integration.

"Given the tremendous growth potential and exciting technological advances associated with micro-LED development and commercialization, I'm very pleased that Axis Technology has the opportunity to support many, if not most, of the technology companies working in this area," says Axis' president Dan Trojan. "With the introduction of our new, state-of-the-art Capstone

CMP system, we also now offer the equipment best suited for implementing such processes in R&D, pilot-production and high-volume manufacturing application," he adds.

"The synergies between Axis and CP will yield display devices of unprecedented speed and performance," believes Axis' process technology

director Peter Wrschka. "Axis offers years of experience in the surface preparation for wafer bonding and subsequent substrate removal, which is needed to successfully build the next-gen miniature displays. The partnership will significantly shorten the time-to-market for monolithically integrated micro-LED displays," he reckons.

"By working together in MiARA, process improvement cycles are naturally accelerated," says CP Display's product development director Julie Chao. "This is imperative in meeting the market schedule from developers to end customers."

Micro-LED technology is continuing to emerge as the display solution with the most potential to meet the critical requirements of AR/MR applications, states Axis. Innovations in manufacturing process are critical in enabling cost reductions and volume production for AR/MR headset commercialization, the firm adds.

www.axustech.com

www.compoundphotonics.com

First UV-C LED point-of-entry system for water treatment

UV LED disinfection expanding into residential & commercial markets

Nikkiso Group company Aquisense Technologies LLC of Erlanger, KY, USA (which designs and makes water, air and surface disinfection systems based on UV-C LEDs) has launched the PearlAqua Deca, the first UV LED disinfection system designed for the point-of-entry residential, commercial and light industrial markets.

Aquisense says that the PearlAqua Deca offers operational benefits specific to LEDs, including intermittent flow management, mercury free, and low cost of ownership. The system provides greater than 99.99% disinfection, it is reckoned, in a small, self-contained unit. It also features automatic on/off switching in addition to Dynamic Power Control, which reduces overall energy consumption and extends lamp replacement intervals. The PearlAqua Deca



System sizing is based on third-party bioassay testing, with additional certifications in-progress, continuing Aquisense's practice of introducing world-first


offers whole house disinfection with flow rates up to 12gpm (45lpm).

While priced competitively with similarly featured conventional UV systems, the benefits of intermittent power use and extended lamp replacement interval means that the total cost of ownership is actually lower after just three years.

UV LED products that are third-party verified.

"This product launch symbolizes maturation of UV LED technology," says CEO Oliver Lawal. "As this market grows, we will begin to see new products in both creative and disruptive applications."

www.aquisense.com





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NS Nanotech's new chip emits far-UVC light to neutralize coronavirus

Personal UV purifier fast-tracked for deactivating airborne pathogens

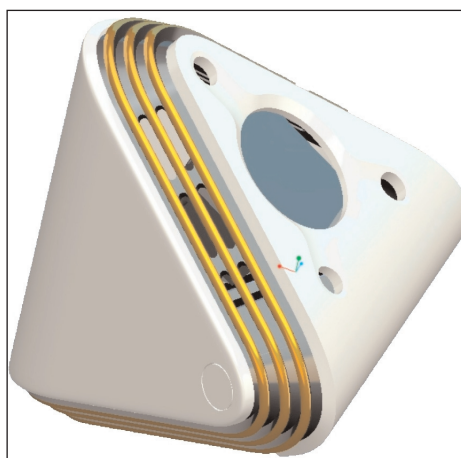
NS Nanotech of Ann Arbor, MI, USA claims that it has produced the first solid-state emissive material to produce shortwave far-UVC ultraviolet light that researchers say can deactivate the SARS-CoV-2 virus and other airborne pathogens. Initial samples of the chip will be available to OEM partners before the end of 2020.

A startup with patented technology developed at the University of Michigan and McGill University, the company says that it is also fast-tracking development of a personal air purifier for business and consumers that utilizes its new chip. Designed to neutralize coronavirus in the user's personal airspace, the portable product will be about the size of a coffee mug and will be available in 2021. It will be for personal and business use in the home, office, schools, airplanes, ride-shares and virtually anywhere you can plug it in, says the firm.

"Our coronavirus-neutralizing chip breaks barriers in semiconductor fabrication that previously prevented delivery of solid-state far-UVC light," claims CEO & co-founder Seth Coe-Sullivan. "With a far smaller form factor and lower potential costs than any other available shortwave ultraviolet light source, it is perfectly suited for many applications with the potential to safely deactivate airborne coronavirus and other pathogens," he adds.

Far-UVC for SARS-CoV-2 intervention

NS Nanotech claims that its new nitride semiconductor chips are the first solid-state devices to emit far-UVC light at wavelengths spanning 200–222nm. Third-party research has shown that light emitted in this wavelength range can neutralize more than 99.9% of airborne coronaviruses in its path, with less potential to harm human skin or eyes than longer-wavelength UVC light.



Concept rendering of portable air purifier (available in 2021) using NS Nanotech's far-UVC light source.

Independent studies at Columbia University and Kobe University have shown that shortwave far-UVC photons, at 222nm or less, can deactivate coronavirus without penetrating or damaging live human cells, making far-UVC sanitizing light safer for humans, with the potential for use in a wide range of products (including personal consumer devices).

The current generation of lamps that emit longer UVC ultraviolet waves of up to 280nm have been used for decades to sanitize air and surfaces in hospitals and other large facilities. But their use has been limited because UVC light has the potential to cause skin cancer, cataracts or other ailments in humans. They are most often used only in enclosed HVAC air filters, with robots, or other environments where the harmful longer-wavelength light won't come into contact with people.

Solid-state design enables thousands of applications

Several UVC lighting suppliers recently introduced far-UVC 222nm lamps. But their products are based on an earlier generation of technology requiring the use of excimer bulbs that are large, fragile, expensive, too hot to touch, and require

filters to block the longer UVC wavelengths that add substantial cost to the lamps, notes NS Nanotech.

The firm claims that, in contrast, the solid-state semiconductor emitter design of its new chips eliminates those problems:

- Because they have the smallest form factor available for any far-UVC germicidal light — each chip is less than 1.5-inches square — they can be designed into everything from wearable devices to classroom whiteboards to office furniture, enabling a wide range of potential consumer and business applications to neutralize coronavirus and future pathogens.
- Because of their solid-state design, they run cool.
- Also, they use power efficiently, which can enable portable, battery-powered operation.

The firm says that prototypes of the new chips will be available for potential partners to evaluate in fourth-quarter 2020, with a fast ramp to volume production in 2021.

Tabletop air purifier to be first line of defense

NS Nanotech says it is also designing a portable personal air purifier that will be the first consumer application for its far-UVC chip. To be available in 2021, the pyramid-shaped tabletop device will be for business and consumer use at home, work, school, at receptionists' desks, retail check-outs, on airline tray tables, etc.

"We are providing a new first line of defense against airborne pathogens," says Coe-Sullivan. "Far-UVC light can deactivate a virus before it reaches you," he adds. "Your face mask, which only traps the virus before you breathe it in, will be your second line of defense. Vaccines, if and when they become available, will be a third line of defense that neutralizes the virus only after you have become infected."

www.nsnanotech.com

Crystal IS and Boston Uni demo Klaran UVC LEDs' effective wavelength for inactivating SARS-CoV-2

Efficacy drops above 260–270nm wavelength range

Crystal IS Inc of Green Island, NY, USA, an Asahi Kasei company that makes proprietary ultraviolet light-emitting diodes (UVC LEDs), and Boston University's National Emerging Infectious Diseases Laboratories (NEIDL) have performed research demonstrating the efficacy of Crystal IS' Klaran UVC LEDs to inactivate the SARS-CoV-2 virus.

Crystal IS initiated the research to understand how SARS-CoV-2, the virus that causes COVID-19, responds to ultraviolet light across the emission range of Klaran UVC LEDs (260–270nm) and at different doses.

During the study, an array of Klaran UVC LEDs was used to irradiate a surface containing SARS-CoV-2. The results show a

log reduction achieved from exposing the virus to a UVC intensity of 1.25mW/cm² at different time intervals. The test was then repeated using a dose of 5mJ/cm² from LEDs that emit at a peak wavelength representing both ends of the Klaran LED wavelength specification (260nm and 270nm). The results indicate similar efficacy across the tested range.

"The research by NEIDL at Boston University demonstrates that SARS-CoV-2 can be effectively inactivated in a matter of seconds through exposure to low doses of UVC light in the key germicidal range," says Crystal IS' president Larry Felton. "However, comparing test results from this study against published results from the University of Miyazaki

[www.tandfonline.com/doi/full/10.1080/22221751.2020.1796529] (which used UVC LEDs emitting at 280nm) highlights a marked drop in efficacy beyond 270nm wavelength," he adds. "While there is much to be done in the fight against the coronavirus pandemic, Crystal IS believes this type of data can be used to help design innovative and effective disinfection solutions."

Klaran UVC LEDs are currently being used by a number of partners, including Healthe Air by Healthe Inc, and Big Ass Fans Clean Air System Haiku with UV-C, which provides continuous disinfection and clean airflow in retail, restaurant, fitness and office settings.

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www.csclean.com



Aledia closes €80m tranche of €120m Series D round Funding to create new 3D micro-LED manufacturing facility

Aledia S.A of Echirolles, near Grenoble, France (a developer and manufacturer of 3D micro-LEDs for display applications based on its gallium nitride nanowires-on-silicon platform) has closed an €80m first tranche (the first of three tranches) of its €120m Series D funding round.

The investment fund Société de Projet Industriel (SPI), a fund managed by Bpifrance and underwritten by the French State as part of the Programme d'Investissements d'Avenir (PIA), is lead investor in the round and is joined by most of the existing strategic investors, including Intel Capital.

The firm will use the proceeds to complete its product development and create what is said will be a first-of-its-kind, high-volume 3D micro-LED manufacturing facility in the Grenoble area for an estimated capital expenditure (CapEx) of €40m (excluding equipment).

Spun out of Grenoble-based micro/nanotechnology R&D center CEA-Leti in 2012, Aledia uses its proprietary technology to develop LED chips for next-generation displays for laptops, tablets, smartphones, smartwatches, augmented-reality (AR) glasses and large TVs.

"There is a major turning point coming in the \$120bn per year dis-

play market as micro-LED technology starts to replace the traditional LCD and OLED technologies," says CEO & co-founder Giorgio Anania. "In addition to being more efficient and brighter than current alternatives, with better colors and a faster refresh rate, these new displays will be competitively priced."

Aledia claims to be the only company targeting this market with a nanocrystal technology that uses very large-size silicon wafers (200–300mm in diameter) and with processes developed by the microelectronics industry, as opposed to the traditional technology of planar 2D LEDs built on smaller, layered sapphire substrates of 100–150mm diameter. The firm's technology is protected by 197 patent families (making Aledia the leading French startup company in filed patents).

"There is significant competition in this market, and this investment allows Aledia to accelerate substantially its development and establish world-class manufacturing capabilities," says Anania. "We are delighted to welcome SPI to our shareholder base, and we are also proud that our largest strategic investors and development partners are all reinvesting in this financing," he adds.

"The display industry is a large strategic market of the future, and Aledia is making a very ambitious play to become a leader in this space," comments Magali Joëssel, SPI fund director at Bpifrance.

"With an investment of over €200m in equipment over the next five years and plans to grow to approximately 500 employees, Aledia's location in the Grenoble area signals a commitment to establish a world-scale industrial manufacturing facility in France," he adds.

"In a world where mobile computing has become essential, the need has never been greater for displays which are energy efficient, high definition and readable in all settings — indoor and outdoor," notes Marshall Smith, senior director materials management at Intel Capital. "Aledia's nanowire micro-LEDs are a key enabling technology for this next generation of mobile consumer devices," he believes.

Aledia's existing investors include Braemar Energy Ventures, Demeter Investment Partners, the Ecotechnologies fund of Bpifrance, Ingka Investments, Intel Capital, Sofinnova Ventures, Supernova Invest, TEL (Tokyo Electron), Valeo, and several large additional technology companies.

www.aledia.com

Seoul Semiconductor obtains injunction in Germany against Leuchtstark Infringing products include LED light bulbs made by Signify subsidiary

South Korean LED manufacturer Seoul Semiconductor Co Ltd says that it has obtained a permanent injunction and destruction in a patent litigation against Leuchtstark Vertriebs GmbH for infringement of its patents in Germany.

Infringing products are LED light bulbs manufactured by Klite Lighting, a subsidiary of Signify (formerly Philips Lighting).

In other recent patent litigations, Seoul Semiconductor has also obtained two permanent injunctions against Philips brand television products.

The District Court of Düsseldorf also ordered the distributor to recall infringing products sold after October 2017 from commercial customers and to destroy those products.

"To enjoy benefits of the second-generation technology, Seoul's intellectual property is absolutely necessary," say Chung Hoon Lee and Young Joo Lee, CEOs of Seoul. "Seoul has a patent license relationship with Nichia Corp and NS only and has no other such a relationship with Korean or US LED companies," they add.

www.SeoulSemicon.com

Lextar partners with Ireland's X Display

Development & license agreement to accelerate μ LED mass production

Vertically integrated LED product maker Lextar Electronics Corp of Hsinchu Science Park, Taiwan and micro-LED display firm X Display Company (XDC) of Cork, Ireland and Research Triangle Park (RTP), NC, USA have entered into agreements, including a development & license agreement and services agreement wherein Lextar has licensed XDC's intellectual property, and both Lextar's and XDC's customers will be supplied with Lextar's micro-LEDs.

The partnership brings "innovative and feasible micro-LED display mass-production technology to Lextar," says C.N. Huang, VP of Lextar Technology Center. "Lextar has committed to developing

micro-LED technology for years and is known for its expertise in the display industry. By virtue of practicing the broad and foundational IP portfolio of XDC with respect to micro-LED, we look forward to the robust cooperation between the two companies to accelerate the commercialization of next-generation display technology," he adds. "Moreover, our customers can benefit from our one-stop service from micro-LED chip to display module."

Lextar has invested in several LED miniaturization projects for micro-LED products - from chip, packaging, testing, assembly, module, circuit drives to sub-systems - and is working closely with partners like XDC.

"Lextar is an innovative and dynamic LED company with strong experience in the display industry," comments Dr Matthew Meitl, co-founder & VP of displays at XDC.

XDC is a pioneer in the mass-transfer of micro-LEDs and has built a broad and foundational IP portfolio of over 400 patents. Its patented elastomer stamp mass-transfer technology provides a viable method to mass produce micro-LED displays for applications ranging from TV, signage, monitors, laptops and smartphones. XDC both licenses its technology and supplies components to the display industry.

www.lextar.com
www.xdisplay.com

Seoul Semi introduces next-gen WICOP UHL LEDs

South Korean LED maker Seoul Semiconductor Co Ltd has introduced its next-generation WICOP UHL (ultra-high luminance) Series LEDs, which reduce headlamp power consumption by up to 20% for electric vehicles (EVs), with an improvement in heat dissipation performance of up to 40%. The firm will begin mass production in 2021, with promotions to key customers.

Battery power consumption is one of the key factors determining the range of an electric vehicle, or the driving distance on a single charge. To reduce the power consumption, it is critical to reduce the overall weight of automobile parts.

The next-generation WICOP UHL Series LEDs are said to exhibit up

to 40% better heat dissipation performance than other LED products currently on the market. By applying WICOP UHL to automobile headlamps, the weight of the lamp heat-sink structure can be reduced by 75%. The LED emitting area of the product is extremely small at about 0.5mm², enabling the headlamp design to be slim. Seoul Semiconductor says that the new LED technology compensates for the disadvantages of heat dissipation, as the light-emitting area is smaller, so it enables not only a slim lamp design but also high performance.

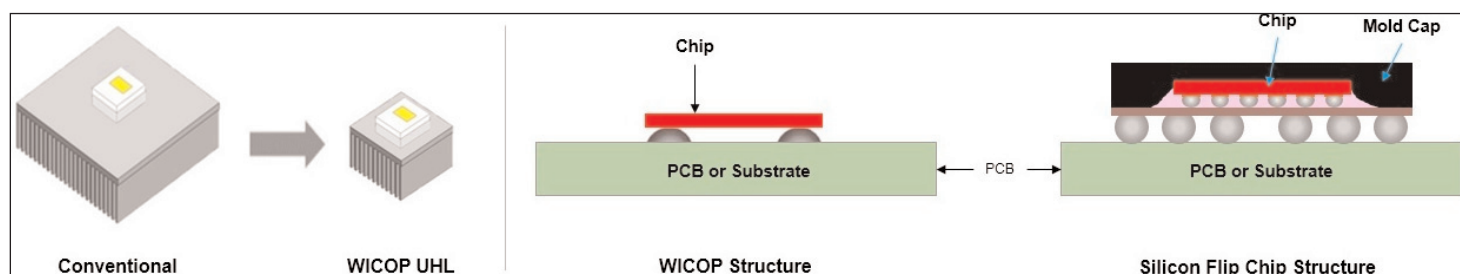
Developed by Seoul Semiconductor, WICOP (Wafer Integrated Chip on PCB), the fundamental technology of the new product, is claimed

to be the first patented packageless LED technology. Unlike flip-chip technology (which must be bonded during semiconductor processing), WICOP LEDs can be surface-mounted (SMT) in the general substrate bonding process. Mini-LEDs can also use WICOP technology with a robust structure.

"This new product will be mass-produced from 2021 according to requests of global headlamp manufacturers," says a representative of Seoul Semiconductor. "And it can be adopted for headlamps of all automobile brands and designs."

Seoul showcased WICOP UHL Series products at the Shanghai International Auto Lamp Exhibition (ALE) in China (15-16 October).

www.SeoulSemicon.com



Cree selling LED business to SMART for up to \$300m Cree focusing on Wolfspeed GaN and SiC devices and materials

Cree Inc of Durham, NC, USA has agreed to sell its LED Products business unit (Cree LED) to SMART Global Holdings Inc for up to \$300m, including fixed upfront and deferred payments and contingent consideration.

Under the terms of the agreement, which has been approved by the Cree's board of directors, the firm expects to receive an initial cash payment of \$50m upon closing and \$125m to be paid upon maturity of a seller note issued by SMART to Cree due August 2023. Cree also has the potential to receive an earn-out payment of up to \$125m based on the revenue and gross profit performance of Cree LED in the first full four quarters after the transaction's completion, also payable in the form of a three-year seller note.

The deal to sell the LED Products business unit follows Cree's sale in May 2019 of its Lighting Products business unit (Cree Lighting, including the LED lighting fixtures, lamps and corporate lighting solutions business for commercial, industrial and consumer applications) to Ideal Industries Inc of Sycamore, IL, USA.

Cree's LED product families include blue and green LED chips,

high-brightness LEDs and lighting-class power LEDs targeted for indoor and outdoor lighting, video displays, transportation and specialty lighting applications.

Having specialized in specialty memory, storage and high-performance computing solutions serving the electronics industry for over 30 years, SMART reckons that Cree LED will be able to leverage its diverse customer base and global operations.

"As the leader in LED lighting technology with a highly respected brand and expansive patent portfolio, Cree has a track record of delivering best-in-class solutions," comments SMART Global Holdings' president & CEO Mark Adams.

Cree's sale of its LED Products business unit represents "another key milestone in our transformational journey to create a pure-play global semiconductor powerhouse," says Cree's CEO Gregg Lowe. Cree will now focus on its Wolfspeed

Cree will now focus on its Wolfspeed silicon carbide materials and silicon carbide power device & gallium nitride RF device business

silicon carbide materials and silicon carbide (SiC) power device & gallium nitride (GaN) RF device business. Wolfspeed product families include silicon carbide materials, power-switching devices and RF devices targeted at applications such as electric vehicles (EVs), fast-charging inverters, power supplies, telecom and military and aerospace.

"This transaction uniquely positions us with a sharpened strategic focus to lead the industry transition from silicon to silicon carbide and further strengthens our financial position, which will support continued investments to capitalize on multi-decade growth opportunities across EV, 5G and industrial applications," says Lowe. "SMART has a strong platform and a solid track record of successfully acquiring and integrating technology businesses," he comments.

The transaction is subject to required regulatory approvals and satisfaction of customary closing conditions, and is targeted to close in first-quarter 2021. SMART will subsequently license and incorporate the Cree LED brand name into the SMART portfolio of businesses.

www.cree.com

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Cree divesting LED business at low price, says TrendForce

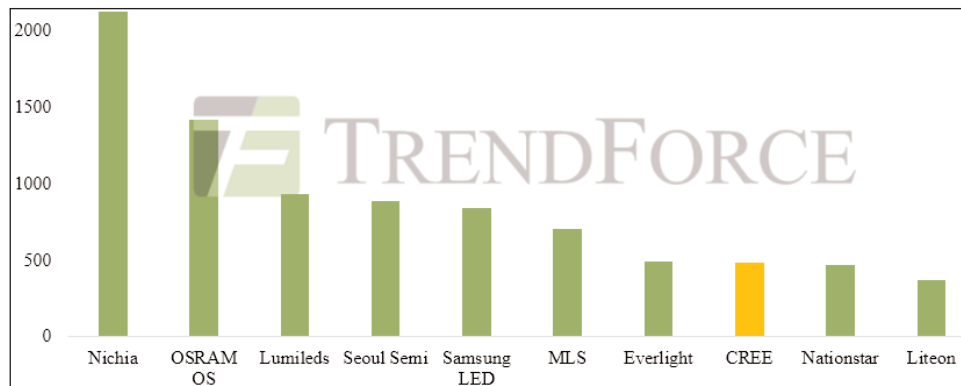
LED supply chain continues shift to Asia

After Cree Inc of Durham, NC, USA divested its Lighting Products business in May 2019, the company has announced plans to sell its LED Products business to SMART Global Holdings Inc (SGH) for \$300m. Market research firm TrendForce indicates that, benefiting from superior production capacities and cost-optimization measures, Chinese manufacturers have quickly risen in the LED industry in recent years, and are continuing to capture market share from major overseas LED companies such as Nichia, Osram Opto Semiconductors (OS), Lumileds, and Cree. Furthermore, given the poor state of the global economy in the past two years, companies that were previously dominant in the LED industry must now deal with the difficult reality of having their business operations or stocks sold off to other companies.

Cree's LED packaging and lighting businesses generated more than \$1bn in annual revenue for the 2013–2014 period. At the time, its LED business ranked second only to that of Nichia in terms of revenue. However, in light of competition from Chinese companies fielding aggressive pricing strategies and the gradually slowing growth of the LED lighting market in recent years, Cree's annual LED revenue was just \$480m in 2019, and the firm's global ranking slid from among the top three to eighth place.

Final price of Cree's LED business limited by regulatory complications with US aerospace & military technologies

According to TrendForce, Cree is estimated to sell its LED Products business for a mere \$300m, a far lower price compared to similar transactions by Lumileds and Osram OS. This low price is primarily due to the myriad restrictions and export controls by the US government specifically targeting sales of technology companies. In addition to Cree's role as a supplier of LED



Global ranking of top 10 LED companies by revenue (in millions of US\$).

lighting products, the company's subsidiary Wolfspeed offers a range of key components made from silicon carbide (SiC). As Wolfspeed has been in close collaboration with the aerospace & defense industries in the USA, it possesses a significant number of sensitive technologies.

On the other hand, the primary advantage of Cree's LED technologies comes from the fact that its SiC substrates massively boost the overall performance of its LED products. Since it is difficult to separate Cree's LED-related patents/technologies from its SiC technologies, potential buyers of Cree's business are therefore limited to US-based parties, in turn placing a limit on the final sales price.

Chinese manufacturers are continuing to capture market share from major overseas LED companies such as Nichia, Osram Opto, Lumileds and Cree

LED supply chain to continue gradual transition to Asia, while Cree may look for chip OEM partners

Under intense pricing pressure from its competitors, Cree has in recent years gradually outsourced its LED business to OEM partners with mature technologies, including Fujian Lightning Optoelectronic and Lextar. TrendForce notes that, even with the upcoming ownership transfer of its LED business, Cree is still an important client of its OEM partners, and its management structure will not change in the short term. That is why the overall trend of the LED supply chain shifting to Asia has not changed, says TrendForce.

In addition, SMART Global Holdings does not have a need for SiC substrate development, so it will likely adopt a more flexible business strategy that involves looking for Asia-based chip OEM partners in the future, the market research firm concludes.

www.trendforce.com

Date	Company	Price (USD)	Notes
2020.10	CREE	\$0.3 billion	Cree agrees to sell its LED business (Cree LED) to SMART Global Holdings for US\$300 million
2019.12	OSRAM OS	\$5.1 billion	ams acquired 55% of OSRAM's shares for €4.6 billion
2016.12	Lumileds	\$2 billion	U.S.-based Apollo Global Management, LLC acquired 80.1% of Lumileds' shares for approximately \$2 billion

Overview of LED industry mergers and acquisitions.

Osram unveils smallest broadband infrared LED for handheld molecular spectroscopy

Osram Opto Semiconductors GmbH of Regensburg, Germany has been developing compact and powerful broadband infrared emitters for spectroscopy for many years. In addition to the broad wavelength range, the energy efficiency of the integrated components is essential to system manufacturers, as are the compact dimensions. The new Oslon P1616 SFH 4737 combines these properties, making mobile spectroscopy solutions a reality, says Osram.

The most important aspect of infrared light sources for near-infrared spectroscopy is to cover as broad a wavelength range of emitted light as possible. The wider the range, the more objects that can be analyzed. To determine ingredients or water content, the target object is illuminated with infrared light of a wide wavelength range (usually 650–1050nm). Parts of this light are reflected, and others are absorbed. This ratio varies by object, resulting in a unique molecular fingerprint for each item. The reflected light is collected by a special detector. Then, software processes this data, compares it with documented information



stored in the cloud, and finally produces the measurement results.

With its compact dimensions of just 1.6mm x 1.6mm x 0.9mm, the Oslon P1616 SFH 4737 is claimed to be the smallest near-infrared LED (NIREL) for spectroscopy applications on the market — and is only half the size of the previous smallest Osram product. Also suiting use in smartphones is the output of 74mW at 350mA, which is about three times the peak values of earlier solutions. The new product also has radiant intensity in the forward direction of 18mW/sr, double that of former Osram NIRELs.

The optimized performance of the whole wavelength range offers another advantage in spectroscopy, says Osram. The sensitivity of legacy silicon-based detectors decreases with increasing wavelength, especially above 950nm. In the past, to compensate for this, higher currents were required. Thanks to a new phosphor, the

component emits more light at higher wavelengths — with positive effects on the overall energy consumption of the system.

“Mobile spectroscopy is a powerful tool for consumers because our NIRELs can help them determine the make-up and quality of their purchases, from the freshness of their produce, to identifying counterfeit medicines and banknotes, and more,” says senior product manager Christophe Goeltner. “It also can benefit industries like agriculture because, for example, it can help farmers pinpoint the ideal time to harvest.”

www.osram.com

Osram defeats Lighting Science Group's patent infringement accusation at ITC

ITC finds that claims of third patent are invalid

At the end of April 2019, US-based Lighting Science Group (LSG) filed a patent infringement complaint at the US International Trade Commission (ITC) against Osram and other companies in the lighting industry. Osram defended the claim against three LSG patents, and the ITC has now determined that none of these patents (all covering LED packages) was infringed by Osram products.

For two patents, the ITC made a

non-infringement finding in April 2020. With the recent decision on the third patent, the ITC terminated its investigation, finding that the asserted claims of the third patent are invalid and that there was no infringement of the patent by Osram. LSG also failed to show that the technical prong of the domestic industry requirement was met.

Osram says that it will continue to take action against unjustified

accusations and will continue to defend its intellectual property rights. With a history dating back more than 100 years, the firm has an extensive patent portfolio globally, including a considerable percentage of it in the USA. The patent portfolio ranges from semiconductor technology (such as LED or laser lighting) to smart and connected lighting solutions and systems.

www.osram-group.com

Lumileds appoints Steve Barlow as president of its Automotive business unit

Leon Pikaar replaces Barlow as head of LED Solutions business unit

Lumileds LLC of San Jose, CA, USA has appointed Steve Barlow as president of its Automotive business unit.

He succeeds Matt Roney, who in September was appointed CEO (replacing Dr Jonathan Rich, who continues as executive chairman of the board).

Barlow has led the Lumileds' LED Solutions business unit for over three years and, in his more than 18 years of executive leadership at Lumileds, he has managed both sales and marketing of automotive, illumination and specialty LED businesses.

Barlow has over 28 years of sales, marketing and business development experience in the semiconductor and LED lighting industry. He first joined Lumileds in 2003 and helped to build its LED lighting business. Barlow re-joined Philips Lumileds in 2017 as senior VP of Illumination. In 2012, he served as chief commercial officer at Intematix Corp and then in 2014 as senior VP of sales & business development at Cree.

"Steve is bringing his significant LED knowledge and his customer-focused business philosophy to our Automotive business unit," comments Lumileds' CEO Matt Roney. "With his previous experience in



Steve Barlow.

the automotive sector, and as one of the industry's innovative thinkers in the LED space,

Steve will continue our commitment to deliver valuable solutions to our automotive customers and end-users."

Leon Pikaar appointed VP & general manager of LED Solutions business unit

Replacing Steve Barlow, Leon Pikaar has been appointed as VP & general manager of Lumileds' LED Solutions business unit.



Pikaar has more than 30 years of experience in the LED and lighting industries.

Leon Pikaar.

try, including an extensive tenure at Philips Lighting and Lumileds where he has led international business organizations, strategic accounts, and developed the specialty business in camera flash, display and UV markets.

His career started at Philips Lighting in The Netherlands. He was soon transferred to Brazil where he became regional manager Latin-America for lamp drivers. In 1999, he joined the team that founded Lumileds as a joint venture between Hewlett Packard and Philips, after which he became responsible for sales & marketing of specialty lamps for Philips Lighting in Europe. Prior to his new role, Pikaar was head of marketing for the LED Solutions business unit, after having served as VP of sales & marketing at RayVio, a startup company in UV-B/C LEDs.

Pikaar has enjoyed successful overseas assignments, is fluent in multiple languages, and holds a Bachelor's degree in Mechanical Engineering from Tilburg Polytechnic in The Netherlands.

"Leon has been at the tip of the spear for Lumileds for more than two decades," comments Roney. "The LED Illumination and Specialty side of our business is in great hands."

ITC backs Lumileds over LSG's asserted LED chip patents Lighting Science Group patent ruled invalid; investigation terminated

Lumileds LLC of San Jose, CA, USA says that the International Trade Commission (ITC) has issued its final determination of no violation in the investigation initiated by US-based Lighting Science Group (LSG) seeking to bar the importation of certain products made by Lumileds into the USA. Lumileds adds that the ITC ruled in favor of it on all fronts, finding that its

products do not infringe US patent number 7,528,421, that the patent is invalid, and that LSG lacked the required domestic industry.

This decision follows a previous determination that Lumileds does not infringe US patent numbers 7,095,053 and 7,098,483. The investigation has now been terminated.

"We are pleased with the ITC's thoughtful analysis of the issues and findings of no violation," comments Lumileds' chief legal officer & senior VP Cheree McAlpine. "We will continue to defend and protect our valuable intellectual property rights while respecting those of others."

www.lumileds.com
www.lsgc.com

BluGlass demos working 405, 420 & 450nm lasers

Manufacturing supply chain qualification for 2” production on schedule to complete this quarter

In an update on its laser diode product development, BluGlass Ltd of Silverwater, Australia says that its laser diode business unit has made progress in all three of its development areas: technology, product development and manufacturing preparedness.

Laser diode technology & product development

BluGlass is developing a range of laser products targeting what it describes as unmet needs in the gallium nitride (GaN) laser industry. These products include standard laser diode designs and novel, remote-plasma chemical vapor deposition (RPCVD) tunnel-junction designs, for multiple market segments, including industrial, display and biotech applications.

The firm remains on track to deliver initial sample products of one of its standard laser diode designs to customers for testing in 2020 and into early 2021, on the back of promising technical results in three of its laser diode product development roadmaps.

Three different standard laser designs (emitting at wavelengths of 405, 420 and 450nm) are demonstrating lasing behaviour, following multiple process steps in fabrication into test devices.

The 405nm design is also showing good performance, approaching commercial specifications in brightness. These results have been verified through multiple fabrication vendors, as BluGlass qualifies both its laser diode designs and its manufacturing supply chain simultaneously.

The laser diode devices are being simulated and modelled, designed and then grown on wafers at BluGlass’ Australian manufacturing facility. They are then shipped to

the USA for multiple wafer processing steps including cleaving (being cut into individual laser chips) before final optical coating (insertion of coated mirrors to enhance the directional emission/lasing), packaging and burn-in testing (performance reliability testing of 100,000 hours).

There are several customer engagement points that can be initiated at different stages of performance throughout the manufacturing process. Some customers order custom laser diode wafer development, or R&D devices, before any of the downstream processing steps are required. Other customers require uncoated or unpackaged laser diodes or pre-burn-in prototypes for custom applications or preliminary evaluation, with others requiring fully processed and packaged lasers.

BluGlass’ target customers range from global research institutions requiring custom laser development to OEMs and distributors. The firm says that it is establishing collaborative customer relationships to develop customized solutions in several of its target markets.

Manufacturing preparedness and supply chain qualification

Product development results from wafers grown earlier in the year were initially delayed due to supply chain impacts caused by the COVID-19 pandemic. As a result,

BluGlass has diversified its supply chain, and is qualifying multiple providers in each segment of the supply chain around the world to help mitigate future delays and ensure that it is working with the best suppliers in each segment.

Processing timelines from design and epitaxial growth through to initial testing have now been significantly expedited. Full supply chain qualification is expected to complete on schedule in this quarter.

The firm’s US test facility is now fully operational. Its US-based team has grown with the addition of two, industry-experienced laser diode testing engineers.

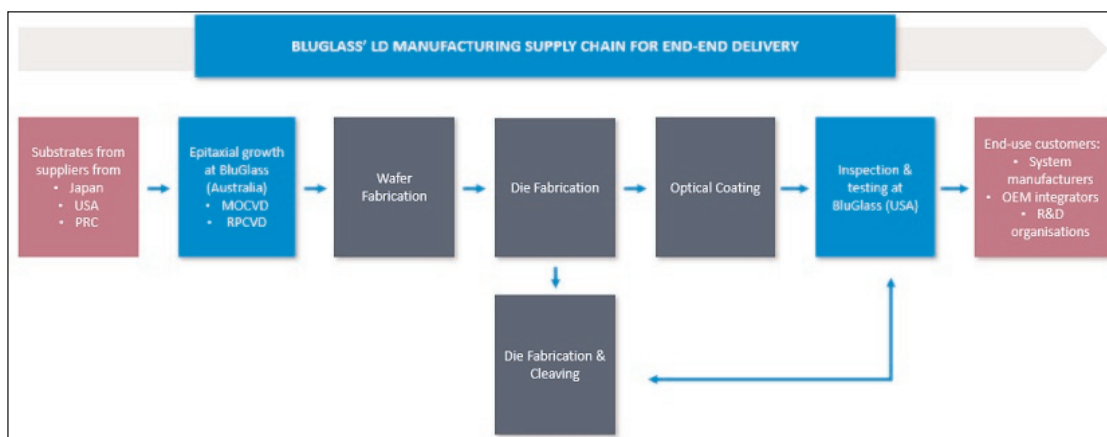
Laser diode product suite

BluGlass says that it is developing bespoke lasers across multiple market segments. Current product development covers a range of wavelengths from violet (395nm), blue and through to green (525nm) for various customer applications.

BluGlass says that its laser diode development, international supply chain qualification and US test facility staffing have all progressed in line with its published goals towards its commercial manufacturing milestone.

The firm now has a number of working laser diode designs, including the 405nm design which is approaching commercial specifications for sample customer products.

www.bluglass.com.au



BluGlass to develop lasers for Yale in DARPA-funded LUMOS program

Custom GaN lasers and epiwafers to be incorporated into photonic integrated circuits

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 and develops low-temperature, low-hydrogen remote-plasma chemical vapor deposition (RPCVD) technology for manufacturing devices such as laser diodes, next-generation LEDs and micro-LEDs — has received a US government-funded subaward contract from Yale University to help the US Defense Advanced Research Projects Agency (DARPA) to develop novel laser diode technology.

BluGlass is commercializing its proprietary low-temperature remote-plasma chemical vapor deposition (RPCVD) technology for manufacturing group III-nitrides, offering better-performing, lower-cost devices and more environmentally sustainable processes for producing LEDs for automotive and overhead LED lighting, micro-LEDs for wearables and virtual reality (VR) displays, and power electronics for efficient power conversion.

In addition, in 2019, BluGlass launched its direct-to-market Laser Diode business unit to exploit its unique tunnel-junction technology

capability in the high-value, high-margin laser diode market. The firm expects to launch its first laser diode commercial product in 2021.

Now, in the first phase of a three-phase program scheduled to last 18 months, BluGlass and Yale will conduct paid R&D under DARPA's Lasers for Universal Microscale Optical Systems (LUMOS) initiative, which seeks to combine efficient integrated optical systems and complete photonics functionality onto a single substrate.

Lasers are essential for optical communications, remote sensing, manufacturing and medical applications. Photonic integrated circuits have allowed unprecedented advances in optical systems for a wide range of applications, including light detection & ranging (LiDAR), signal processing, chip-scale optical clocks, gyros, and data transmission. However, these two technologies are currently limited by the incompatibility of the materials used to create them — silicon photonics are easy to manufacture but are poor light emitters while compound semiconductors enable efficient emitters but are difficult to scale for use in complex integrated circuits.

Together, Yale and BluGlass research teams are aiming to combine these two technologies to create high-performance lasers and amplifiers with photonic integrated circuits in a single device for applications such as compact optical phased-array LiDAR and neuromorphic optical computing.

BluGlass is supplying custom GaN laser diodes and laser epitaxial wafers to Yale for incorporation into a photonic integrated circuit (PIC). BluGlass says that its unique technology capabilities provide increased design and manufacturability options to combine nitrides and photonic integrated circuits. Specifically, the firm's epiwafers will pump a novel Yale laser design that is to be fabricated under the program.

"This opportunity allows BluGlass to showcase our capabilities in GaN laser epitaxial growth technology, while demonstrating the integration of our technology into next-generation laser applications such as photonic integrated circuits, that could lead to further commercial opportunities," says executive VP Brad Siskavich.

www.bluglass.com.au

SDK splitting off optical semiconductor business

Showa Denko Photonics subsidiary formed

Tokyo-based Showa Denko K.K. (SDK, which produces petrochemicals, gas products, specialty chemicals, electronics, inorganics, aluminum, etc) has decided at its board of directors' meeting to split off its business in optical semiconductors (visible-light & infrared LEDs and light-receiving epitaxial wafers) and rare-earth alloys — currently part of the firm's Electronics Sector — through an

'absorption-type company split', effective 1 January 2021, forming the subsidiary Showa Denko Photonics Co Ltd of Chichibu, Saitama Prefecture (with Masahiko Usuda as president).

In its medium-term business plan 'The TOP 2021', SDK classifies its optical semiconductor business as a growth business, aiming to expand it by providing products and technologies that meet customer needs.

To achieve this, SDK will make the business an operating company, increasing the speed of decision-making and sharing of the latest market information.

By focusing on the growing business in infrared light-receiving/emitting devices, the firm aims to meet customer requirements by taking advantage of its customizing capabilities.

www.sdk.co.jp

II-VI's high-power laser range available on 6" GaAs Platform for 3D sensing and high-speed Datacom applications extended to fiber-laser pump chips

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA says that its full product line of high-power semiconductor lasers is now available on its 6-inch gallium arsenide (GaAs) platform.

The intensifying competition and anticipated increase in demand in the laser systems market, including for Industry 4.0, medical diagnostics and surgery, and aerospace & defense applications, is favoring semiconductor laser diode suppliers that can deliver reliably in volume while driving economies of scale, reckons the firm. To meet the growing demand for fiber-laser pump chips, II-VI is now in volume production on its 6-inch GaAs platform for high-power edge-emitting diodes. It says it achieved this by leveraging decades of expertise in manufacturing highly reliable high-power GaAs edge-emitting pump

lasers, and by building on its momentum in deploying 6-inch GaAs optoelectronics platforms for 3D sensing and high-speed datacom applications.

"While there are very few 6-inch GaAs technology platforms for optoelectronics in the world, II-VI already operates several at scale, in three locations globally, including two in the USA and one in Switzerland," says Dr Karlheinz Gulden, senior VP of the Laser Devices and Systems business unit. "To our knowledge, we are the first in the world to produce reliable high-power pump laser diodes and bars on such a scalable platform," he adds. "By achieving this milestone, II-VI is once again validating the long-term strategic benefit of developing vertically integrated technology platforms in-house, which is the ability to leverage those investments over time

across multiple applications," Gulden states.

II-VI's high-power pump lasers are offered as bare dies and mounted chips. Its broad portfolio of components for laser systems includes seed lasers, acousto-optic modulators, fiber Bragg gratings, and kilowatt pump and signal combiners, as well as ion beam sputtering (IBS) coated laser optics and micro-optics for high-power isolators.

In addition to its 6-inch GaAs technology platform for optoelectronics, II-VI has established 6-inch GaAs and GaN-on-SiC (gallium nitride on silicon carbide) technology platforms for RF electronics. The firm has also announced plans to establish a 6-inch SiC vertically integrated platform for power electronics, and recently joined the US Semiconductor Industry Association.

www.ii-vi.com

II-VI's CEO named Entrepreneur Of The Year 2020 East Central Award winner

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA says that CEO Dr Vincent D. (Chuck) Mattera Jr has been named an Entrepreneur Of The Year 2020 East Central Award winner.

Sponsored by Ernst & Young LLP (EY US), the award recognizes entrepreneurial leaders who are excelling in financial performance, overcoming adversity, societal impact and commitment to building a values-based company, innovation, and talent management. Mattera was selected by an independent panel of judges. The award was announced through the program's first-ever virtual awards celebration, hosted by Deborah Norville, anchor of Inside Edition, on 7 October.



As an East Central Award winner, Mattera is now eligible for consideration for the Entrepreneur Of The Year 2020 National Awards. Award winners in several national categories, as well as the Entrepreneur Of The Year National

Overall Award winner, will be announced 19 November, during a virtual awards gala. The awards are the culminating event of this year's virtual Strategic Growth

Forum, a gathering of high-growth, market-leading companies in the USA. The Entrepreneur Of The Year National Overall Award winner will then move on to compete for the EY World Entrepreneur Of The Year Award in June 2021.

Rockley closes \$50m growth funding round

Chief commercial officer appointment targets healthcare market

Rockley Photonics of Oxford, UK and Pasadena, CA, USA has closed an additional \$50m of growth funding from venture capital, strategic investors and institutional funds including Credit Suisse-backed SIG-i Capital and Applied Ventures LLC (the venture capital arm of Applied Materials Inc) as well as existing shareholders. Rockley has so far raised over \$225m of financing.

Rockley was formed in 2013 by a management team that has previously had success with two silicon photonics companies. Founder & CEO Andrew Rickman founded the first firm to commercialize silicon photonics, Bookham Technology (which had an IPO in 2000, became Oclaro in 2009 and is now a part of Lumentum), and later became chairman of Kotura (sold to Mellanox in 2013). Rockley has developed a highly versatile, third-generation application-specific silicon photonics platform designed for optical integration in next-generation sensor systems and communications networks.

"It is testament to the strength of our technology and emerging market

opportunities that we have attracted such a preeminent list of new investors to join many of our existing shareholders in this funding round," says Rickman. "This round provides the funding for Rockley as it moves into the next exciting growth phase and develops next-generation disruptive silicon photonics-powered healthcare and wellness sensors and communications products for its tier-1 customers," he adds.

CCO appointment targets healthcare market

Rockley has appointed Vafa Jamali as chief commercial officer (CCO), responsible for the firm's commercial strategy, driving business growth and market share. With over 25 years of experience in the medical device industry (most recently at



Medtronic), Jamali has extensive medical device knowledge across several specialties and patient conditions.

CCO Vafa Jamali.

"Our optical sensing chipsets, with their unique analytical capabilities, bring benchtop testing capabilities to healthcare and well-being markets within handheld and wearable devices," notes Rickman. "Vafa's extensive experience in the medical devices field will help to position Rockley for growth in this multi-billion-dollar, high-volume market."

Rockley developed its photonics platform to facilitate cost-effective volume manufacture of highly integrated optical/electronic devices. The platform enables both multiple healthcare and wellness applications in consumer sensors and applications in data communications and machine vision.

"Personalized monitoring of multiple biophysical and biochemical biomarkers will revolutionize the way we look after our health and well-being," reckons Jamali. "Rockley's technology is transformative," he adds.

In September, Rockley was recognized by The Sunday Times as one of the top 10 British tech companies to watch.

www.rockleyphotonics.com

II-VI wins Fujitsu Supplier Award for Optical Modules

Performance Review Program recognizes quality and delivery

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA (which supplies optical transceivers) has received the 2019 Supplier Award for Optical Modules from information technology equipment & services company Fujitsu Ltd of Tokyo, Japan.

Takashi Yamanishi, senior VP & head of Fujitsu's Global Supply Chain unit (who presented the award), recognizes "II-VI's outstanding results in our 2019 Suppliers' Performance Review Program, especially in the areas of

quality and delivery. We look forward to growing our partnership."

The award is a "testament to our strong execution and ability to deliver advanced transceivers at scale to a world-class equipment manufacturer that demands superior quality," says Dr Lee Xu, senior VP of II-VI's Transceivers business unit. "Our strong core competency in optoelectronics, together with our vertically integrated transceiver platform, our operational excellence and our close customer relationships, are the key factors that sustain our market leadership

in optical modules."

II-VI offers transceivers that are fully compliant with all the most widely deployed standards, including Ethernet, Fibre Channel, InfiniBand, SONET/SDH/OTN, CPRI, and PON. Operating at data rates in excess of 100Gbps and over extended voltage and temperature ranges while minimizing jitter, electromagnetic interference (EMI) and power dissipation, they range from very short to very long reaches, encompassing data-center, campus, access, metro and long-haul applications.

POET and Sanan IC to form Super Photonics Xiamen JV to offer optical engines for transceiver modules

POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — and Sanan Integrated Circuit Co Ltd of Xiamen City, Fujian province (a subsidiary of Sanan Optoelectronics Co Ltd, China's first 6" pure-play compound semiconductor wafer foundry) have signed a definitive joint venture contract and applied for the registration of Super Photonics Xiamen Co Ltd to offer a new generation of cost-effective, high-performance optical engines to transceiver module manufacturers, systems suppliers, data-center operators and network providers globally.

The venture has been capitalized with a commitment of cash and

manufacturing expertise from Sanan IC and intellectual property and design know-how from POET. Super Photonics will assemble, test, package and sell optical engines, a primary component of optical transceivers that transmit data between switches and servers in data centers and between data centers and metro areas. Modular pluggable transceivers represent a major portion of the capital spending for equipment by companies such as Google, Alibaba, Facebook, Tencent and others engaged in building hyperscale data centers.

"Sanan IC is dedicating significant capital and management talent to this new joint venture," says the firm's CEO Raymond Cai. "By combining Sanan IC's manufacturing capabilities and devices with POET's

advanced optical engine designs, Super Photonics will be able to offer highly attractive solutions to the data communications and telecommunications markets," he believes.

"Super Photonics is both the culmination of a long path for POET and the beginning of a new phase in our growth and development as a company," says POET's chairman & CEO Dr Suresh Venkatesan.

Super Photonics intends to design, manufacture and sell products for a variety of applications including optical engines for transceivers used in data centers and for the fiber-based segments of the 5G communications market (each among the highest-growth segments of the datacom and telecom markets).

www.sanan-ic.com

www.poet-technologies.com

POET readies Optical Interposer for production, in line with roadmap

POET has added several new features to its proprietary POET Optical Interposer platform and completed the design for products identified on its roadmap.

The new features include:

- waveguide designs and process integration methods that minimize reflections of laser light within the Optical Interposer platform;
- fiducials that better enable the sub-micron accuracy of automated pick-and-place assembly of lasers and other components mechanically placed on the platform;
- vertical mirrors that extend the platform applicability to top- and bottom-surface-access optical devices, such as top-entry photodetectors and vertical-cavity |surface-emitting lasers (VCSELs);
- improved spot-size converters that provide efficient coupling of lasers and modulators to waveguides (key for 400G and 800G optical engines);
- the latest generation of low-loss Mach-Zehnder interferometry (MZI)-based multiplexers embedded in

the waveguides; and

- newly developed IP to efficiently align fiber-attach-units (FAUs) to POET's optical engines.

"We have determined that the Optical Interposer platform is now production-ready," says president & general manager Vivek Rajgarhia. "We have proven out all of the features and production methods for the platform itself, including the flip-chip assembly and bonding steps for lasers, which has historically been the 'Achilles' Heel' for other approaches to optoelectronic integration. The basic platform features, now completed, apply to all of the products that we are engaged with customers to develop. The pre-alpha and alpha prototypes that are now being assembled differ primarily in the particular components included, and in most cases, those designs have been validated," he adds.

"The POET Optical Interposer platform is fully compatible with standard CMOS semiconductor processing methods and equipment,"

Rajgarhia continues. "It seamlessly incorporates the best features of a planar lightwave circuit (PLC), silicon optical benches (SiOB) and interposer functionality and is fabricated solely within the production limits of silicon-based semiconductor processing. In addition to being fundamental to lower-cost and the higher-performance value proposition of the Optical Interposer, the processing compatibility with CMOS opens up a variety of applications to POET that are simply not available using other integration approaches seen in the market today."

POET's product roadmap, presented in late August at its annual general meeting of shareholders, revealed four products under development, each associated with an individual customer or potential groups of customers. The firm reported that the 100/200G CWDM4 Optical Engine, the 400G LightBar, 400G FR4 Receiver, and the 400G FR4/DR Optical Engines all remain on schedule.

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Giving our customers the lead through mass production of high performance TCOs, metals and DBRs with the best cost of ownership is our daily business. However, leveraging our know how to help customers develop new more demanding processes or ramp up production of next generation Optoelectronic devices like Micro LED or OLED on CMOS is where we add value too, and in this edition of LAYERS you can also read about solutions we can offer for exactly that.

Stefan Seifried, Head of BU Optoelectronics

Marvell acquiring Inphi and shifting HQ to USA

Combination to provide end-to-end technology for cloud data-center and 5G infrastructure

Bermuda-based Marvell Technology Group Ltd (which provides semi-conductors for storage, processing, networking, security and connectivity infrastructure) and Inphi Corp of San Jose, CA, USA (a provider of high-speed mixed-signal ICs for communications, computing and data-center markets) have announced a definitive agreement, unanimously approved by the boards of directors of both companies, for Marvell to acquire Inphi for \$66 in cash and 2.323 shares of stock of the combined company for each Inphi share. Upon closing of the transaction, Marvell shareholders will own about 83% of the combined company and Inphi stockholders will own about 17%.

Marvell intends to finance the transaction with cash on hand, plus additional financing. The firm has obtained debt financing commitments from JPMorgan Chase Bank N.A. The transaction is not subject to any financing condition and is expected to close by second-half 2021, subject to the approval of Marvell shareholders and Inphi stockholders and the satisfaction of customary closing conditions (including applicable regulatory approvals).

In conjunction with the transaction, Marvell (whose US headquarters is in Santa Clara, CA) intends to reorganize so that the combined firm will be domiciled in the USA, creating a US-based firm with an enterprise value of about \$40bn.

Inphi has built a high-speed data interconnect platform that is claimed to be uniquely suited to meeting the demand for increased bandwidth and low power for future cloud data centers and global networks. Inphi's high-speed electro-optics portfolio provides the connectivity fabric for cloud data centers and wired and wireless carrier networks, just as Marvell's copper physical layer portfolio does for enterprise and future in-vehicle networks.

Combining Marvell's storage, networking, processor and security portfolio with Inphi's electro-optics interconnect platform aims to provide end-to-end technology for data infrastructure. It is reckoned that this complementary transaction will expand Marvell's addressable market (to \$23bn), strengthen its customer base, and enhance its position in hyperscale cloud data centers and 5G wireless infrastructure.

Machine learning and other data-driven workloads have expanded beyond the confines of the server and now span the entire cloud data center, making the software-defined data center the new computing paradigm, says the firms. This trend drives hyper-connectivity within the data center, putting electro-optical interconnects at the heart of the cloud architecture.

In addition, the need for bandwidth between data centers continues to grow rapidly. Combined with Internet traffic

growth and the rollout of new ultra-fast 5G wireless networks, the importance of Inphi's high-speed data interconnect solutions will only accelerate, it is reckoned. The combined company will be positioned to serve the data-

Combining Marvell's storage, networking, processor and security portfolio with Inphi's electro-optics interconnect platform aims to provide end-to-end technology for data infrastructure. This complementary transaction will expand Marvell's addressable market, strengthen its customer base, and enhance its position in hyperscale cloud data centers and 5G wireless infrastructure.

driven world, addressing high-growth end-markets — cloud data-center and 5G.

The combined scale should provide more resources and capabilities to continue to invest and better manage the rapidly ramping process technology costs. The transaction is expected to generate annual run-rate synergies of \$125m (to be realized within 18 months after the transaction closes) and is expected to become accretive to Marvell's non-GAAP earnings per share by the end of the first year after the transaction closes.

"Our acquisition of Inphi will fuel Marvell's leadership in the cloud and extend our 5G position over the next decade," reckons Marvell's president & CEO Matt Murphy. "Inphi's technologies are at the heart of cloud data-center networks and they continue to extend their leadership with innovative new products, including 400G data-center interconnect optical modules, which leverage their unique silicon photonics and DSP [digital signal processing] technologies. We believe that Inphi's growing presence with cloud customers will also lead to additional opportunities for Marvell's DPU and ASIC products," he adds.

"Marvell and Inphi share a vision to enable the world's data infrastructure and we have both transformed our respective businesses to benefit from the strong secular growth expected in the cloud data-center and 5G wireless markets" says Inphi's president & CEO Ford Tamer. "Combining with Marvell significantly increases our scale, accelerates our access to the next generations of process technology, and opens up new opportunities in 5G connectivity." Upon closing the transaction, Tamer will join Marvell's board of directors.

www.inphi.com
www.marvell.com

Verizon completes 400ZR trial using Inphi COLORZ II DWDM QSFP-DD optics

Leverages existing 100GbE IP-over-DWDM infrastructure deployed with COLORZ QSFP28

Inphi Corp of Santa Clara, CA, USA (a provider of high-speed mixed-signal ICs for communications, computing and data-center markets) and Verizon Media have validated a seamless upgrade from 100GbE QSFP28 optics, using Inphi's COLORZ, to 400GbE QSFP-DD over the same production open line system (OLS), using Inphi's COLORZ II. The demonstration consisted of adding a 400ZR from an Arista 400G switch into a 100GHz DWDM channel without affecting any of the existing 100GbE waves.

To build a better content delivery network, which brings rich high-quality media to millions of users, Verizon Media needs to connect super PoPs with low-latency and high-capacity DWDM interconnects. Verizon Media is advancing the disaggregation of optics, switching and optical line systems in preparation for a surge in data, driven by cloud, HD video and 5G applications.

COLORZ is said to be the first silicon photonics 100G PAM4 platform solution for 80km DWDM data-center interconnects (DCIs) in QSFP28 form factor. Utilizing pulse amplitude modulation (PAM4) signaling, COLORZ delivers up to 4Tb/s of bandwidth over a single fiber and

allows multiple data centers located up to 80km from each other to be connected and act like a single data center.

COLORZ II is claimed to be the first 400ZR QSFP-DD pluggable coherent transceiver for cloud DCIs to major cloud operators and OEMs. It enables large cloud operators to connect metro data centers at a fraction of the cost of traditional coherent transport systems and allows switch and router companies to offer the same density for both coherent DWDM and client optics in the same chassis. This eliminates a layer of network connectivity that was previously required and supports high-capacity DWDM connectivity directly from data-center switches.

Both generations of Inphi's COLORZ optics enable data-center connectivity directly from any switch or router port, allowing for the same density as client optics, while accelerating the paradigm shift to IPoDWDM. Leveraging existing 100GHz optical line systems, COLORZ II increases fiber capacity from 4Tb/s to 16Tb/s while further lowering power and cost per bit.

"To ensure our CDN [content delivery network] remains ready for the web of tomorrow, we must

constantly stay at the leading edge of technology to ensure efficiency and scalability of our network while remaining price competitive," says Verizon Media's principal infrastructure architect Nitin Batta. "For this reason, the scalability and roadmap offered by COLORZ products will allow us to add terabytes of capacity in response to customer demands."

Both Inphi's COLORZ optical platforms use a single silicon photonics integrated circuit technology for all transmit and received functions. With strong market adoption of over 100,000 units COLORZ deployed, COLORZ II will further benefit from strong industry support with a multi-vendor ecosystem and a well-accepted interoperable 400ZR standard, reckons Inphi.

"As data-center network traffic continues to grow exponentially, it is critical for infrastructure suppliers to continue providing innovative scalable solutions," says Tomas Maj, senior director, marketing, Optical Interconnect at Inphi. "COLORZ products continue to open new possibilities for DCI total cost of ownership reductions, while providing a seamless upgrade path to 400G."

www.inphi.com/products/colorz

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NeoPhotonics consolidating InP production and cutting staffing by 4%

Growth drivers to include 64/96Gbaud and 400ZR products

NeoPhotonics Corp of San Jose, CA, USA — a vertically integrated designer and manufacturer of silicon photonics and hybrid photonic integrated circuit (PIC)-based lasers, modules and subsystems for high-speed communications — has announced preliminary results for third-quarter 2020, incorporating changes made to better align the firm's infrastructure and more efficiently manage its cost structure.

As announced at the end of August, the firm has adopted a conservative approach to exclude from its outlook any future contributions from China-based Huawei Technologies, following 17 August's tightening of restrictions on export license requirements by the US Department of Commerce's Bureau of Industry and Security (BIS).

"Our actions better align our capacity and production infrastructure with expected demand levels, and accelerate our goal of returning to profitability," says chairman & CEO Tim Jenks. "We are maintaining our focus on developing products for next-generation coherent systems and modules, wherein our silicon photonics, lasers and advanced hybrid photonic integration technologies provide the highest value, fully supporting our

expansion into the data-center market with coherent products. We are increasingly optimistic about our ability to drive growth both in the near-term with our 64Gbaud solutions and in the mid-term with 96Gbaud solutions and as our 400ZR products ramp in mid-2021," he adds. "With these changes, we continue to pursue growth opportunities and deploy our best-in-class products and solutions for the highest speed over distance applications, and with a more diverse customer set."

NeoPhotonics has taken steps to tighten production operations, account for Huawei-specific assets and inventory, consolidate indium phosphide (InP) production and implement an approximately 4% reduction in force. The costs to implement these changes are expected to be \$12.1m, with \$1.1m in severance costs and \$11m in inventory and idle asset charges. The firm expects to incur \$10.7m of these costs in Q3/2020, \$0.7m in Q4/2020, and the remainder as accelerated depreciation charges through 2021.

The actions taken are expected to reduce expenses with immediate impact and achieve a reduction in quarterly operating expense of

about \$2m when fully implemented by Q2/2021, in addition to reductions in cost of goods sold (COGS). As a result, the firm expects to lower its revenue breakeven level and to return to non-GAAP profitability in Q3/2021 and GAAP profitability in Q4/2021.

Given these changes, NeoPhotonics also provided preliminary estimated financial results for Q3/2020, with non-GAAP results in the upper end of the previous guidance ranges given in early August. Specifically, revenue should be \$101–103m (rather than \$97–105m), gross margin should be 32–34% (rather than 30–34%) and earnings per share are expected to be \$0.10–0.14 (rather than \$0.03–0.13).

This non-GAAP outlook for Q3/2020 excludes the impact of expected severance and asset write-down charges of \$10.7m, amortization of acquisition related intangibles and other costs of about \$0.3m, and the anticipated impact of stock-based compensation of about \$3.5m, of which \$0.7m is estimated for cost of goods sold.

As of end-September 2020, NeoPhotonics' cash, cash equivalents and restricted cash totaled about \$120m.

www.neophotonics.com

Emcore's September-quarter revenue to exceed guidance

MSOs ramped up investments, driving greater-than-expected growth in Broadband

In preliminary financial results for its fiscal fourth-quarter 2020 (to end-September), Emcore Corp of Alhambra, CA, USA — which provides mixed-signal products for the aerospace & defense and broadband communications markets — says that it expects revenue of about \$33.5m, exceeding its guidance range (given in mid-August) of \$29–31m.

"MSOs [multi-service operators] ramped up their investments to break network bottlenecks, driving greater-than-anticipated growth in our Broadband business. L-EML [linear externally modulated laser] transmitter shipments were particularly strong, demonstrating the unique value of this product," notes president & CEO Jeff Rittichier. "Revenue for QMEMS [quartz

micro-electro-mechanical system] and Defense Optoelectronic products within our Aerospace & Defense segment also exceeded our expectations," he adds. "Looking ahead, we see the robust order book for our cable TV products extending through the March 2021 quarter."

Emcore will provide final fiscal Q4 results by 30 November.

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100G Lambda MSA releases 400G spec for 10km of single-mode fiber

Consortium members address market demand for 10km spec

The 100G Lambda Multi-Source Agreement (MSA) Group, which has rapidly grown to include 45 member companies, has released a 400 Gigabit Ethernet (GbE) specification up to 10km based on 100Gb/s-per-wavelength 4-level pulse amplitude modulation (PAM4) optical technology. This specification is targeting applications for data centers and service provider networks, enabling multi-vendor interoperability for optical transceivers produced by different manufacturers and in various form factors. The new 400GbE specification is designated as 400G-LR4-10 for duplex single-mode links up to 10km and relies on multiplexing four wavelengths of 100Gb/s PAM4 modulated optical signals.

Building on its previously published and broadly adopted specifications, the MSA members developed the 400GbE specification to fully address market requirements for 2-10km reaches over duplex single-mode for both 100GbE and 400GbE. The MSA believes that the 10km-reach specification will be fully interoperable with the 6km version being

developed by another industry standards group. The nomenclature use of '-10' in 400G-LR4-10 will inform users of the target reach.

"Industry organizations are valued for producing rigorous specifications assuring reliable, interoperable communications," remarks Dale Murray, principal analyst for LightCounting Market Research. "The 100G Lambda MSA members were able to, again, quickly identify the market requirements and build on their earlier work to extend it to meet the market need for a full 10km specification at 400G," he comments.

"The MSA received feedback from the industry of a strong need for a 400GbE 10km specification to be available and the MSA has worked hard to provide specifications to enable interoperable products to meet this demand," says 100G Lambda MSA co-chair Mark Nowell.

"Maintaining consistency and interoperability with industry standard's progression has always been a target for the MSA members," adds co-chair Jeffery Maki. "With this updated specification we continue to support the industry's

needs to make specifications available in a timely manner," he adds.

The 100G Lambda MSA Group says that it is going to continue its work by next addressing extended-reach specifications beyond 10km.

The 100G Lambda MSA Group member companies are: II-VI, Alibaba, Applied OptoElectronics, Arista, Broadcom, Cambridge Industries Group, China Unicom, Ciena, Cisco Systems, Color Chip, Credo, Delta, Eoptolink, Fujitsu Optical Components, HG Genuine, HiSense, HiSilicon, IDT, Innolight, Inphi, Intel, Juniper Networks, Keysight Technologies, Lightwave Logic, Lumentum, MACOM, Maxim, Maxlinear, Mellanox, Microsoft, Mitsubishi Electric, Molex, Multi-Lane, Neophotonics, Nokia, Panduit, Rockley Photonics, Semtech, Sicoya, SiFotonics Technologies, Source Photonics, Sumitomo Electric, TE Connectivity, TFC Optical Communication, Tektronix and ZTE. Companies are invited to join the consortium as Contributor members.

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Acacia sampling 100G coherent DWDM pluggable

Before the SCTE ISBE Cable-Tec Expo 2020 (which took place virtually, 12–16 October), Acacia Communications Inc of Maynard, MA, USA (which develops and makes high-speed coherent optical interconnect products) sampled a new 100G coherent dense wavelength division multiplexing (DWDM) pluggable module designed to help service providers, carriers and cable operators meet bandwidth demand in edge and access networks.

Offered in QSFP-DD form factor, Acacia's new 100G coherent DWDM module was designed to provide a scalable traffic aggregation solution, as well as an upgrade path to migrate from existing 10G WDM networks to higher-performing 100G DWDM coherent links for new architectures in access networks, such as cable/fiber deep and 5G wireless X-haul applications.

"As with our recently announced 100G point-to-point (P2P) solutions, Acacia is working to satisfy the

requirements of service provider edge and access applications with coherent solutions designed for this market," says director of product management Anuj Malik. "The benefits of coherent have been demonstrated in the metro, long-haul and submarine markets and, with these new products, Acacia is looking to deliver the same scalability, operational simplicity and improved total cost of ownership to the edge and access space," he adds.

"The edge of the network is evolving, and we're bringing new solutions to market designed to provide scale and ease of use for new applications around IoT and edge computing," says Jörg-Peter Elbers, senior VP of advanced technology at optical network equipment maker ADVA. "As service providers upgrade their access and aggregation infrastructure, it is only a matter of time before coherent technologies make inroads in this space. Acacia has been a leading

provider of pluggable coherent optics, and their latest innovation provides interesting possibilities," he comments.

Acacia's pluggable coherent solutions in QSFP-DD were designed to enable network scalability to 200G and 400G versions in the future.

Acacia's new 100G coherent DWDM module leverages Acacia's 3D Siliconization approach, which utilizes high-volume manufacturing processes and benefits from the maturity of Acacia's silicon photonics technology.

Acacia's 100G coherent point-to-point and DWDM pluggable solutions were designed to meet the form factor, low power consumption and cost requirements that edge and access providers need to scale their networks in the future. Acacia says that these innovations have been made possible through its expertise in silicon photonics and low-power DSPs.

www.acacia-inc.com

Sampling 100G coherent bi-directional CFP2-DCO pluggable modules

Acacia is sampling new coherent bi-directional pluggable optical modules designed to transmit and receive data in both directions on a single fiber for 100G and beyond.

Offered in a pluggable CFP2-DCO form factor, the new coherent bi-directional module is designed to deliver an operationally efficient and cost-effective way for telecom and cable operators to increase capacity in fiber-limited networks.

"With the addition of this coherent bi-directional solution to our recently announced 100G point-to-point and DWDM coherent solutions, Acacia is now able to offer a portfolio of products to address a wide variety of requirements in the edge and access market," says VP of product line management Fenghai Liu. "In fiber-limited networks, optical waves are transmitted in a single fiber medium from both directions. In these networks,

coherent receivers can efficiently help to eliminate the crosstalk from back reflections when it operates at a different wavelength than its transmitter. Acacia's coherent bi-directional CFP2-DCO module is purpose-built for these applications."

In cable networks, particularly Remote PHY and fiber deep applications, providers often run into situations where only a single fiber is available, says Acacia. Historically, these networks have been served by 10G bi-directional optical modules. To meet growing bandwidth demands, a coherent bi-directional solution can provide these networks with an upgrade path to 100G and beyond. When wireless networks are migrating from 4G LTE to 5G, fibers are more often constrained because of a large number of remote nodes and some fibers are utilized by existing

services. In these instances, coherent bi-directional modules can alleviate both bandwidth and fiber constraints.

"Signal AI recognized an opportunity for 100G coherent in the edge and access market back in 2018, and Acacia is the first to aggressively pursue it," comments Scott Wilkinson, lead analyst at market research firm Signal AI. "The time is right for network operators, such as cable MSOs, to bring coherent technology to their fiber-constrained networks, where Acacia's bi-directional module can help them increase capacity."

The new coherent bi-directional pluggable solutions, with two independent full-tunable laser sources, leverage Acacia's 3D Siliconization approach, which utilizes high-volume manufacturing processes and benefits from the maturity of the firm's silicon photonics technology.

First Solar's Series 6 is first PV module to be EPEAT-rated

The Green Electronics Council (GEC) has announced that the Series 6 cadmium telluride (CdTe) photovoltaic (PV) module, designed and manufactured by First Solar Inc of Tempe, AZ, USA, is the world's first PV product to be included in the launch of the EPEAT Photovoltaic and Inverters product category.

EPEAT (Electronic Product Environmental Assessment Tool) is said to be the leading life-cycle based Type-1 ecolabel used by public and private sector institutional purchasers globally. To be the first PV product included in the new EPEAT PV Modules and Inverters category, First Solar Series 6 sustainability benefits have been verified by a reputable third-party international certification firm.

The EPEAT ecolabel allows easy identification of credible sustainable electronic products from a broad range of manufacturers, and the online EPEAT Registry lists those products. Designed to help institutional purchasers, EPEAT is used by national governments (including the USA) and thousands of private-sector institutional purchasers worldwide as part of their sustainable procurement decisions. The GEC, which manages EPEAT and ensures its integrity, has launched the new EPEAT PV modules and Inverters product category in recognition of the tremendous growth of the solar sector.

"The EPEAT PV Modules and Inverters category provides those tasked with buying renewable

energy the means to specify that the hardware used is truly sustainable," says GEC CEO Nancy Gillis. "First Solar is leading the solar industry towards more sustainable practices by becoming the first PV module manufacturer to have its products included in the EPEAT Registry, giving its customers confidence that they are purchasing an environmentally leading product from a socially responsible company."

Series 6 was awarded an EPEAT Silver rating, certifying that it has exceeded the required stringent environmental and social criteria of a Bronze rating. "By launching at the Silver tier, First Solar has shown their commitment to sustainability," says Gillis. "GEC calls upon the other PV module manufacturers to follow their lead."

EPEAT addresses the full product life-cycle, including managing substances in the product, manufacturing energy and water use, product packaging, end-of-life recycling, and corporate responsibility. EPEAT also requires manufacturers to commit to continuous improvement in environmental and social responsibility, including labor and

The PV industry has historically lacked a comprehensive, credible and transparent standard to certify manufacturers' environmental and sustainability claims

human rights, across their operations and supply chain. This helps to ensure that PV modules and inverters, and their components, are not produced using forced labor and that fair and safe labor practices are adhered to.

"With solar PV expected to be the fastest-growing renewable energy technology from now to 2050, the sector has a collective responsibility to ensure that today's clean energy solutions are certifiably sustainable. However, the PV industry has historically lacked a comprehensive, credible and transparent standard to certify manufacturers' environmental and sustainability claims," says Andreas Wade, First Solar's director, Global Sustainability. "The EPEAT ecolabel effectively addresses this gap, creating a stringent industry standard that will help purchasers evaluate the lifecycle impact of a PV module."

Designed and developed at First Solar's R&D centers in California and Ohio, the Series 6 PV module is claimed to set industry benchmarks for quality, durability, reliability, design and environmental performance. With a carbon footprint that is up to six times lower and a water footprint that is up to 24 times lower than crystalline silicon PV panels manufactured using conventional, energy-intensive production methods, Series 6 is said to deliver a superior environmental profile and the lowest-carbon solar available. www.greenelectronicscouncil.org

869MW of Series 6 modules for Vistra's utility-scale projects in Texas

Vistra Corp has selected First Solar's CdTe solar modules to power its six recently announced solar energy projects across Texas. First Solar will supply 869MW_{DC} of Series 6 modules to power five utility-scale solar projects, developed by Vistra, ranging from 50MW_{AC} to 200MW_{AC}.

Based in Irving, Texas, Vistra is the largest competitive residential electricity provider and largest

competitive power generator in the USA, with a diverse generation portfolio of about 39,000MW.

"We're committed to transforming our power generation portfolio, investing in renewables, and providing our customers with the power solutions they are seeking to meet their sustainability objectives," says Vistra's chief operating officer Jim Burke. "We're proud to

take that commitment a step further by investing in powering our newest renewable energy generation assets with the leading solar technology available today," he adds. "Series 6 is the right module and First Solar is the right partner to help us deliver our mission to net-zero."

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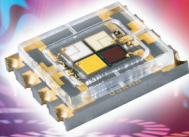


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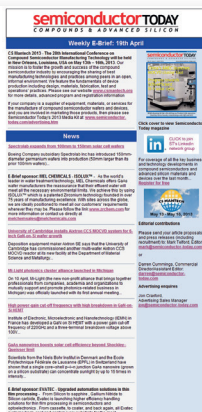


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ZSW, MLU and HZB pinpoint losses in CIGS solar cells

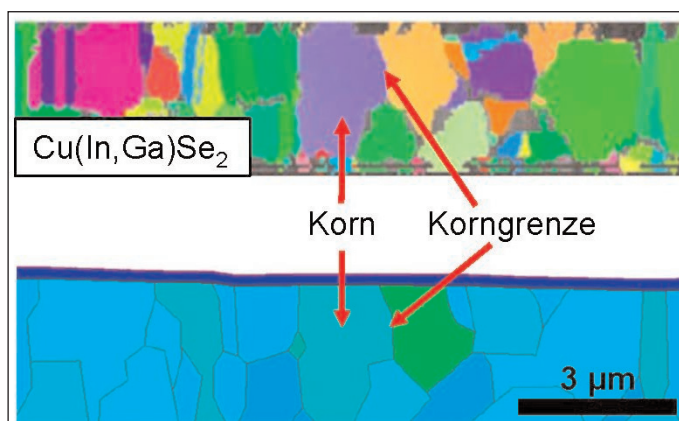
Larger grains & reduced grain boundary density could boost efficiency

Copper indium gallium diselenide (CIGS) thin-film solar cell efficiency has already exceeded 23%, but now a further increase looks to be within reach. A team at Germany's ZSW (Zentrum für Sonnenenergie- und Wasserstoff-Forschung — or Center for Solar Energy and Hydrogen Research — Baden-Württemberg), Martin Luther University Halle-Wittenberg (MLU) and the Helmholtz-Zentrum Berlin (HZB) recently identified a key point where the performance of thin-film solar cells can be improved for the cell to convert more sunlight into electricity (Maximilian Krause et al, 'Microscopic origins of performance losses in highly efficient Cu(In,Ga)Se₂ thin-film solar cells', Nature Communications 11 (2020) 4189). The results of this investigation reveal how manufacturers of CIGS thin-film solar cells can achieve even higher efficiencies, it is reckoned.

Strides have been made in recent years towards CIGS thin-film solar cells' maximum theoretical efficiency of about 33%, but around ten percentage points of potential remains untapped. This shortfall is attributable to loss mechanisms in the CIGS solar cell in the functional layers and at diverse interfaces. Where exactly and why these losses occur has been a point of conjecture and the subject of much debate.

Reducing the density of electrically active grain boundaries boosts performance

ZSW, MLU and HZB have now learned more about their origins. "Some of the losses occur at the boundaries between the individual CIGS crystals in the solar cell," says project manager Dr Wolfram Witte at ZSW. "Positive and negative electrical charges can neutralize each other at these grain boundaries, some of which are electrically active," he adds. "This reduces the cell's performance."



Top image depicts measured grain structure of the CIGS solar cell produced at ZSW, with colors indicating the grains' different crystallographic orientations. Bottom image shows the two-dimensional simulation based on these measurements. Artwork: ZSW, based on illustrations in Nature Communications.

Researchers were able to identify this type of loss mechanism by combining experimental measurement methods with computer simulations. HZB analyzed a highly efficient CIGS solar cell with various electron microscopy techniques and optoelectronic measuring methods such as photoluminescence to provide realistic values to the two-dimensional device simulation developed at MLU.

ZSW manufactured the CIGS cell in a co-evaporation process that deposits copper, indium, gallium and selenium simultaneously in a vacuum. The cell's efficiency was 21% without an additional anti-reflective layer. The physical microstructure of this cell and the values obtained in experiments with various analytical methods served as the input parameters for two-dimensional simulations.

Computer simulations showed that increased recombination at electrically active grain boundaries within the CIGS layer constitutes a significant loss mechanism. Above all, this decreases the open-circuit voltage and fill factor, which reduces the cell's efficiency.

"What needs to be done to further improve the efficiency of CIGS

thin-film solar cells and modules is to reduce the density of the electrically active grain boundaries and produce CIGS layers with larger grains," says Witte. This could be achieved with technical means, for example, by augmenting the CIGS layer with additives, adapting the substrate material or optimizing the temperature balance during coating.

These would be

promising points of departure for the photovoltaic industry's efforts to raise the efficiency of CIGS modules, it is reckoned.

EFFCIS project

The findings described in Nature Communications comprised one of several partial results obtained in the joint project EFFCIS. Funded by Germany's BMWi (Bundesministerium für Wirtschaft und Energie, the Federal Ministry for Economic Affairs and Energy), this research venture ended in 2020 after three and a half years. Nine partners teamed up in a consortium that had experts from research institutes, universities and industry working together under the leadership of the ZSW. Their efforts focused on localizing and learning more about the dominant loss mechanisms in CIGS thin-film solar cells and modules to then reduce or eliminate these losses with innovative measures. The partners used analytical tools with high temporal and spatial resolutions to determine the chemical and physical properties of the functional layers and interfaces in CIGS solar cells.

www.nature.com/articles/s41467-020-17507-8

www.zsw-bw.de

Midsummer's solar cells trialed on side of hybrid truck trailer

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) — is participating in a development project (partially financed by Sweden's innovation agency Vinnova) in which its solar panels are installed on truck trailer made by Swedish commercial vehicle manufacturer Scania. The objective is to investigate how much the electricity generation from the solar panels can extend the range of a hybrid truck and ultimately both save fuel and reduce carbon dioxide emissions.

Measurements will also be made whether the trailer can feed electricity into the grid when not running. Theoretical calculations by the University of Uppsala indicate fuel savings of 5–10% in Sweden and 10–20% in Malaga, Spain.

"Our technology has previously successfully powered electrical vehicles such as buses and smaller



vehicles," says CEO Sven Lindström. "It is promising that project calculations indicate good possibilities for actual fuel savings. Our type of flexible and thin-film solar cells is necessary to drive the development in the direction that the automotive industry needs to take in order to reach global climate goals," he adds.

"Being able to power our trucks with solar energy would be a massive breakthrough for the truck industry," believes Eric Falkgrim,

technology leader in Vehicle Design, Scania R&D.

Commercial trials will run throughout 2021. In June, Vinnova announced funding of SEK8.3m (US\$0.93m) for phase 2 of the project and that the participants had also committed to financing the project.

As well as Midsummer and Scania, participants include the University of Uppsala (project manager); Eksjö Maskin & Truck (constructor of the trailer); Ernst Express (commercial operator of the truck and trailer); and Dalakraft (contributing competence and project management for safe and sustainable energy transfer).

www.scania.com

www.vinnova.se/en

www.midsummer.se

Midsummer and Rollgum team on solar roofs for the Iberian peninsula

Letter of intent signed to supply commercial customers in Spain, Portugal and Andorra

Midsummer and Spanish single-ply membrane roofing supplier Rollgum Corp have signed a letter of intent to provide solar integrated roofs to commercial customers in Spain, Portugal and Andorra.

Rollgum is the official and exclusive distributor in Spain, Portugal and Andorra of Firestone Building Products, which include a range of sustainable building and roofing products. One of them is the UltraPly TPO roofing solution, a single-ply roofing membrane that is suitable for a wide range of building types.

Through the new collaboration, customers on the Iberian peninsula can install a TPO membrane roof integrated with Midsummer's lightweight, no-perforation and flexible thin-film solar panels.

"As the leading supplier of advanced roofing solutions in Spain and Portugal, we are always looking at new innovative solutions for our growing customer base," says Rollgum's founder & manager Joan Palou.

"Our range of thin-film solar panels is really the only practical solution for the many membrane roofs

that cover factories, warehouses, shopping malls and other commercial buildings since traditional framed silicon panels are simply too heavy for these types of roofs," claims Midsummer's CEO Sven Lindström. "A building-integrated photovoltaic roof will produce electricity for cooling, heating or powering whatever operations takes place in the building in question and can also be fed into the electrical grid if not used, rendering the roof structurally, economically and environmentally sound."

www.midsummer.se

Large-area liquid-phase indium–V growth on SiO₂

Hall measurements give mobility values comparable to epitaxial material.

University of Southern California Los Angeles and NASA Jet Propulsion Laboratory in the USA have produced single-crystal indium arsenide (InAs) and indium phosphide (InP) structures on amorphous silicon dioxide (SiO₂) using a direct templated liquid phase (TLP) growth process [Jun Tao et al, Appl. Phys. Lett., vol117, p042103, 2020]. The area of the structures exceeded 1500µm². The linear dimensions were up to 100µm. Previous work using TLP had been restricted to less than 10µm sizes.

The new work allowed Hall measurement structures to be created, which showed room-temperature mobility of TLP InAs reaching 3200cm²/V-s. The researchers comment: “The excellent electronic performance is due to the single crystallinity of the grown material and creates new avenues for the monolithic direct integ-

ration of high-performance materials on non-epitaxial substrates, including silicon, and amorphous substrates, such as glasses and metals.” The team sees the TLP process as a viable alternative to chip bonding or vapor phase epitaxy methods of heterogeneous integration.

The III–V material growth was prepared by creating a patterned mesa region of indium metal on 5nm molybdenum oxide (MoO_x) buffer and with a silicon dioxide (SiO₂) cap. The patterning was achieved by lithography, evaporation and lift-off techniques. The substrate was a thermal SiO₂ layer on silicon carrier.

The III–V growth process was carried out in a single-zone tube furnace. The indium was heated to the point of melting, while maintaining its shape. The V precursor was in the form of hydride gas — arsine (AsH₃) or

Figure 1.
(a) Overview of large-area TLP growth. (b) (i)–(vi) Representative gray-scale optical microscope (OM) images of different stages of growth of InP in Hall-element geometry. (c) (i)–(vi) EBSD maps indicating single crystallinity.

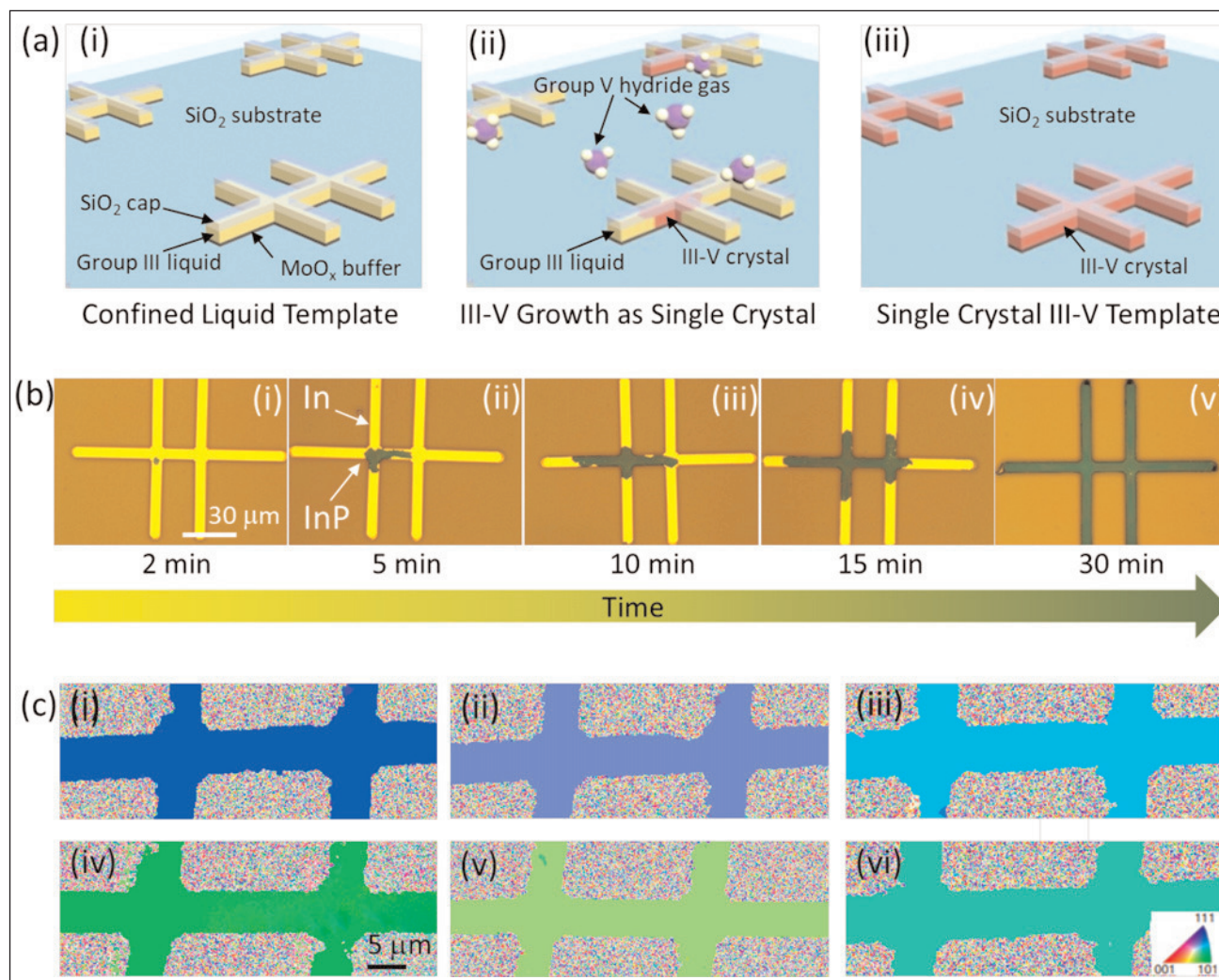


Figure 2. Hall mobility and sheet resistance of TLP InAs, (a, b, respectively) and InP (c, d).

phosphine (PH_3) — in hydrogen carrier. The precursor flow was controlled to maintain just enough supersaturation to initiate and precipitate a single crystal of In-V material within a single mesa.

The researchers explain: “Once the first nucleation event happens in a single connected pool of indium, the balance between the rate of growth at that temperature and the rate of nucleation determined by group V flux and diffusion of the group V species in liquid group III metal leads to the growth of the first nucleation and prevents another nucleation in the same mesa.”

The crystallinity of the grown material was analyzed using electron backscatter diffraction (EBSD) mapping. The maps indicated a single out-of-plane crystal orientation

through a color code. The resolution is limited by the electron spot size.

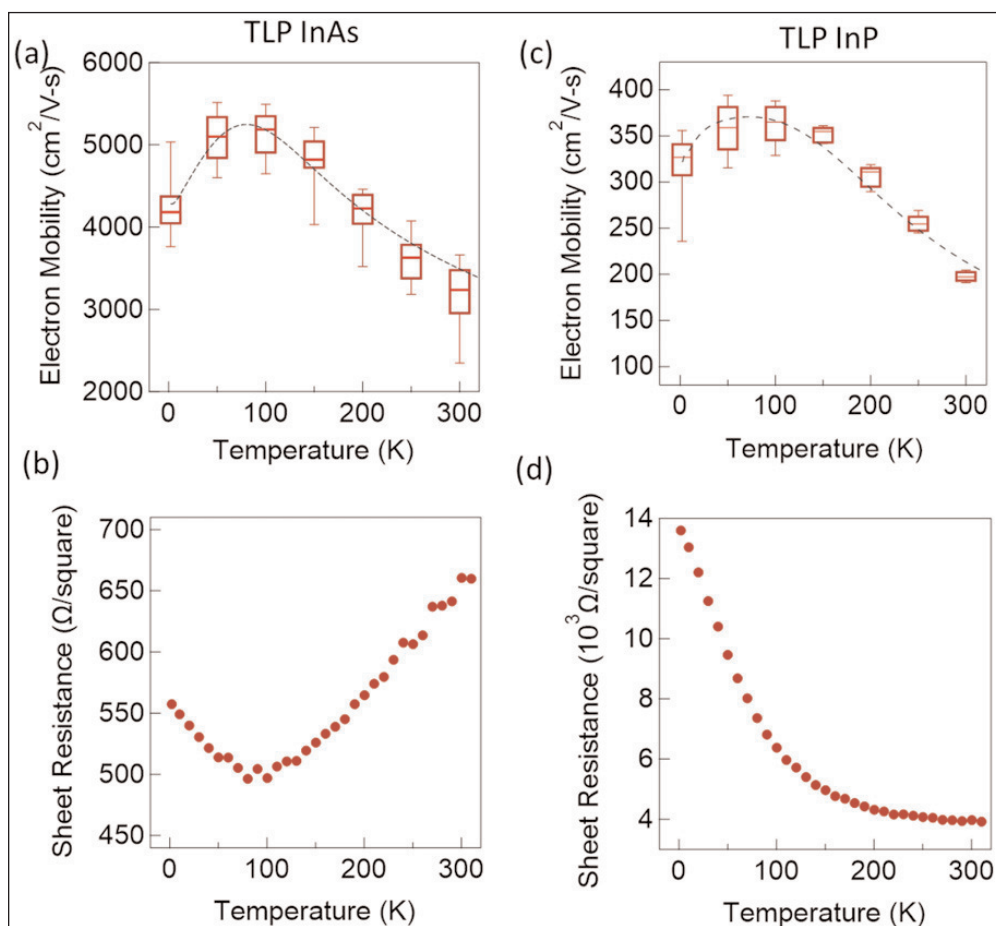
Photoluminescence spectra obtained from TLP InP material showed a main peak at 1.34eV, which is the same as for commercial InP substrates. The full width at half maximum of the TLP material was only marginally larger than for commercial InP. The difference is described as “negligible” by the team.

Raman analysis of TLP InAs showed wavenumber shifts of 218.4/cm and 239.5/cm, corresponding to transverse (TO) and longitudinal (LO) optical phonon emissions in bulk InAs of 218/cm and 239/cm, respectively.

The technique was used to grow elements for Hall measurements. The initial indium layer was 225nm, which controlled the eventual In-V material thickness. The length and width of the structures were 100 μm and 5 μm , respectively.

The TLP growth was found to result in extraneous ‘side-growth’ of III-V material through a vapor phase process. This unwanted fuzz was removed using plasma etching, using the SiO_2 cap as a mask. The etching thus reduced surface roughness scattering from the sidewalls in subsequent electron transport analysis.

The final preparation for van der Pauw Hall measurements was to remove the SiO_2 cap, using wet or dry etching, and to deposit patterned annealed nickel/gold electrodes.



The peak median mobility for InAs was registered around 100K at $5100\text{cm}^2/\text{V}\cdot\text{s}$ (Figure 2). The room-temperature (300K) result was a respectable $3200\text{cm}^2/\text{V}\cdot\text{s}$. The peak at 100K is seen as being consistent with surface roughness scattering rather than a grain boundary impact on mobility, confirming the single-crystal nature of the material. A similar peak is found with epitaxially grown material.

The background carrier concentration was around $1 \times 10^{17}/\text{cm}^3$. The researchers used an electron-beam deposition process for the SiO_2 cap, resulting in non-stoichiometric material with a silicon excess that could diffuse into the In-V crystal structure and provide unintentional n-type doping.

The mobility measurements for InP were lower with a peak of $370\text{cm}^2/\text{V}\cdot\text{s}$ at 100K, and $200\text{cm}^2/\text{V}\cdot\text{s}$ at 300K. The similarity in the curve shape is again seen as being limited by surface roughness scattering and indicative of single crystallinity.

The researchers comment: “Temperature-dependent mobility characteristics indicate that the grown materials are of comparable crystalline quality to that of epitaxially grown thin films. Importantly, this demonstration potentially opens up an avenue to integrate high-performance electronic and optoelectronic III-V devices on inexpensive amorphous substrates.” ■

<https://doi.org/10.1063/5.0006954>

Author: Mike Cooke

Boron strain therapy for high-indium-content InGaAs layers

Researchers achieve the longest near-infrared PL wavelength so far of 1.4 μm

University of Texas at Austin in the USA has claimed the longest photoluminescence (PL) wavelength achieved so far of 1.4 μm in the near infrared (NIR) for boron gallium indium arsenide (BGaInAs) along with electroluminescence (EL) experiments emitting close to the same wavelength region [R. H. El-Jaroudi, *Appl. Phys. Lett.*, vol117, p021102, 2020]. The 1.3 μm wavelength is particularly interesting for fiber-optic data transmission, along with light detection & ranging (LiDAR) and face-recognition technologies.

Vertical-cavity surface-emitting lasers (VCSELs) and related devices are a much desired technology for this range, but are limited in performance due to the difficulty in producing suitable light-emitting active layers.

A particular problem is that high-indium-content InGaAs is compressively strained relative to the surrounding GaAs and aluminium gallium arsenide (AlGaAs) used to achieve carrier injection and distributed Bragg reflectors (DBRs), along with the GaAs substrate base.

Attempts have been made to modify the InGaAs layer to reduce strain effects such as using quantum dots or nitrogen incorporation (InGaNAs). The quantum dot approach suffers from low modulation bandwidth, and nitrogen substitution is hard to achieve effectively.

The Texas/Austin team comments: "The advantage of dilute borides over the dilute nitrides is a predicted higher solid solubility of boron than nitrogen, enabling higher incorporation and simplified growth of dilute-boride alloys compared to nitride alloys."

However, boron-V semiconductors ('boron pnictides') are also difficult to realize, since they have higher melting points than other compounds in the III-V family. Up to now, demonstrated BGaInAs PL emission has peaked at less than 1.2 μm wavelength.

The researchers used solid-source molecular beam epitaxy (MBE) to produce BGaInAs heterostructures on (100) on-axis semi-insulating GaAs substrate at 380 $^{\circ}\text{C}$. The arsenic flux came from a valved cracker system. The gallium and indium were produced by effusion cells.

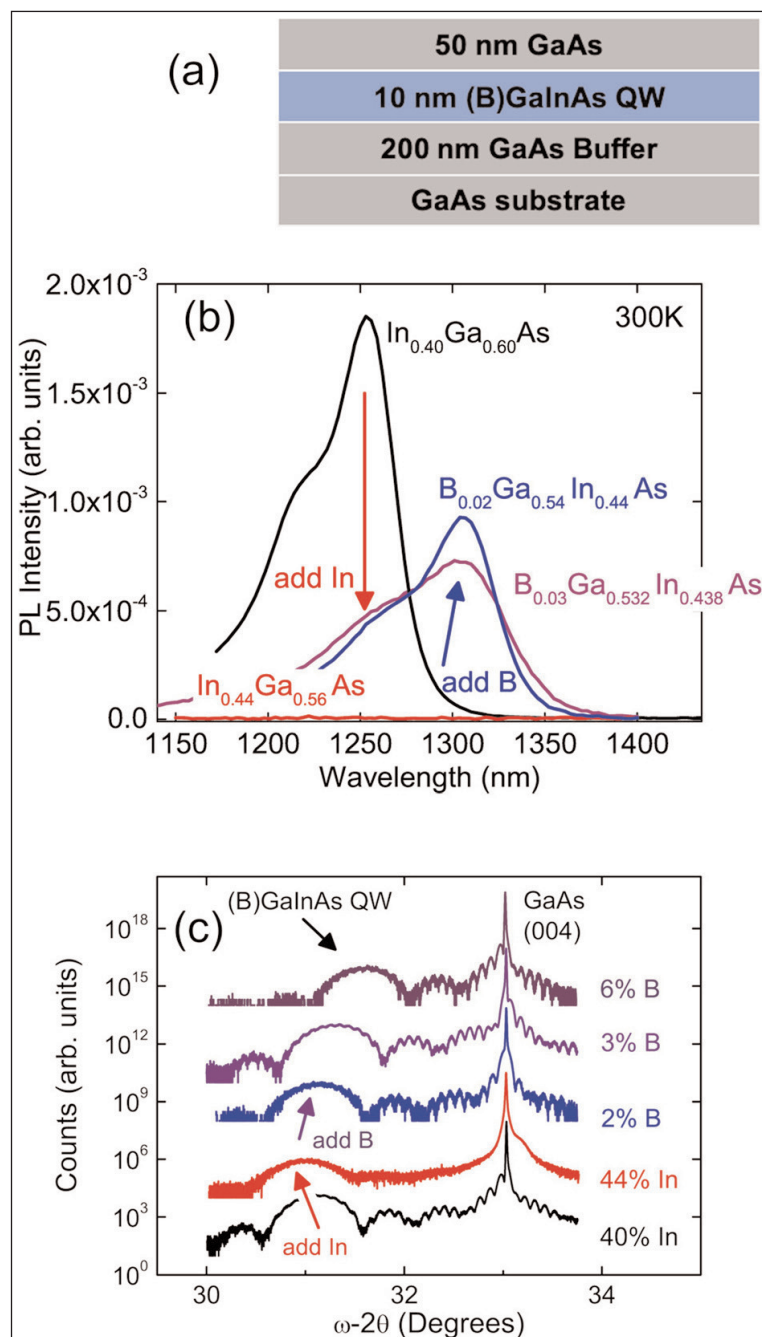


Figure 1. (a) Layer structure of (B)GaInAs PL samples. (b) PL of the (B)GaInAs QWs on GaAs, targeting 1.3 μm . (c) High-resolution x-ray diffraction (HR-XRD) of (B)GaInAs QWs on GaAs.

Figure 2. (a) EL structure with BGaInAs QW active region. (b) Light output versus input current (L-I) curve and (c) emission spectrum at 0.5kA/cm² current density.

The boron was evaporated using an electron-beam system with the flux controlled by the input power. One drawback of this was that it inhibited the use of reflection high-energy electron diffraction (RHEED) for in-situ process monitoring. However, when the boron flux was completed, the researchers did observe the hoped-for 'streaky' RHEED patterns indicative of a two-dimensional growth mode.

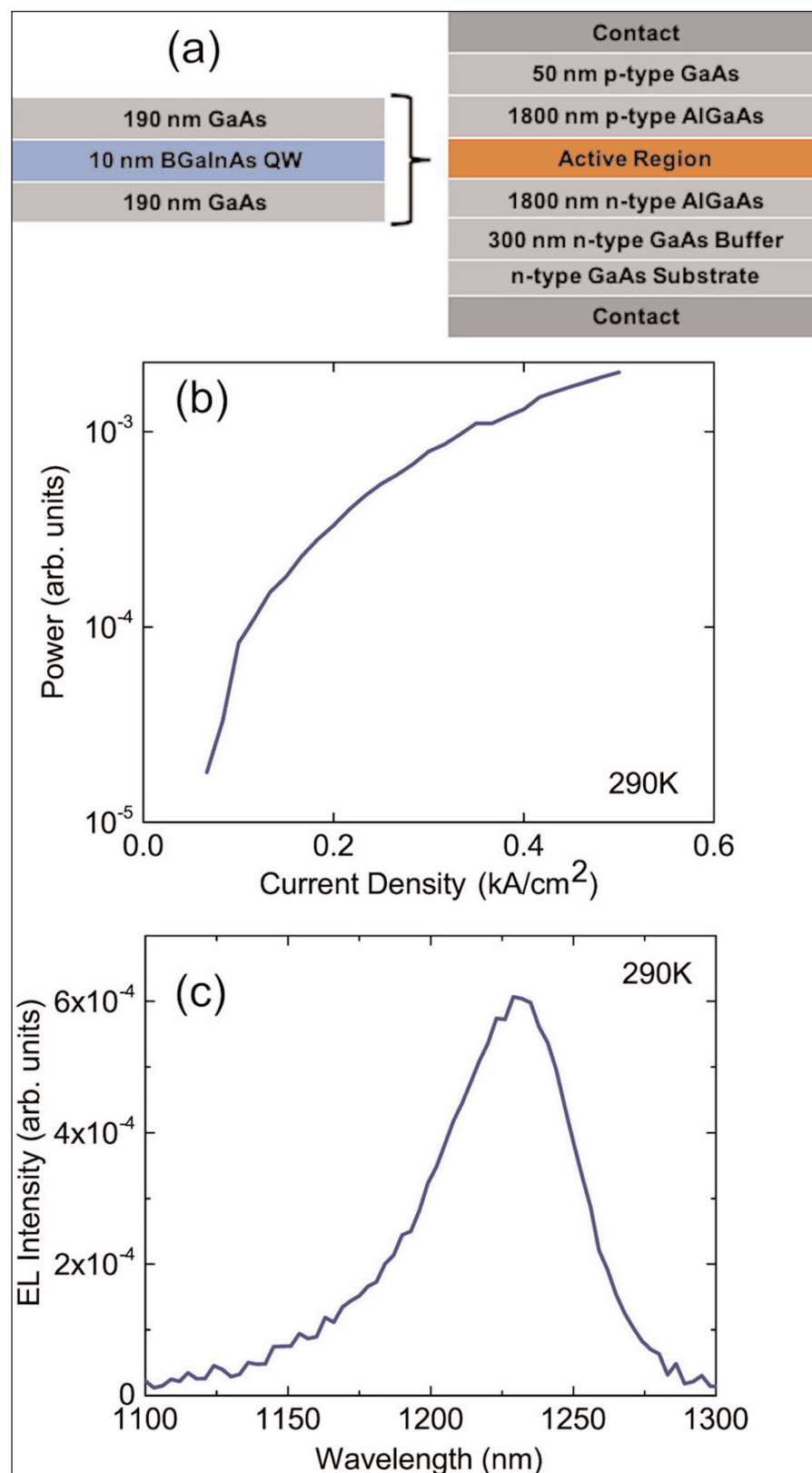
Samples for photoluminescence (PL) study consisted of 200nm GaAs buffer, 10nm (B)GaInAs quantum well (QW), and 50nm GaAs cap. The process conditions were determined through a series of calibration experiments involving InGaAs/GaAs superlattices and BGaAs films.

The researchers grew QWs with over 40% indium which, without boron, suffered from complete suppression of PL. This was attributed to a high compressive strain of -3%. The introduction of between 2% and 6% boron compensated the compression, giving strain values nearer 0%: -2.7% and -2.1%, respectively, according to x-ray analysis.

The incorporation of 2% boron enabled optical quality to be improved, as evidenced by recovery of finite thickness fringes in the x-ray analysis and increased PL intensity (Figure 1). By contrast, the incorporation of 1% nitrogen has been found to severely reduce InGaAs optical quality at 1.3µm target wavelengths.

The team also produced an electroluminescence (EL) structures with B_{0.02}Ga_{0.54}In_{0.44}As QW active light-emission region (Figure 2). Aluminium gallium arsenide (AlGaAs) grown at 580°C was used for the p- and n-type carrier injection. The substrate was (100) n-GaAs. The n- and p-type dopants were silicon and beryllium, respectively. Although the BInGaAs was produced under the same conditions as the PL sample, the EL emission peak was at a shorter wavelength of less than 1.25µm. The device was operated in pulsed mode.

The researchers studied the effect of ex-situ annealing in the range 550–700°C, suggesting that the blue-shift in the EL device was due to an in-situ annealing effect on the QW from the high temperature needed for AlGaAs MBE. The ex-situ annealing was indeed found to cause a blue-shift in PL studies. With InGaAs,



such a blue-shift from annealing has been attributed to rearrangement of In-N nearest neighbors.

A PL sample with B_{0.05}Ga_{0.45}In_{0.50}As QW annealed at 700°C for 1 minute had an emission peak at 1.3µm. The annealing also increased the PL intensity relative to an unannealed sample. Without annealing, the QW emitted around 1.4µm. ■

<https://doi.org/10.1063/5.0011147>

Author: Mike Cooke

VCSEL market to grow at 18.3% CAGR from \$1bn in 2020 to \$2.7bn in 2025

Telecom & infrastructure applications of vertical-cavity surface-emitting lasers will grow at 13.2% from \$277m to \$516m, reckons Yole Développement.

The vertical-cavity surface-emitting laser (VCSEL) market will rise at a compound annual growth rate (CAGR) of 18.3% from more than \$1bn in 2020 to \$2.7bn in 2025, forecasts the report 'VCSELS — Market and Technology Trends 2020' from Yole Développement.

In particular, telecom and infrastructure applications (mainly datacom) are expected to generate revenue of \$277m in 2020 and should reach \$516m in 2025 at a CAGR of 13.2%. "Other applications are not significant yet but could emerge in the mid- to long-term, such as automotive applications like LiDAR [light detection & ranging] or driver monitoring systems," reckons Pierrick Boulay, Solid State Lighting and Lighting Systems, in Yole's Photonics, Sensing & Display division.

Up to 2017, the VCSEL market was driven by datacom

applications, says Yole. Since then, datacoms has been replaced step by step as the market driver by 3D sensing (rising to 75% of VCSEL revenue in 2020), especially since the strategic technical choice made by Apple and the implementation of the Face ID module in its iPhones.

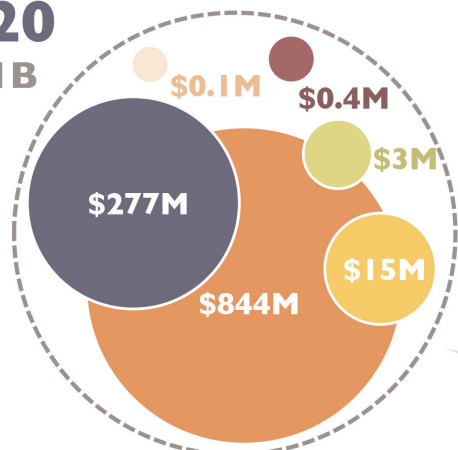
"The LiDAR uses a VCSEL coming from Lumentum," notes project manager Sylvain Hallereau in Yole company System Plus Consulting's 'Apple iPad Pro LiDAR Module' report. "Therefore, Lumentum is in tight collaboration with Apple and generated more than \$100m only with Apple's smartphones," he adds. "In its LiDAR, the laser is designed to have multiple electrodes connected separately to the emitter array. A new design with mesa contact is used to enhance wafer probe testing."

2020-2025 VCSEL market overview

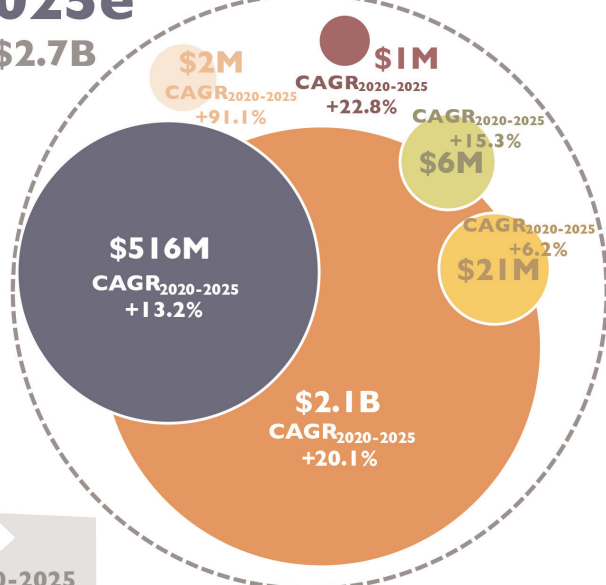
(Source: VCSELS - Market and Technology Trends 2020 report, Yole Développement, 2020)

- Mobile & consumer
- Telecom & infrastructure
- Industrial
- Defense
- Medical
- Automotive & mobility

2020
\$1.1B

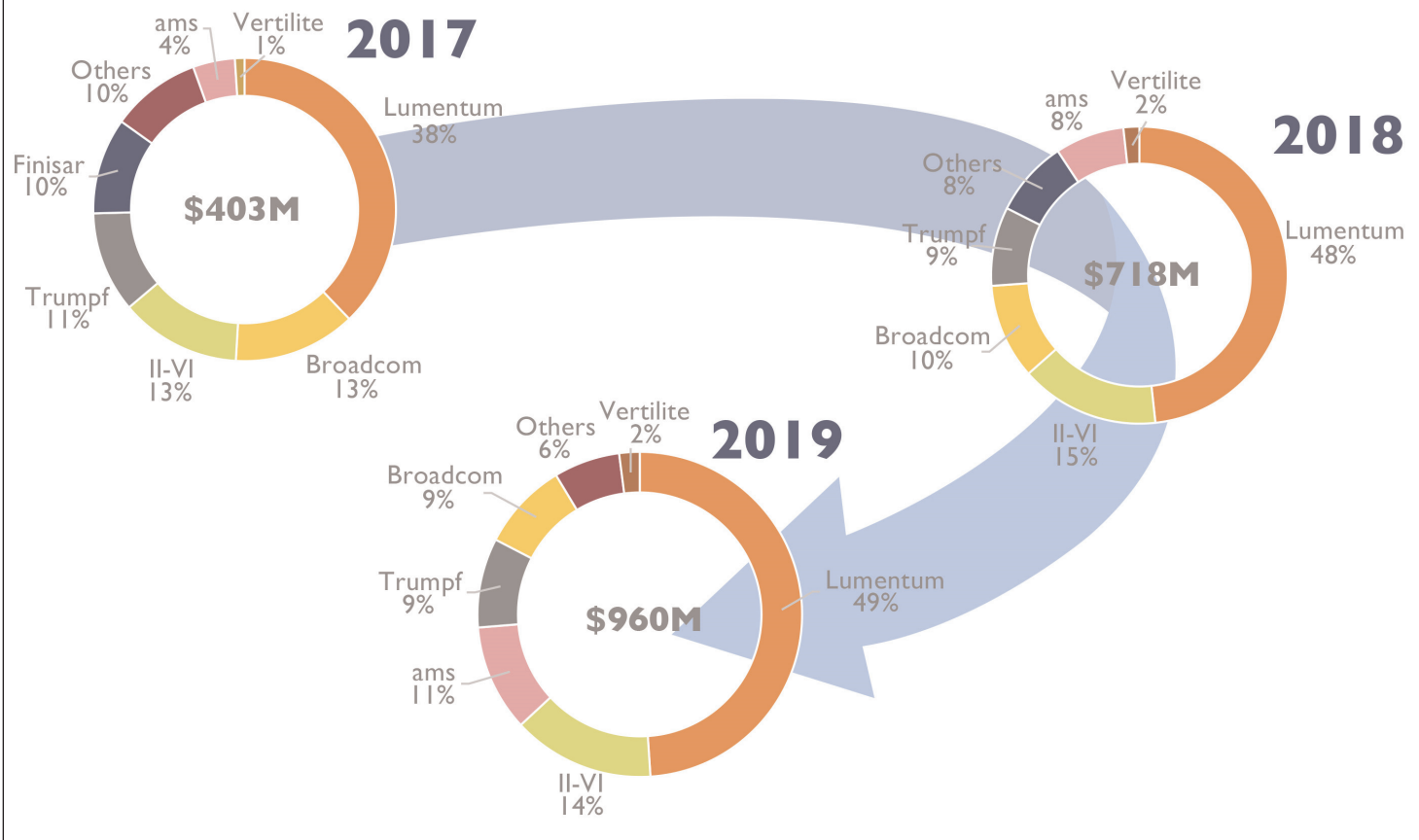


2025e
\$2.7B



CAGR₂₀₂₀₋₂₀₂₅
+18.4%

Global VCSEL market share evolution – 2017 to 2019



Following the release of the iPhone X, several manufacturers have decided to follow the same path and implement 3D sensing modules in the front side of their smartphones for face recognition. It was subsequently expected that other Chinese smartphone makers would also implement such modules on the front side. This was the case the following year, but the trend rapidly declined.

"3D sensing modules moved from the front side to the world-facing side, mainly for photography applications," notes Boulay. "This can be explained by several factors, including the cost of 3D sensing modules, the intellectual property around structured light solutions, and the competition with under-display fingerprint solutions that were more accessible to mid-price smartphones," he adds.

This transition from the front side to the world-facing side certainly has an important consequence for the VCSEL market. It was expected that front 3D modules would use structured light solutions with two VCSELs. In contrast, world-facing 3D modules use time-of-flight (ToF) solutions with only one VCSEL. In this dynamic context, mobile and consumer applications are expected to generate revenue of \$0.8bn in 2020, then grow at a CAGR of 20.1% to \$2.1bn in 2025.

Since the adoption of VCSEL solutions for 3D sensing modules in smartphones, Apple has been consuming

the majority of VCSELs produced by Lumentum. In 2017, 41 million units were implemented in iPhones and in 2020 more than 325 million of VCSEL are expected to be used in iPhones. "This number represents more than two-thirds of the total VCSEL consumption for mobile 3D sensing," notes Boulay. "Lumentum, as the main supplier of Apple's VCSELs, is clearly leading the mobile and consumer market, with 68% of the market in 2020." Behind Lumentum, ams and Trumpf have market shares of 15% and 7%, respectively.

The supply chain has also been severely impacted by political decisions and the trade war between the USA and China, notes the report. In May 2019, the US banned exports to China's Huawei Technologies. Lumentum stopped supplying Huawei, which must find a new provider of VCSELs. This ban severely damaged Huawei's supply chain. Huawei therefore had no choice but to build its own supply chain, giving rise to Chinese supplier Vertilite.

Other Chinese VCSEL suppliers are expected to emerge as other smartphone makers like Oppo, Xiaomi and Vivo could follow this trend and develop a local ecosystem to secure their supply chain, the report concludes. ■

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Gallium nitride VCSEL with electrically conductive bottom mirror and contact

Nanoporous GaN has been used to create a distributed Bragg reflector structure with a 39nm stop gap.

Researchers based in the USA and South Korea claim the first electrically injected III-nitride vertical-cavity surface-emitting laser (VCSEL) using an electrically conductive distributed Bragg reflector (DBR) containing nanoporous (NP) gallium nitride (GaN) [Rami T. ElAfandy et al, Appl. Phys. Lett., vol117, p011101, 2020].

The team from Yale University in the USA and Sunchon National University in South Korea hope that their work will help overcome the limitations of present attempts at producing blue and ultraviolet VCSELs from III-nitride materials with similar performance to those produced for infrared and longer visible wavelengths.

The team sees the “main bottleneck” as being the bottom DBR needed for forming the vertical cavity that confines the optical field. Yale reported its electro-chemical technique for creating porous GaN in 2010. The porous material has a tunable refractive index,

allowing the creation of a DBR structure. The researchers have produced m-plane GaN VCSELs using the technology, reported in 2019, but an intracavity was used, rather than a bottom contact, because the DBR was too resistive. The new c-plane structure allows a bottom-contact operation.

The team reports: “The present studies demonstrate that the conductive nanoporous GaN DBR can potentially fulfill all the requirements for the VCSEL operation and offer a unique pathway for scalable and controllable mass production.”

Some of the Yale research money came from IP Group Inc, a fund for investors in R&D.

The epitaxial material was grown on 2-inch c-plane bulk GaN substrate, offcut 0.35° in the m-direction (Figure 1). The bottom DBR material consisted of layers alternately doped with silicon (Si) and germanium (Ge) with concentrations of $5 \times 10^{18}/\text{cm}^3$ and $6 \times 10^{19}/\text{cm}^3$, respectively. The epitaxial structure was annealed at

p-contact	p⁺⁺-GaN	15nm
p-contact	p-GaN	60nm
EBL	p-Al_{0.2}Ga_{0.8}N	12nm
MQW	5x(InGa_N/Ga_N)	5x(3nm/7nm)
Intracavity n-contact	n-GaN	806nm
DBR	25x(Si-/Ge-doped) GaN	
Bottom n-contact	n-GaN	1µm
	Undoped GaN	50nm
Substrate	Bulk GaN	

Figure 1. Epitaxial material with indium gallium nitride (InGa_N) multiple quantum wells (MQWs) and aluminium gallium nitride (AlGa_N) electron-blocking layer (EBL).

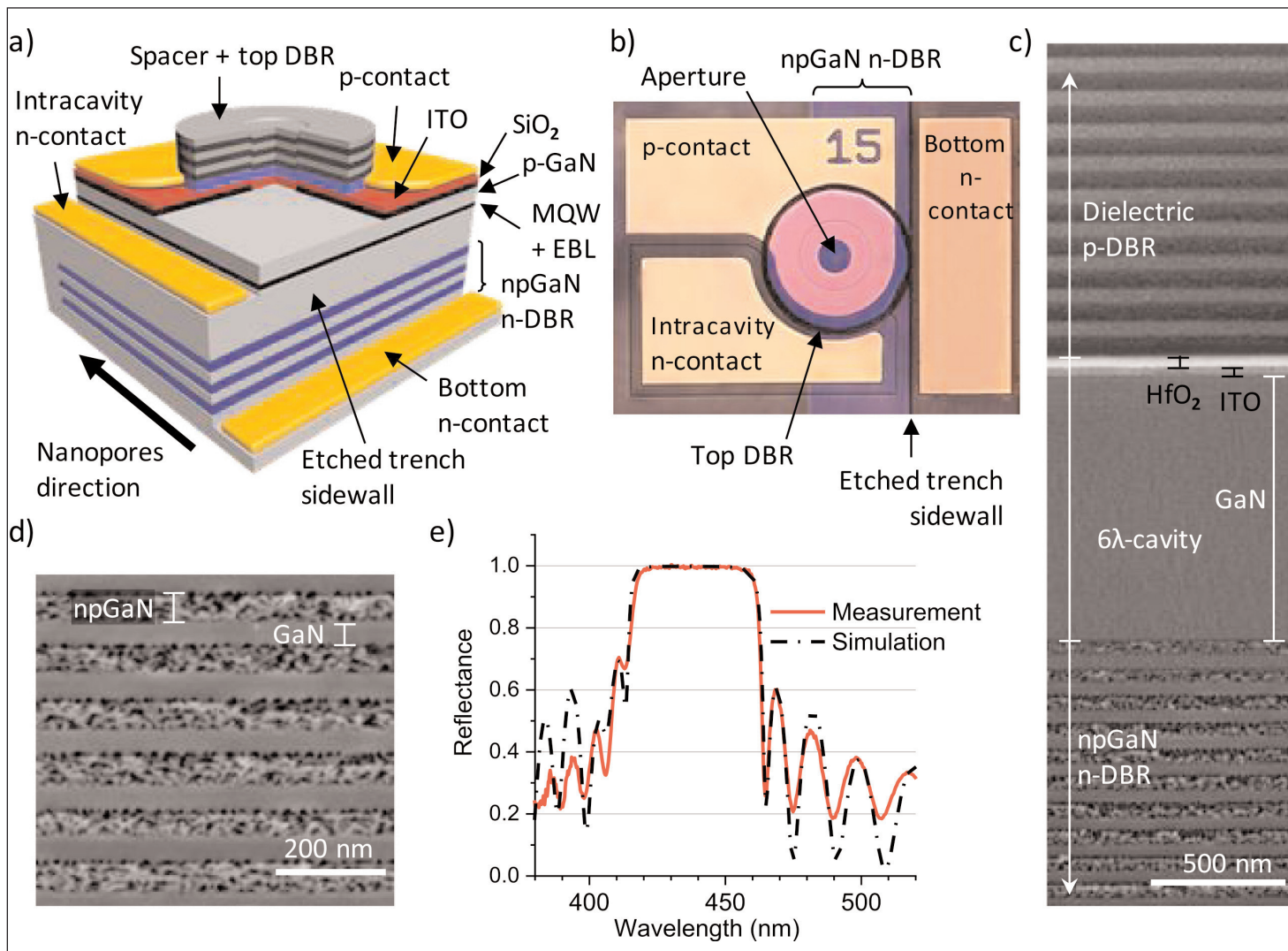


Figure 2. (a) Schematic representation and (b) top-view optical image of nanoporous GaN blue VCSEL. (c) Cross-sectional scanning electron micrograph (SEM) of full VCSEL device. (d) Cross-sectional SEM and (e) reflection spectrum (measured, red; simulated, black) of nanoporous GaN DBR.

800°C in nitrogen for 20 minutes in the metal-organic chemical vapor deposition (MOCVD) reactor to activate the magnesium doping of the p-contact layers. The cavity was designed to be six wavelengths (6λ) long.

Inductively coupled plasma etching was used to create platforms for intracavity (150nm deep) and bottom (3.5 μ m deep) n-contacts, and to expose the DBR material for the porosification process with nitric acid coupled with a 1.6V bias (Figure 2).

The p-contact structure consisted of 30nm silicon dioxide (SiO₂), defining the current aperture, and 30nm indium tin oxide (ITO) for current spreading. The contact metal stacks consisted of titanium/aluminium/nickel/gold. The top reflector was a dielectric structure consisting of 40nm hafnium dioxide (HfO₂) spacer, and SiO₂/HfO₂ DBR pairs.

Using calibration structures before producing the VCSEL, the researchers determined the stop gap of the bottom DBR at 39nm for more than 98% reflection, and peak reflectance of 99.6%. The team reports: "This stop band is at least two times wider than the

previously reported epitaxial DBRs, with a uniformity of <2nm shift in the center wavelength across a 2" wafer." The nanoporous GaN had a refractive index of 2.06, according to a fit using the transfer matrix method.

The VCSELs were tested using 200ns pulse current injection with 0.4% duty cycle. With intracavity injection, the turn-on voltage was 5.4V and the laser threshold came at 42kA/cm² current density (Figure 3). The maximum light output power was 0.17mW at 78kA/cm². The peak wavelength was 434nm.

Inspection of the laser output showed bright spots, associated with filamentary laser structures in the device. The light output power had kink increases at 54kA/cm² and 74kA/cm², which were attributed to additional filaments beginning its lase.

Using the bottom contact increased the turn on voltage by 0.4V. The threshold current and light output power performance with respect to current injection showed "no observable difference", according to the researchers. Visual inspection of the output showed similar emission patterns and filamentation.

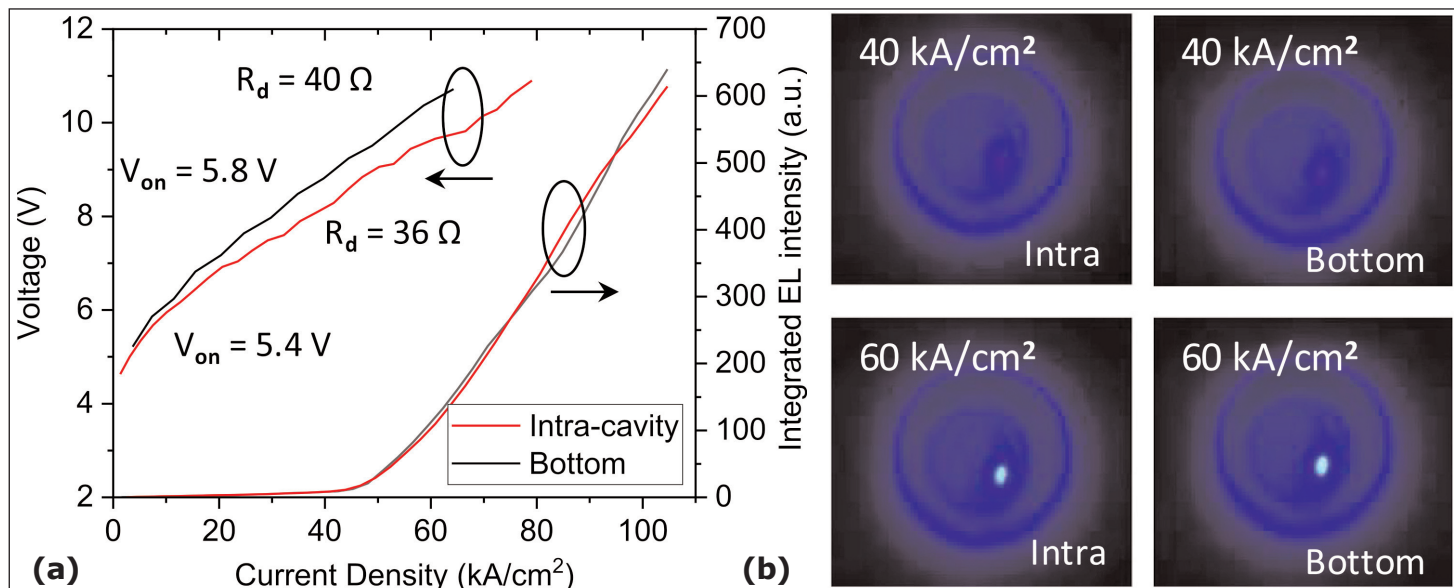


Figure 3. (a) Voltage and light output power versus current density of nanoporous GaN VCSEL through intracavity (red) and bottom (black) injection. (b) Near-field images of aperture below ($40\text{kA}/\text{cm}^2$) and above ($60\text{kA}/\text{cm}^2$) lasing threshold from intracavity (left) and bottom (right) injection.

The team comments: "This study establishes the bottom contact as a viable and efficient current injection scheme for the nanoporous GaN VCSELs, bringing the III-nitride VCSELs closer to technological feasibility."

The threshold was rather high, so the researchers examined the material under a phase-contrast optical microscope. They found undulations, which they believe to be due to step-bunching occurring during

the growth process as a result of heavy doping in the bottom DBR layers. The team comments: "These grown-in surface undulations can impact regions including DBR mirror, InGaN quantum wells, and the p-type doping." ■

<https://doi.org/10.1063/5.0012281>

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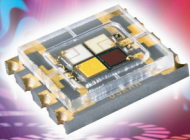


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UVC LED market growing at 61% CAGR to \$2.5bn in 2025

The COVID-19 pandemic is driving interest in UVC LEDs for disinfection applications, says Yole Développement.

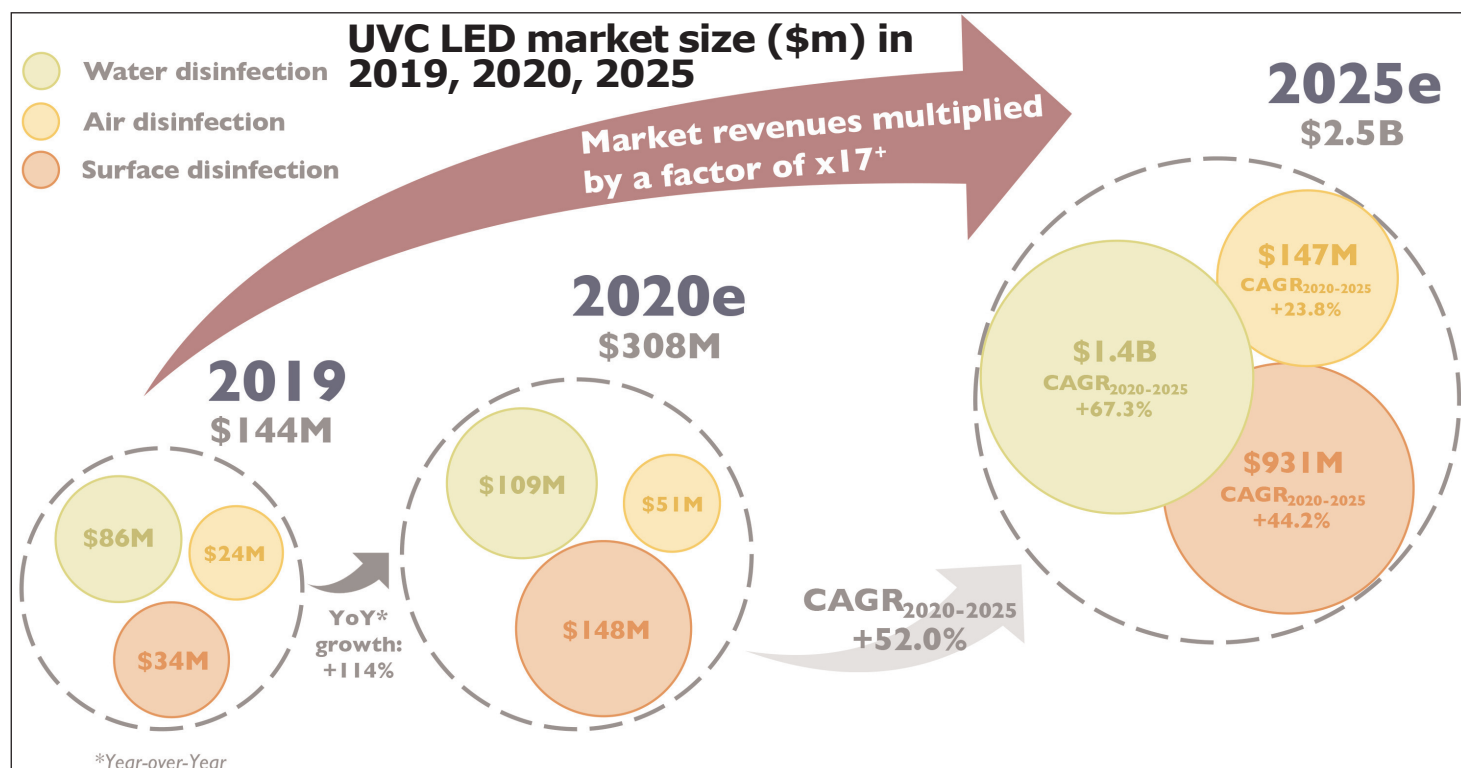
The UVC light-emitting diode (LED) market could rise at a compound annual growth rate (CAGR) of 61% over 2019-2025 to reach \$2.5bn, forecasts Yole Développement in the report 'UV LEDs – Market and Technology Trends 2020'.

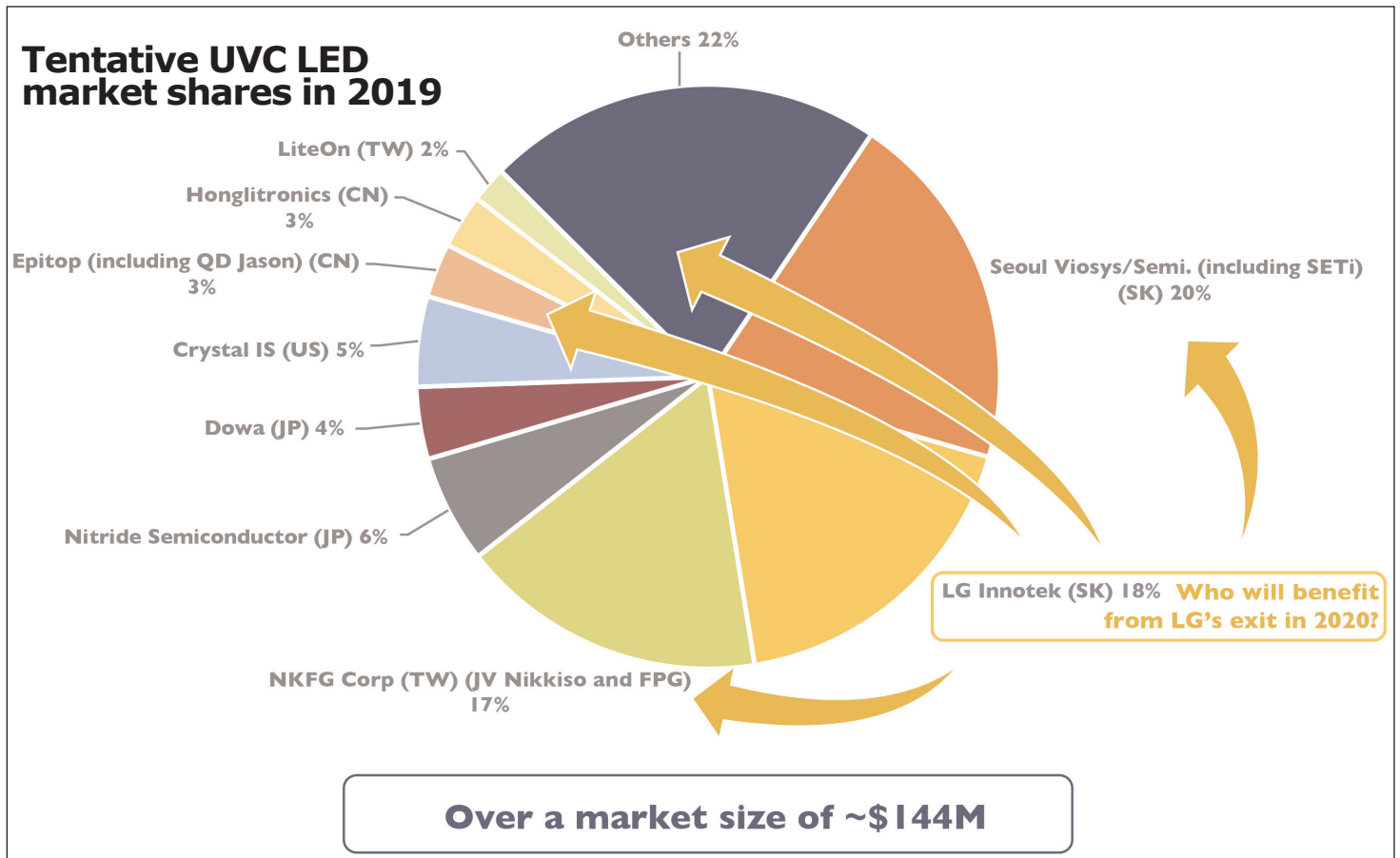
"After more than 10 years of waiting, in 2020 the UV LED market could ramp up and reach the billion-dollar mark very rapidly," reckons Pars Mukish, business unit manager, Solid-State Lighting & Display at Yole Développement. "There is good in everything bad, and the recent COVID-19 pandemic has created some perfect use-cases for the technology to spread across a rapidly changing disinfection/purification market," he adds.

"Indeed, according to the optic and photonic innovation platform, in the current context of health crisis due to the SARS-CoV-2 virus, the need to prevent contagion through disinfection has become a major issue," notes Joël Thomé, CEO of photonic innovation services firm PISEO, which has issued the report 'UV-C LEDs at the Time of COVID-19'. "Like other coronaviruses, this new virus can be destroyed by UVC radiation. With the emergence of UVC LEDs, the question of the relevance of using this technology to stop the current epidemic arises."

From being about \$20m in 2008, the UV LEDs market reached the first milestone of \$100m in 2015, driven mostly by UVA LEDs being increasingly used in UV curing applications. But further growth was then restricted by the industry's overcapacity and strong price pressure following the massive entry of visible LED players starting from 2012. In this context, the attention of the industry was then focused on UVC LEDs that could act as a game-changer for disinfection/purification applications. But UVC LED technology is intrinsically different to UVA LED technology. Also, whereas the external quantum efficiency (EQE) of UVA LEDs has rapidly exceeded 50%, the EQE of UVC LEDs is still below 10% in most commercial devices. Consequently, the technology was not considered mature by integrators and only early adopters started implementing it.

"But that was before the COVID-19 pandemic," notes Pierrick Boulay, market & technology analyst, Solid-State Lighting and Lighting Systems Photonics, in Yole's Sensing & Display division. "SARS-COV-2, the virus that causes COVID-19, has one of the highest reproduction/transmissibility rates compared to all viruses that have emerged in our modern society".





To reduce the spread of the disease, many recommendations have been made by the World Health Organization (WHO) and governments/authorities. But those best practices are mostly preventing infection from direct contacts. For infection based on either close contacts or indirect ones through contaminated objects or surfaces, disinfection technologies are required to further reduce spread of the virus. In this field, UV lighting, which can deactivate bacteria and viruses through physical methods, has gained unprecedented attention.

The COVID-19 pandemic has created momentum for the UVC LED industry. From \$144m in 2019, the UVC LED market is expected to more than double in 2020 to \$308m. It could have been even bigger if production capacity could keep up with demand. With market growth now being triggered, Yole expects it to exceed \$2.5bn in 2025, driven first by surface applications and then application to water.

"With the COVID-19 epidemic, many UVC products, mainly for surface disinfection, are appearing on the market," notes Thomé. "The current regulations and standards cover the safety aspects related to the use of these devices, but do not cover the disinfection aspect."

For now, manufacturers of disinfection systems generally rely on scientific publications and have their products tested by microbiology laboratories as a guarantee of the quality of their product in terms of disinfection. However, even a laboratory test is not a guarantee for the user, as the test conditions may be different from the conditions of use (type of surface, etc). Eventually, faced with the photo-biological risk, countries have

decided to ban the sale and use of UVC disinfection products outside the medical environment.

Yole's UV LED report also includes a dedicated part focused on the UV lamp. In the current dynamic context, some traditional UV lamp manufacturers have already made a move to benefit from this momentum by increasing their production capacity and/or developing new products. One concrete example is market leader Signify (formerly Philips Lighting), which plans to multiply its production capacity eightfold very rapidly. Another trend is related to the development of far-UVC lamps that emit at wavelengths around 222nm in order to avoid the harmful effects of traditional UVC wavelengths.

"The traditional UV lamp industry has also a role to play as UVC LEDs are still less efficient and more expensive than traditional UV lamps," says Mukish. "UVC lamps also have the advantage of fixed specifications, structural design, and circuits. These features allow manufacturers to easily produce systems according to specific requirements of the application, accelerating development time of products," he adds. "Finally, there is still some lack of knowledge about UVC LEDs' disinfecting effectiveness, which will benefit incumbent technology".

Ultimately, Yole expects growth in the UV lamp industry to come back to UV LEDs when the technology is on a par with traditional UV lamps. Such a transition might then also further increase value at the system level, the firm concludes. ■

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Halogen-free vapor phase epitaxy for gallium nitride

Process sought for vertical power device high-voltage applications.

Toyota Central R&D Labs Inc in Japan has been developing a halogen-free vapor phase epitaxy process for gallium nitride (GaN) with a view to power devices with high breakdown voltage (1200V and above) [Taishi Kimura et al, Appl. Phys. Express, vol13, p085509, 2020].

“Our study shows that the HF-VPE technique can be employed to achieve high-quality and cost-effective bulk crystal and epitaxial layer growth for GaN devices,” reports the team, which included researchers from University of Tsukuba and Nagoya University in Japan, in addition to the Toyota personnel.

In many respects, the material had performance comparable to that obtained from low-defect-density hydride vapor phase epitaxy (HVPE).

The HVPE process involves reacting group III metals (e.g. Ga) with hydrogen chloride (HCl), producing gaseous chlorides (GaCl, for instance). The epitaxy then proceeds through reaction with ammonia (NH₃).

The halogen-free vapor phase epitaxy (HF-VPE) process instead uses direct reaction of the group-III metal in gaseous form with NH₃:



This avoids the production of ammonium chloride (NH₄Cl), which clogs up production equipment, and needs frequent chamber cleaning processes, which interrupts manufacturing, increasing costs.

The researchers built on their previous work, producing HF-VPE GaN

layers on commercial free-standing GaN and GaN/sapphire templates. The templates were from a metal-organic chemical vapor deposition (MOCVD) process.

The team avoided dislocation formation at the initial growth interface by carefully controlling the process conditions: substrate holder at 1283–1393K, source crucible at 1530–1537K, and

2kPa growth pressure. The crucible was heated using RF irradiation.

The aim was to eliminate void-like defects, which have been found to be a prime source of interface dislocations. The carrier, sheath, diluent and reaction gases were supplied at 0.3 standard liter per minute (slm) N₂, 0.2slm N₂, 1.6–5.0 slm N₂ and 1.0–4.0slm NH₃. The team targeted a relatively low 30–40μm/hour growth rate.

X-ray study revealed little difference in the width of rocking curves between the substrates and the overlying HF-VPE GaN layers, suggesting minimal addition of dislocations at the initial growth interface. The team also points out that they found no evidence of Ga inclusions in the HF-VPE material — Ga inclusions are another source of crystal defects in GaN.

Secondary-ion mass spectroscopy showed hydrogen, oxygen and carbon at a sub-background impurity level in the HF-VPE layer: less than 3x10¹⁶/cm³, 8x10¹⁵/cm³ and 6x10¹⁵/cm³, respectively.

The silicon (Si) impurity level did increase somewhat — to around 2x10¹⁷/cm³. In vertical-conduction power devices, it is often desired to have thick drift layers with the Si concentration as low as possible. The researchers comment: “These unintentional Si impurities (typically 10¹⁶–10¹⁷/cm³) could be attributed to the quartz parts located in the high-temperature region in the HF-VPE apparatus. A modified growth setup is currently being developed to reduce Si.”

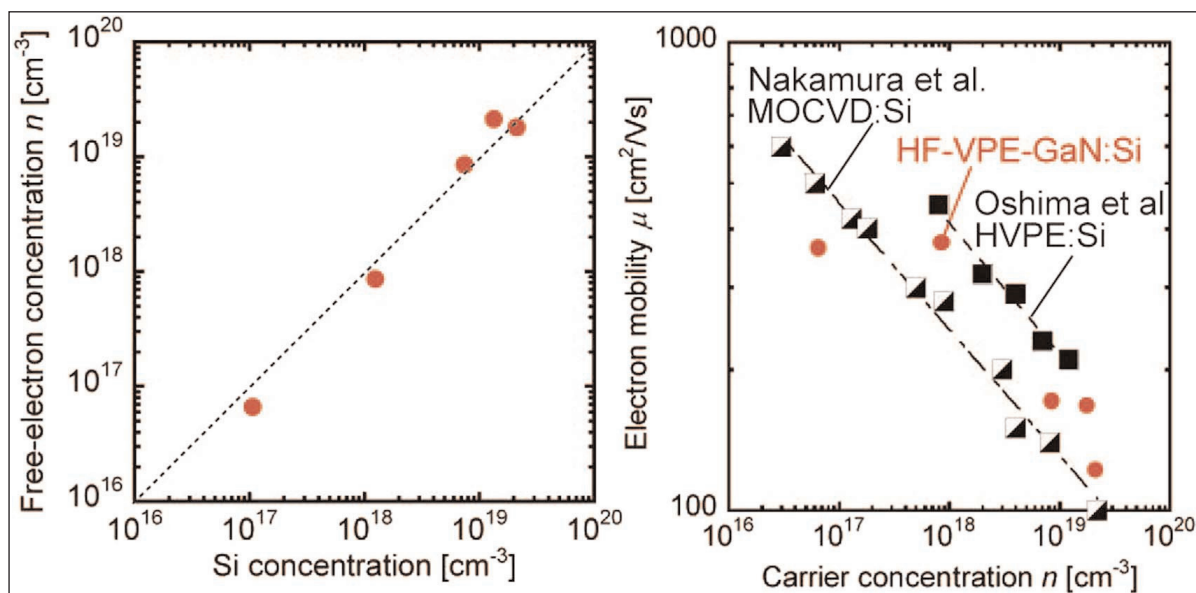


Figure 1. Relationship of Si vs net donor ($N_d - N_a$) concentrations for Si-doped HF-VPE GaN. Dependence of electron mobility on carrier concentration for GaN layers at 300K (right).

Hall measurements were carried out on HF-VPE layers grown on high-resistivity MOCVD GaN/sapphire templates. The HVPE freestanding substrates were conductive, and therefore not suitable for accurate Hall analysis of carrier concentration and mobility.

The varying free-electron concentration was achieved using Si doping, which was well controlled above $10^{17}/\text{cm}^3$ up to $10^{19}/\text{cm}^3$ (Figure 1). Lower free-electron levels need the modified growth setup referred to above.

The mobility measurements were compared with MOCVD- and HVPE-grown n-GaN layers by other groups. The HF-VPE generally showed improved mobility performance over MOCVD GaN, except at the lowest free-carrier concentration ($6.6 \times 10^{16}/\text{cm}^3$). However, the HVPE GaN comparison was better.

The team explained the reduced mobility performance, compared with the HVPE report, as probably arising from the high dislocation density of the MOCVD template used. MOCVD GaN dislocation densities are of the order $1\text{--}3 \times 10^9/\text{cm}^2$, while HVPE achieves much reduced dislocation generation around $3\text{--}5 \times 10^6/\text{cm}^2$.

The low mobility of the HF-VPE GaN at the lowest electron concentration could be due to the presence of acceptor-like compensating impurities or Ga vacancy point defects, degrading the performance.

Positron annihilation spectroscopy (PAS) confirmed there was a particular problem for HF-VPE layers grown on MOCVD GaN/sapphire templates.

The 'S-parameter' was higher on the templates than for material grown on freestanding GaN — 0.445, compared with 0.442, using 28.6keV incident positrons. The S-parameter compares the gamma-ray photon emissions ($\sim 511\text{keV}$) from electron-positron emissions from the central peak region with the total emissions. Annihilation with less mobile electrons reduces Doppler broadening. A high S-parameter therefore indicates the presence of more electrons trapped at electroneutral or negatively charged vacancy-type defects.

Analyzing the S-parameter versus incident positron energy behavior allowed extraction of positron diffusion lengths. This was highest for HVPE material $\sim 100\text{nm}$. The HF-VPE process on freestanding GaN reduced the diffusion length to the range 70–80nm. The material on MOCVD templates gave a value of $\sim 40\text{nm}$.

Positron diffusion lengths are reduced both by

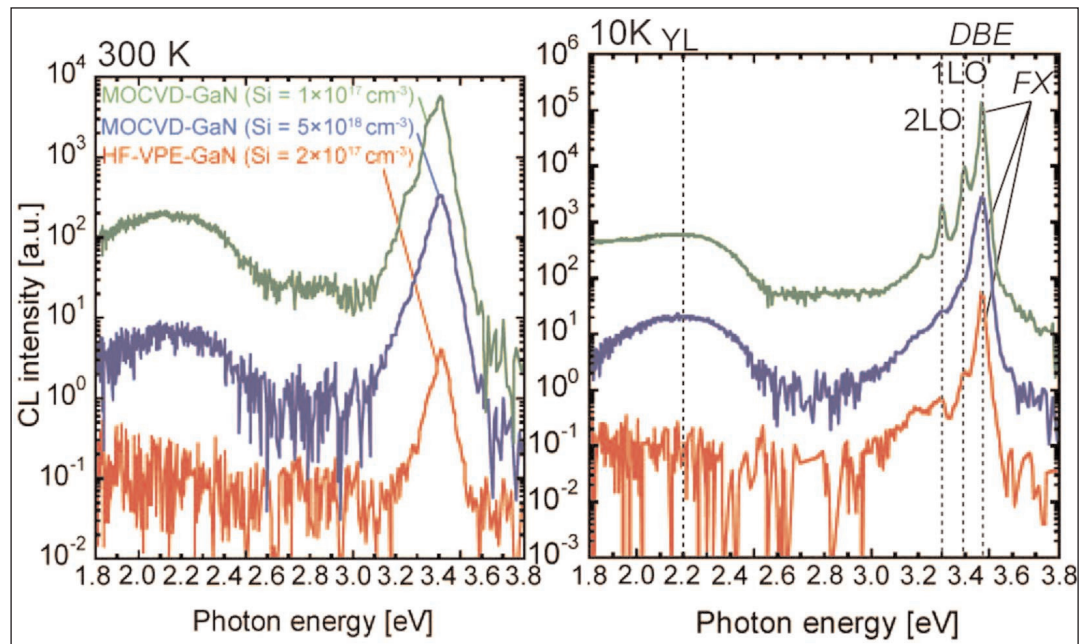


Figure 2. CL spectra for HF-VPE-GaN at 300K (left) and 10K (right). Spectra for Si-doped MOCVD-grown GaN also shown. The spectra for Si-doped MOCVD-grown GaN are shifted upward by factors of 10 and 100 for clarity.

positron trapping by vacancy-type defects and positron scattering by impurities.

Using a two-state trapping model, the researchers estimated a Ga vacancy complex density (V_{Ga}) on MOCVD templates of $\sim 10^{17}/\text{cm}^3$.

Deep-level defects were explored by cathodoluminescence (CL) — studying light emission from irradiation with a 5keV electron beam (Figure 2). The spectra showed near-ultraviolet peaks associated with free exciton (FX, 3.48eV), donor-bound exciton (DBE, 3.47eV), and longitudinal optical (LO) phonon replicas of FX (3.39, 3.30 and 3.21eV) near-band-edge emissions.

In MOCVD GaN, one also finds a broad 'yellow luminescence' (YL) hump (2.2–2.3eV), which is associated with deep-level defects. The level of YL in HF-HVPE was at least an order of magnitude lower than for MOCVD GaN.

The researchers comment: "Although the origin of YL peaks is still under discussion, many researchers have reported that it originates from complexes in which gallium vacancies are related to oxygen ($V_{\text{Ga}}\text{--O}_N$) and/or carbon ($V_{\text{Ga}}\text{--C}_N$)."

Oxygen and carbon are unavoidable in metal-organic CVD processes. Quartz equipment can also contribute oxygen. The researchers comment: "The absence of a YL peak is attributable to the high-purity (O-free and C-free) growth of the HF-VPE method."

The team sees the slightly lower PAS diffusion length and CL intensity of HF-VPE GaN compared with HVPE GaN as indicative that other impurities may be present in HF-VPE GaN layers, whose identification and removal could raise electron mobility and CL intensity in HF-VPE-GaN. ■

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Author: Mike Cooke

Avoiding mobility collapse in high-voltage gallium nitride power devices

Highest mobility yet achieved — $1470\text{cm}^2/\text{V}\cdot\text{s}$ — in very lightly doped n-type material suitable for thick vertical drift layers.

Japan's SCIOCS Co Ltd has claimed the highest mobility achieved at room temperature for n-type gallium nitride (n-GaN) with low carrier density of the order of $10^{15}/\text{cm}^3$ [Hajime Fujikura et al, Appl. Phys. Lett., vol117, p012103, 2020]. Such low-doping layers are key components of vertical power devices with voltage ratings up to 10kV. The requirement is for thick drift layers to reduce electric fields, while maintaining conductivity (proportional to the mobility and free carrier density).

The SCIOCS material avoided an effect called 'mobility collapse', which is associated with carbon (C) contamination. Such contamination is almost unavoidable in the usual metal-organic chemical vapor deposition (MOCVD) used in commercial manufacturing — organic molecules, of course, contain large amounts of C. Also, the C incorporation is highly sensitive to off-angle variations in the GaN crystal structure, of the order of 0.3° , leading to high free-carrier density variations across a wafer.

Instead, the SCIOCS team used hydride vapor phase epitaxy (HVPE), which employs gallium metal and ammonia (NH_3) as the source materials, avoiding the presence of C. A further advantage of HVPE is a much faster growth rate over MOCVD — more than $100\mu\text{m}/\text{hour}$ versus a few microns/hour, respectively.

To enable precise control of the silicon (Si) doping needed for low-electron-density material, the researchers have developed a 'quartz-free' (QF) HVPE process — quartz consists of crystalline silicon dioxide (SiO_2). The QF-HVPE growth was achieved by removing quartz from the high-temperature regions of the equipment. A further advantage is the avoidance of oxygen contamination, which has an n-type doping effect on GaN.

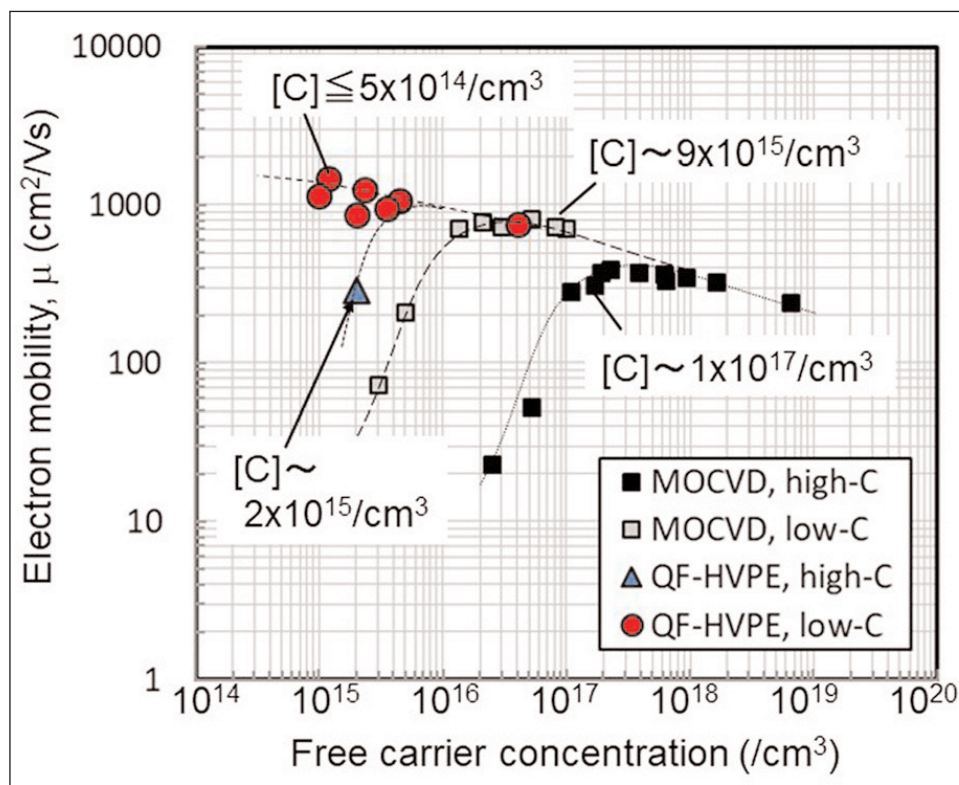


Figure 1. Free-electron density versus mobility in n-GaN layers grown by MOCVD and QF-HVPE with 'low' and 'high' [C]. MOCVD data from samples grown on sapphire at North Carolina State University et al, and reported in 2016.

The researchers used their QF-HVPE process at atmospheric pressure, and the temperature was set at 1050°C . The substrate was 2-inch, +c-oriented, Si-doped, n-type freestanding GaN produced using a void-assisted separation method developed at SCIOCS. The QF-HVPE growth rate was around $1\mu\text{m}/\text{minute}$. The threading dislocation density of the n-GaN layers was uniform in the $1\text{--}3 \times 10^6/\text{cm}^2$ range.

Samples for capacitance-voltage analysis were grown directly on the freestanding substrate. For Hall measurements, a C-doped insulating interlayer up to $10\mu\text{m}$ thick was introduced.

The team was able to produce n-GaN layers with controllable silicon concentrations ([Si]) as low as $1.5 \times 10^{15}/\text{cm}^3$, according to secondary-ion mass spectro-

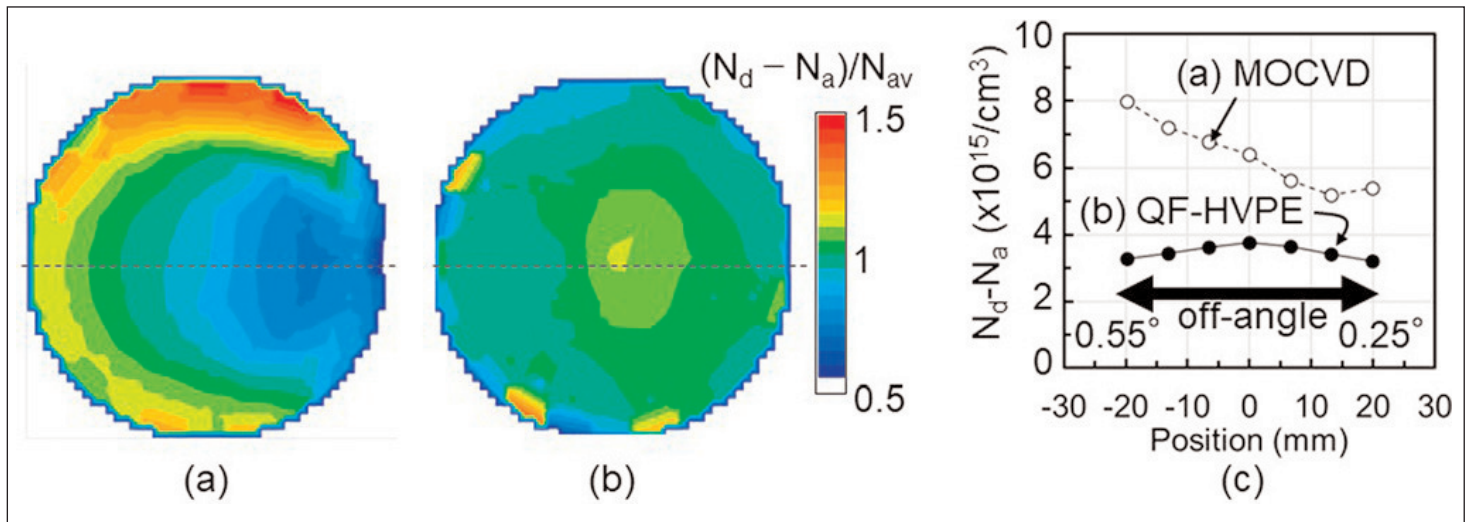


Figure 2. Net carrier concentrations over 2-inch wafers grown by (a) MOCVD and (b) QF-HVPE, according to contactless capacitance–voltage measurements. (c) Line profiles of carrier concentrations along horizontal broken lines in (a) and (b).

metry (SIMS). By contrast, MOCVD samples tend to bottom out [Si] at around $9 \times 10^{15}/\text{cm}^3$.

While the carrier concentration is typically considerably below the Si-doping level in MOCVD, $2.5 \times 10^{15}/\text{cm}^3$ in the case above, for the QF-HVPE samples produced with $1.5 \times 10^{15}/\text{cm}^3$ [Si] the carrier concentration was around $10^{15}/\text{cm}^3$.

The SIMS analysis also showed [C] and [O] at less than $5 \times 10^{14}/\text{cm}^3$. With [C] kept below this level, the team was able to maintain mobility at very low free-carrier densities (Figure 1). By deliberately introducing C into the HVPE growth process, the researchers demonstrated a mobility collapse effect similar to that seen with MOCVD.

The free-carrier density threshold for mobility collapse in MOCVD has been found to be around $2\text{--}3 \times [C]$: $3 \times 10^{17}/\text{cm}^3$ with [C] at $1 \times 10^{17}/\text{cm}^3$, and $2 \times 10^{16}/\text{cm}^3$ for $9 \times 10^{15}/\text{cm}^3$ [C].

The highest mobility of $1470 \text{cm}^2/\text{V}\cdot\text{s}$ in the low-[C] QF-HVPE process was found with the free electron density at a very low value of $1.2 \times 10^{15}/\text{cm}^3$. The researchers comment: "This is the highest reported room-temperature mobility for GaN crystals thus far."

By introducing a small piece of carbon into the QF-HVPE chamber, the [C] level rose to $2 \times 10^{15}/\text{cm}^3$. A layer with [Si] at $4 \times 10^{15}/\text{cm}^3$ saw the free-carrier density drop to $2 \times 10^{15}/\text{cm}^3$. The mobility was a paltry

$288 \text{cm}^2/\text{V}\cdot\text{s}$.

The team also measured carrier density uniformity across wafers grown by MOCVD and QF-HVPE (Figure 2). The average carrier densities were $7 \times 10^{15}/\text{cm}^3$ and $3.4 \times 10^{15}/\text{cm}^3$, respectively.

The carrier density non-uniformity in the MOCVD had a standard deviation of 16.7%. The researchers comment: "This large variation can be attributed to the off-angle-dependent C-incorporation efficiency, as reported previously." For the QF-HVPE, the non-uniformity/standard deviation was 4.0% of the already low average carrier density.

Photoluminescence study of the QF-HVPE n-GaN showed sharp 363nm-wavelength near-band-edge emission peak, along with weak broad green emissions centered around 520–530nm. Such green luminescence is associated with nitrogen vacancies. There was no sign of yellow luminescence that is usually attributed to C contamination.

SCIOCS emerged out of Hitachi Cable, and then was part of Hitachi Metals, but is now part of the Sumitomo Chemicals Group. The company is located in the city of Hitachi, where the first company of the same name was founded in 1910. ■

<https://doi.org/10.1063/5.0014528>

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15 Assembly/packaging materials

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

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

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

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

16 Assembly/packaging equipment

CST Global Ltd
4 Stanley Boulevard,
Hamilton International Technology
Park,
Blantyre, Glasgow G72 0BN, UK
Tel: +44 (0) 1698 722072
www.cstglobal.uk

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

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

PI (Physik Instrumente) L.P.
16 Albert St . Auburn ,
MA 01501,
USA
Tel: +1 508-832-3456,
Fax: +1 508-832-0506
www.pi.ws
www.pi-usa.us

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

17 Assembly/packaging foundry

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

18 Chip foundry

CST Global Ltd
4 Stanley Boulevard, Hamilton
International Technology Park,
Blantyre,
Glasgow, G72 0BN,
UK
Tel: +44 (0) 1698 722072
www.cstglobal.uk

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

19 Facility equipment

RENA Technologies NA
3838 Western Way NE,
Albany, OR 97321,
USA
Tel: +1 541 917 3626
www.rena-na.com

20 Facility consumables

PLANSEE High Performance Materials

6600 Reutte,
Austria
Tel: +43 5672 600 2422
info@plansee.com
www.plansee.com

W.L. Gore & Associates

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

21 Computer hardware & software

Crosslight Software Inc

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

Semiconductor Technology Research Inc

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

22 Used equipment

Brumley South Inc

422 North Broad Street,
Mooresville, NC 28115, USA
Tel: +1 704 664 9251
Email: sales@brumleysouth.com
www.brumleysouth.com

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Class One Equipment Inc

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Decatur, GA 30035, USA
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Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

Riff Company Inc

1484 Highland Avenue,
Cheshire, CT 06410, USA
Tel: +1 203-272-4899
Fax: +1 203-250-7389
www.riff-co.com

TECDIA Inc

2700 Augustine Drive, Suite 110,
Santa Clara,
CA 95054 ,
USA
Tel: +1-408-748-0100
Fax: +1-408-748-0111
Contact Person: Cathy W. Hung
www.tecdia.com

24 Resources

Al Shultz Advertising Marketing for Advanced Technology Companies

1346 The Alameda,
7140 San Jose,
CA 95126, USA
Tel: +1 408 289 9555
www.alshultz.com

SEMI Global Headquarters

San Jose, CA 95134,
USA
Tel: +1 408 943 6900
www.semi.org

Yole Développement

69006 Lyon, France
Tel: +33 472 83 01 86
www.yole.fr

SEMI Global Headquarters

3081 Zanker Road,
San Jose,
CA 95134, USA
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www.semi.org

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Monterey Marriott, CA, USA (now a virtual conference)

E-mail: cs@cshawevent.com

www.bcicts.org

10–13 November 2020

SEMICON Europa 2020

Munich, Germany

E-mail: SEMICONEuropa@semi.org

www.semiconeuropa.org

16–18 November 2020

PCIM (Power Conversion, Intelligent Motion) Asia 2020

Shanghai, China

E-mail: pcimasia@china.messefrankfurt.com

www.pcimasia-expo.com

6–8 December 2020

2020 IEEE 51st Semiconductor Interface Specialists Conference (SISC)

San Diego, CA, USA

E-mail: mpasslack@ieeesisc.org

www.ieeesisc.org

6–10 December 2020

(postponed from 20–24 September)

46th European Conference on Optical Communication (ECOC 2020)

Brussels Expo, Brussels, Belgium

E-mail: info@ecoc2020.org

www.ecoco2020.org

12–16 December 2020

IEEE International Electron Devices Meeting (IEDM 2020) – now a virtual, online event

Hilton San Francisco and Towers, San Francisco, CA, USA

E-mail: info@ieee-iedm.org

www.ieee-iedm.org

17–19 December 2020

SEMICON Japan 2020

Tokyo Big Sight, Tokyo, Japan

E-mail: semicon@sakurain.co.jp

www.semiconjapan.org/en

10–15 January 2021

(postponed from 13–18 September 2020)

23rd European Microwave Week (EuMW 2020)

Utrecht, The Netherlands

E-mail: eumwreg@itnint.com

www.eumweek.com

14–18 February 2021

IEEE International Solid-State Circuits Conference (ISSCC 2021)

San Francisco, CA, USA

E-mail: Issccinfo@yesevents.com

www.isscc.org

12–15 March 2021

(postponed from 22–25 July 2020)

International Congress on Advanced Materials Sciences & Engineering (AMSE)

Vienna, Austria

E-mail: eve@istci.org

www.istci.org/amse2021

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17–19 March 2021

LASER World of PHOTONICS CHINA 2021

Shanghai, China

E-mail: info@world-of-photonics-china.com

www.world-of-photonics-china.com/en

21–25 March 2021

IEEE Applied Power Electronics Conference and Exposition (APEC 2021)

(postponed to 9–13 June 2021)

Phoenix, AZ USA

E-mail: registration@apec-conf.org

www.apec-conf.org

25–27 March 2021

International Conference on Nano Research and Development (ICNRD-2021) – Breakthrough and Innovation in Nano Science and Technology

Grand Copthorne Waterfront Hotel, Singapore

E-mail: laura@icnrd.com

www.istci.org/icnrd2021

28 March – 1 April 2021

(postponed to 6–10 June 2021)

Optical Networking and Communication Conference & Exhibition (OFC 2021)

Moscone Center, San Francisco, CA, USA

E-mail: OFC@csreg.zohodesk.com

www.ofcconference.org

15–16 April 2021

EPIC Annual General Meeting 2021

Radisson Blu Hotel Lietuva,

Vilnius, Lithuania

E-mail: neringa.norbutaite@epic-assoc.com

www.epic-assoc.com/epic-annual-general-meeting-2020

18–21 April 2021

(postponed from 26–29 April 2020)

2nd International Conference on UV LED Technologies & Applications (ICULTA 2021)

Berlin, Germany

E-mail: contact@iculta.com

www.ICULTA.com

20–22 April 2021

(postponed from 21–23 April 2020)

24th Annual Components for Military & Space Electronics Conference & Exhibition (CMSE 2021) – now a virtual, online event

Four Points by Sheraton (LAX) Los Angeles, CA, USA

E-mail: info@tjgreenllc.com

www.tjgreenllc.com/cmse

9–14 May 2021

2021 Conference on Lasers & Electro-Optics (CLEO)

San Jose Convention Center, San Jose, CA, USA

E-mail: CLEO@compusystems.com

www.cleoconference.org

11–14 May 2021

10th World Congress of Nano S&T 2021

Venetian Macao Resort Hotel, Macao, China

E-mail: esther@bitcongress.com

www.bitcongress.com/nano2021-macao

6–10 June 2021

(postponed from 28 March – 1 April 2021)

Optical Networking and Communication Conference & Exhibition (OFC 2021)

Moscone Center, San Francisco, CA, USA

E-mail: OFC@csreg.zohodesk.com

www.ofcconference.org

9–13 June 2021

IEEE Applied Power Electronics Conference and Exposition (APEC 2021)

(postponed from 21–25 June 2021)

Phoenix, AZ USA

E-mail: registration@apec-conf.org

www.apec-conf.org

20–24 June 2021

International Congress on Photonics in Europe – co-located with LASER World of PHOTONICS

ICM – Internationales Congress Center München,

Munich, Germany

E-mail: info@photonics-congress.com

www.photonics-congress.com/en

21–24 June 2021

LASER World of PHOTONICS 2021

Messe München, Munich, Germany

E-mail: info@world-of-photonics.com

www.world-of-photonics.com/en

22–24 June 2021 (postponed from 9–11 Feb 2021)

Strategies in Light 2021

Santa Clara Convention Center, Santa Clara, CA, USA

E-mail: registration@endeavorb2b.com

www.strategiesinlight.com

4–9 July 2021 (postponed from 14–19 June 2020)

20th International Conference on Metal Organic Vapor Phase Epitaxy (ICMOVPE XX)

Stuttgart, Germany

E-mail: info@icmovpexx.eu

www.icmovpexx.eu



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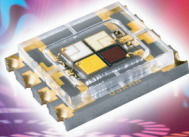


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